FUTURE TALKS

009
THE CONSERVATION OF MODERN MATERIALS IN APPLIED ARTS AND DESIGN
OCTOBER
22/23 2009
DIE NEUE SAMMLUNG THE INTERNATIONAL DESIGN MUSEUM MUNICH
CONTENT

006 EDITORIAL
BY PROF DR FLORIAN HUFNAGL

LECTURES

006 001 A CONDITION SURVEY METHODOLOGY AND DATABASE FOR PLASTIC OBJECTS AT THE METROPOLITAN MUSEUM OF ART
BY KATE MOOMAW

016 002 MEETING THE NEEDS OF CONTEMPORARY DESIGN: A NEW SURVEY METHODOLOGY
BY BARBARA SCHERTEL

026 003 AGING OF PLASTICS – WHAT CAN WE DO ABOUT IT?
BY ANDREAS HOLLÄNDER

032 004 FINE-TUNING ATMOSPHERIC PLASMA TO IMPROVE THE BONDABILITY AND COATABILITY OF PLASTICS IN MODERN AND CONTEMPORARY ART AND DESIGN
BY ANNA CORNIOTTO

040 005 PLASTIC BAGS – RESEARCH INTO THE PRICE OF PRISTINE PMMA
BY YVONNE SHASHOUA, ANJA LISS PETERSEN, ESTHER RAPOPORT

050 006 NAUM GABO’S SCULPTURE ‘CONSTRUCTION IN SPACE: CRYSTAL’ (1937): EVALUATING A SUITABLE BONDING STRATEGY FOR STRESS LOADED POLYMETHYL METHACRYLATE
BY ANNA CORNIOTTO, MARC EGER

070 007 MENDING BROKEN PIECES RESEARCH INTO METHODS AND MATERIALS FOR ADHERING BROKEN UNSATURATED POLYESTER ARTWORKS
BY THEA B. VAN OOSTEN, ANNA LAADA

078 009 WORK IN PROGRESS - PRACTICAL EXPERIENCE IN THE CONSERVATION OF HIGH-GLOSS POLYESTER RESIN AND FLEXIBLE POLYVINYL CHLORIDE BASED ON EXEMPLARY CASES
BY SUSANNE GRANER

086 010 CARING FOR DESIGN OBJECTS: DAILY PRACTICE AND ADVANCED ANALYTICAL TOOLS
BY LUCIA TONIOLO, ARTURO DELLAQUA, BELLEVIS, SILVANA AHECHABBAOUI, DANIELA COMELLI, GIORGIO GALLEANI, MARINELLA LEVI, AUSTIN NEVIN, FRANCESCA TOJA

094 011 PRESERVATION OF THE DDR-CULTURE OF EVERYDAY-LIFE MADE OF PLASTICS
BY FREDRIK WAENTING, STEPHANIE GROSSMAN, CHRISTOPH WENZEL

102 012 STILETTO. DOUBLE-SIDED PROBLEMS WITH A SELF-ADHERING, FLEXIBLE PVC-FILM
BY TIM BECHTHOLD

110 013 COLD WAR FASHION. TWO CASE STUDIES FROM AN EXHIBITION AT THE VICTORIA & ALBERT MUSEUM
BY BOYIN MORRIS

118 014 ‘GLOBE CHAIR’, ADHESION AND COHESION: AN INTERIOR PROBLEM
BY DANA MELCHAR, NIGEL BAMFORTH

124 015 PEDICURES FOR ‘FIGURA N. 37’ BY ANTONIO BUENO: A PLASTIC CONSERVATION CASE STUDY FROM THE MODERN ART GALLERY (GAM) OF TURINO, ITALY.
BY REBECCA PLOEGER, ROBERTA VERTERAMO, OSCAR CHIANTORE

132 016 TURN IT ON: TURN IT OFF LIGHTING IN MOMA’S COLLECTION OF ARCHITECTURE AND DESIGN
BY ROGER GRIFFITH, REINHARD BEK, MARCO DELIDOW

140 017 AN ATTEMPT TO HANDLE AND PRESENT OBJECTS FROM THE BAUHAUS ERA IN A NEW WAY – THE EXPOSURE OF THE ORIGINAL PAINT ON THE ‘TSIP’ BY MARCEL BREUER
BY DELLA MULLER-WUSTEN

144 018 ARTISTS CREATE THEIR ARTWORK WITH DESIGN OBJECTS AND READY-MADE DECORATION ACCESSORIES. CONSERVATION CHALLENGES WITHIN AN INSTALLATION BY ISA GENZKEN.
BY KATHRIN KEESL

152 019 CHARACTERIZATION AND DEGRADATION OF FLUORESCENT COLOURS IN WORKS OF ART: PRELIMINARY STUDIES
BY ALAIN COLOMBINI, CLAIRE VALAGEAS

160 020 ANTIAGING FOR CULTURAL HERITAGE OBJECTS CONTAINING ELASTOMERS
BY DIETMAR LINKS, RUTH KELLER, MAXIE TAFLER

164 021 VOC ANALYSIS: A POTENTIAL TOOL FOR DECAY MONITORING
BY ELENA GÓMEZ-SÁNCHEZ, MINNA HAKKARAINEN, STEFAN SIMON, LARS-CHRISTIAN KOCH

178 001 NON INVASIVE TECHNIQUES FOR IDENTIFICATION AND CHARACTERIZATION OF POLYMERS IN CONTEMPORARY ARTWORKS
BY COSTANZA CUCCI, RAFFAELLO PICCOLI, ROBERTO OLMI

184 002 PY-GC/MS FOR THE IDENTIFICATION OF MODERN SYNTHETIC MATERIALS USED FOR CONSERVATION IN CHINESE WALL PAINTINGS
BY SHUYA WEI, GUOZHI ZHAO, MANFRED SCHEINEBERG

188 003 THE VITREOUS RETOUCHING OF POLYESTER RESIN ARTWORKS
BY EVA BRACHERT

190 004 THE VITREOUS RETOUCHING OF POLYESTER RESIN ARTWORKS
BY ANTONIO BUENO

194 005 TOWARDS A NEW METHODOLOGY OF CONSERVATION / RESTORATION OF ELECTRONIC MUSICAL INSTRUMENTS AND SOUND STRUCTURE
BY MARIE-ANNE LÖPPER-ATTIA

017 POSTERSESSIONS

226 SUPPLIERS AND REFERENCES

240 BIOGRAPHIES

252 ACKNOWLEDGEMENTS

253 PHOTO CREDITS

254 IMPRINT

APPENDIX

226 SUPPLIERS AND REFERENCES

240 BIOGRAPHIES

252 ACKNOWLEDGEMENTS

253 PHOTO CREDITS

254 IMPRINT
In summer 2008 the head of our conservation department approached me with the idea of organising a conference focusing on the conservation of modern materials.

To be honest, it didn’t need much to convince me. For as a matter of course a design museum (which is exactly what Die Neue Sammlung was founded as over 100 years ago, long before the term existed in the German-speaking world) is confronted with modern materials in virtually every object in its collection. Indeed, it is precisely new materials and their intelligent application that often provide the necessary impulse for contemporary and innovative design.

However, unlike most traditional materials these are often subject to a dynamic aging process and after only a short time often already bear irreversible traces of degradation. Corresponding types of damage can hardly be reconciled with the respective designer’s original intentions and are often problematic in terms of conservation. Keeping this in mind, the idea to provide an international and interdisciplinary discussion forum for conservation professionals and scientists from various disciplines seemed likely and promising. Since its founding in 2002, our Conservation Department has become an important hub for the conservation and maintenance of modern design objects, through research into the deterioration and preservation of the collections, the development of new conservation processes and the knowledge of its original technology. It also plays an active role in networking and information sharing. In our case the initiation of a conference, focusing on the conservation of modern materials, was (would have been) a corollary.

Nevertheless the enormous response and interest in this event was overwhelming. With more than 200 participants from 13 countries, FUTURE TALKS 009 was an exciting platform for discussions and the exchange of knowledge and experience of professionals in this field. Moreover the huge success of FUTURE TALKS 009 is the initial point and a mission for our museum to feature further events related to the technology and conservation of modern materials. I’m glad that we have succeeded in transferring these two conference days, which were full of interesting talks and discussions, based on mutual curiosity and interest in sharing knowledge, to this present compendium.

A publication which is not just an exciting compilation of current scientific research but also a fancy tome which catches the kind atmosphere of a collegial and successful event. I’m confident that this publication takes its place easily next to the few standard works dealing with the conservation of modern materials.

Enjoy reading!

PROF DR FLORIAN HUFNAGL
DIRECTOR GENERAL, DIE NEUE SAMMLUNG
THE INTERNATIONAL DESIGN MUSEUM MUNICH
ABSTRACT
In 2008-2009, a condition survey was developed and implemented for plastic objects in the Department of Nineteenth Century, Modern and Contemporary Art at the Metropolitan Museum of Art. Condition surveys are of great importance for plastic objects, which are frequently unstable or fragile and require further conservation research. The project focused on developing a condition survey form and relational database, which together allow for systematic information gathering and searchable data. Both survey tools were developed using readily available software: Microsoft Word and Filemaker Pro. The tools were applied to a group of 50 of the 250 objects with plastic components in the collection. An overview of the tools is presented including a description of what information should be obtained about plastic objects. The importance of analysis to identify plastic materials is discussed. In addition, findings of the survey are presented, with case studies of objects including a 1920s cellulose acetate box from the workshop of René Lalique, a group of lamps, a 1970s Capitello Sidechair in painted polyurethane foam, and a Soft Chaise Longue by Werner Aisslinger with discoloured Technogel cushions. Preventive conservation measures that could be put in place quickly and at low cost are described.

KEYWORDS
plastics and rubbers, condition survey, database, preventive conservation, documentation, collection management

INTRODUCTION
This paper discusses the development and implementation of a condition survey of plastic and rubber objects in the Department of Nineteenth Century, Modern and Contemporary Art at the Metropolitan Museum of Art in New York. The project was conducted during a one-year fellowship and, as such, was somewhat exploratory and experimental in nature. The task involved developing a form to be used when examining objects and a database to store the information gathered with the forms. These tools were then used to conduct a condition survey of the approximately 250 objects with major plastic or rubber components in the collection. Condition surveys are of particular importance for objects with plastic and rubber components, as opposed to objects made of more stable, robust materials. The instability and fragility of many plastic materials means that they have special preventive conservation needs, and surveys are helpful in planning and prioritizing preventive conservation steps. When photographic documentation is included, surveys can also document the changing appearance of objects. Finally, as plastic materials and the field of plastics conservation are both relatively young and artists and designers are constantly experimenting with new plastic materials that have not been studied in a conservation context, condition surveys can be useful research tools through recognition and documentation of new degradation phenomena or plastic-specific damage.

It is hoped that this paper will be useful in sharing ideas about what information needs to be gathered during a condition survey of this type of object and what kinds of tools are helpful in gathering and organizing such data for maximum usefulness.

SURVEY OBJECTIVES
The general aims of the survey were:
1) To plan and prioritise preventive conservation steps,
2) To document the condition of the objects so that any changes in condition could be monitored,
3) To document the objects photographically so that their current appearances were recorded for posterity,
4) As a part of the survey, storeroom conditions were also monitored, but the aim of the survey was not solely to assess storage conditions or rate the overall condition of the collection but rather to document, plan, and implement conservation steps for individual objects.

To plan preventive conservation for plastics and rubber, the most important information needed is the identification of the
polymer and sometimes the additives making up the plastic material. This is due to the fact that, although the various plastics are related materials, some types have unique storage requirements. For instance, research has shown that objects made from plasticised poly(vinyl) chloride (PVC) are likely to benefit from storage in a sealed container with no passive absorbers in order to slow down plasticiser evaporation. On the other hand cellulose acetate and cellulose nitrate require ventilation or storage with passive absorbers to remove acidic gases that accelerate degradation (Shashoua 2008: 195-7, 201-7).

An additional complication is that the various plastics and rubbers are difficult to distinguish by appearance. To give one example from the survey, the sticks of a 1920s fan were described in museum records as being made of cellulose nitrate (see Figure 1). Upon initial examination, the amber-like appearance of the sticks and even some internal cracking in the material seemed consistent with cellulose nitrate. However, analysis by Fourier transform infrared spectroscopy (FTIR) showed that the material was not cellulose nitrate but rather a protein-based material, probably casein formaldehyde. Cellulose nitrate and casein formaldehyde have very different aging properties and distinct storage requirements. Low humidity is recommended to slow down hydrolysis of cellulose nitrate but is not advisable for casein formaldehyde, a hygroscopic material that might shrink and crack in dry conditions. Identifying the material of the sticks correctly was quite significant in this case.

One aim of the survey was thus to identify as many plastic materials as possible, either through reliable documentation or through analysis. To accomplish this, museum files were reviewed, objects were researched, and still-unidentified plastics were analysed using FTIR by Adriana Rizzo of the museum’s Department of Scientific Research. In addition, manufacturing techniques of plastic objects were described whenever possible, as these can also affect the condition of plastic objects. All of this information was gathered and used to make recommendations for storage, exhibition, and handling.

As noted above, the second objective of the survey was to document the condition of the objects. To this end, objects were...
The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

- Object Information - This section records registration information about the object, including title, date, and an inventory number. This can also include a link to an anatomic or digital model.
- Condition - Next is a section for recording materials identification, manufacturing techniques, and condition. This section is the heart of the record, providing essential documentation of the object and thus merits an extended discussion.
- Documentation Available and Required - Here a list of materials and systematic manner. The form was developed in Microsoft Word and uses checklists rather than drop-down menus for data entry.
- Analysis - This final section includes a record of samples taken, a record of any analysis completed and location of reports, and suggestions for future analysis.
- Exhibition, Handling, Transport Requirements - Tick-box menus provide a place for environmental requirements, light levels, packing needs, etc.
- 'Portal' feature of FileMaker Pro allows one to make an unlimited number of records for a single object. The system was designed to be flexible and scalable, with the ability to add new fields or tables as needed.

The codes are designed with recognition that, in general, some condition survey articles encourage the use of an numeric code that could be meaningfully and consistently assigned. In this form, this would not be of much use in tracking changes of condition in later examinations of objects. A condition issue would have to change drastically before the evaluation code would change. Some condition survey articles encourage the use of an even number of options for such codes. Otherwise, there is a tendency to overuse the middle option. This was a useful feature for some of the multi-part objects in the survey. Some objects also had separate components with different materials. This was a useful feature for some of the multi-part objects in the survey. Some objects also had separate components with different materials.

The 'portals' feature of FileMaker Pro allows one to make an unlimited number of records for a single object. The system was designed to be flexible and scalable, with the ability to add new fields or tables as needed. This was a useful feature for some of the multi-part objects in the survey. Some objects also had separate components with different materials. This was a useful feature for some of the multi-part objects in the survey. Some objects also had separate components with different materials.

For all of the information gathered during the survey to be accessible, a documentation system had to be developed. It was decided that the information on each part and the condition descriptions in the survey database format, all of this information is linked to the object's accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The sections of the database continue as follows:

- Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

- Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

- Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

- Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

- Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.

The database was developed using FileMaker Pro software, but in principle such a database could be built using other systems. Most of the database record is to be filled in by hand, though the survey focused on documenting the changes in the digitized condition of objects. Each menu also allows for the term ‘Other’ to be selected and includes free-text ‘Notes’ fields for further explanation. The menus can also be edited to include additional terms as they are needed. Copious free-text ‘Notes’ sections allow for more detail and discussion, though they cannot be searched as easily. In terms of content, the database record for each object is structured as follows:

- Object Information - This section records registration information about the object, including title, date, and accession number. Searches can be performed in any of the data fields using the drop-down menus, and searches facilitate responsible and practical conservation planning.
entry. The use of checklists takes up more space on the paper but on the other hand provides a quick overview of options for identifications, manufacturing techniques, condition issues, etc. This encourages thoroughness and consistency in object examination and simplifies database entry. If one becomes very familiar with the database and its menus, it is possible to fill out the database record without the use of the paper survey forms. However, the paper forms may be useful for new users of the database and future surveys.

For the survey, each object was examined and documented using the paper survey form. The data from the survey forms was then entered onto the database, and the records were re-exported from the database as a PDF file, an option provided by FileMaker Pro. A hard copy of each record was printed and filed and the PDF files were stored in digital files for each object, along with the photographs taken during the survey. Note that the database records can also be exported as Microsoft Excel files. The paper survey forms were not retained, as all information was transferred to the database. This documentation system is only one option for condition surveys and it has advantages and disadvantages. One advantage is that FileMaker Pro is reasonably user-friendly and allowed for the database to be designed and edited by a conservator without specialist support. However, the disadvantage is that the database is not linked to the curatorial collection database, which is run with The Museum System (TMS) software. Thus the information is less accessible and is not as likely to be maintained and migrated as necessary in the long-term. Another advantage of the system is that the structure of the database allows it to be easily searched. However, the structure that makes it so searchable, the use of charts with drop-down menus, means that the database does not store condition reports written in prose that might be useful for certain purposes. More sophisticated database systems allow for a less rigid structure with more free-text entry while not sacrificing ability to search.

These systems employ search functions that can recognize misspelled terms and can use thesauri, like the Getty Art and Architecture Thesaurus, to return records with synonyms for the search term. The Sherman Fairchild Center for Objects Conservation at the Metropolitan Museum of Art has a project underway to develop a documentation Wiki that would combine easy and flexible data entry with sophisticated search capabilities. It may be possible to one day integrate the data from the FileMaker Pro database into a less structured database like this.

SURVEY RESULTS

The database was helpful in compiling some statistics about the objects surveyed. However, it is important to note that the objects surveyed were not chosen at random but were high priority objects for documentation, and so these figures are not representative of the whole collection. Of the 50 survey objects, 16 were found to be in need of major treatment or re-search, and 12 were found to be in need of minor treatment. Over 20 different types of polymers were found in the collection, and of the 50 objects surveyed, 16 were found to contain at least one of the following unstable materials: cellulose acetate, poly(vinyl) chloride (PVC), rubber, or polyurethane foam.

To take a closer look at one particular material, cellulose acetate was found in three objects. One of these was a cellulose acetate decorative box with a cherry motif produced by the workshop of René Lalique. The box had been acquired in the 1920s. When examined in 2008, it was showing signs of deterioration, including a vinegar smell and warping of the material that made it impossible to separate the top and bottom of the box. As this object was particularly vulnerable, some additional monitoring steps were taken during the survey. Colour measurements were taken, and the state of deterioration was measured with A-D Strips. The analysis section of the survey database provided a place to note that the colour measurements had been taken and that there was documentation of these measurements available in museum files. The results of the A-D Strips test were also recorded in the analysis section.

Another object with cellulose acetate was an example of the Radio Nurse Radio Transmitter designed by Isamu Noguchi. As the handle appeared to be made from Bakelite. When the object was examined in 2009, the case, but not the transmitter, fluoresced a dim brown colour, as was typical of Bakelite objects examined in the survey. However, the handle fluoresced bright white (see Figure 4). As the handle appeared to be made from a different material from the case, it was decided to sample it for analysis. FTIR was used to identify the material as cellulose acetate. The third object found to contain cellulose acetate was the diffuser of a lamp designed by Walter Dorwin Teague. The diffuser of a lamp designed by Walter Dorwin Teague. The database was used to document the identification of the cellulose acetate components of each of the three objects, and to flag these objects as requiring monitoring.

Another vulnerable set of objects from the survey is a group of 11 lamps with major plastic components. Parts included a fiberglass shade with scraching and fine cracks in the gel coat, a PVC tube with tears that would complicate changing of light bulbs, and an acrylic diffuser exhibiting some stress cracking. As heat and light produced by the light bulbs could exacerbate existing conservation issues and speed degradation, the lamps were flagged in the database as requiring research to determine guidelines for safely exhibiting them lit. The inevitably decreasing ease in acquiring replacement bulbs for the lamps was also a concern, and stockpiling of bulbs was recommended.

An example of the Gufram Side Chair produced by Gufram presented some troubling conservation issues. The chair is made from polyurethane foam coated with a spongy and flexible white paint. The foam is protected from light by a fiberglass shade with scraching and fine cracks in the gel coat, a PVC tube with tears that would complicate changing of light bulbs, and an acrylic diffuser exhibiting some stress cracking. As heat and light produced by the light bulbs could exacerbate existing conservation issues and speed degradation, the lamps were flagged in the database as requiring research to determine guidelines for safely exhibiting them lit. The inevitably decreasing ease in acquiring replacement bulbs for the lamps was also a concern, and stockpiling of bulbs was recommended.

Another example of the Cappellini Side Chair produced by Cappellini presented some troubling conservation issues. The chair is made from polyurethane foam coated with a spongy and flexible white paint. The foam is protected from light by a fiberglass shade with scraching and fine cracks in the gel coat, a PVC tube with tears that would complicate changing of light bulbs, and an acrylic diffuser exhibiting some stress cracking. As heat and light produced by the light bulbs could exacerbate existing conservation issues and speed degradation, the lamps were flagged in the database as requiring research to determine guidelines for safely exhibiting them lit. The inevitably decreasing ease in acquiring replacement bulbs for the lamps was also a concern, and stockpiling of bulbs was recommended.

Over 20 different types of polymers were found in the collection, and of the 50 objects surveyed, 16 were found to contain at least one of the following unstable materials: cellulose acetate, poly(vinyl) chloride (PVC), rubber, or polyurethane foam.
The Technogel cushion of Werner Aisslinger’s Soft Chaise Longue is an example of a new material with an unexpected condition issue. The cushion was designed in 1999 and has been on permanent display at the Department of Nineteenth Century, Modern and Contemporary Art. Since its acquisition in 2006, the cushion yellowed severely, turning to a yellowish hue. This change in condition is believed to be due to the degradation of the cushion’s Technogel material, which is a polyurethane-based foam. The degradation process involves the loss of plasticizer, a substance added to the foam to improve its flexibility and prevent it from becoming brittle or hardening over time.

To address this issue, the cushion was placed in airtight storage in a climate-controlled environment with optimal humidity and temperature conditions. This was done to slow down the degradation process and prevent further yellowing. Additionally, the cushion was monitored regularly to track its condition and assess the effectiveness of the storage conditions.

Furthermore, the degradation of the Technogel cushion is also an opportunity to raise awareness about the importance of conservation documentation. The treatment, storage, and monitoring of the cushion provide valuable lessons for the conservation of similar materials in the future. The decision to store the cushion in airtight conditions and monitor its condition over time exemplifies the importance of comprehensive conservation planning and the need for ongoing monitoring of condition changes.

ACKNOWLEDGMENTS

Thanks to the following staff members of the Sherman Fairchild Center for Objects Conservation at the Metropolitan Museum of Art (MMA) and others for their contributions to this project: Kendra Roth, Meeka Baumeister, Nancy Britton, Daniel Hausdorff and Lawrence Becker. Thanks also to the Department of Scientific Research, Mr. Jean Frohnert, particularly for his help with the survey database. Julie Arslanoglu and Marco Leona, and to the Department of Nineteenth Century, Modern and Contemporary Art. Special thanks are also due to Christine Frohnert and Sandra Weedenburg for sharing their experience with surveys, Yvonne Shashoua for her advice during the project, Emily Cortes and Hannelore Roemich for their assistance with colour measurements, and Toma Fotothu for his advice on survey form design and the use of sealed bags. Thanks also to the Sherman Fairchild Fellowship Program and by Mrs. Anneke de la Renta.

ENDNOTES

(1) The aim of the survey and the use of a database were suggested by James Newhall, Curator of Objects Conservation, Stedelijk Museum in Amsterdam. This work was developed by Rozsa Verbene and Sandra Weedenburg with contributions from other staff members of the museum and the Rijksmuseum Twenthe (Verberne-Khurshid 2002).

(2) AIP A-D Strips are strips of paper impregnated with a dye that changes colour in response to changes in pH. They were used for regular monitoring of Technogel cushion condition.

(3) The principle of using separate pages for different types of data was derived from a database development project for sculpture developed by Sandra Weedenburg, Head of Conservation at the Stedelijk Museum, Amsterdam.

(4) A list of evaluation criteria and the evaluation code that was selected was influenced by survey forms developed by Christine Frohnert and Sarah Spafford-Ricci et al (Frohnert 2003: 63-73; Spafford-Ricci, Fraser and Smith 1992: 28-30).

(5) The Cushion aims to use a database developed by the Stedelijk Museum, Amsterdam. This work was developed by Rozsa Verbene and Sandra Weedenburg with contributions from other staff members of the museum and the Rijksmuseum Twenthe (Verberne-Khurshid 2002).

(6) The colour of the A-D Strip corresponds with level 5 on the A-D Scale and with a 10 on the IPI scale. The IPI A-D Strip guide, indicates the start of rapid, autocatalytic degradation of the cellulose acetate.
ABSTRACT
The San Francisco Museum of Modern Art (SFMOMA) is undertaking a detailed survey of the three-dimensional objects in the Architecture and Design (A&D) collection funded by the Institute of Museum and Library Services (IMLS). Objects to be surveyed in the course of two years are: furniture, lighting, architectural models, textiles and design objects. This paper provides an overview of SFMOMA, its A&D collection and the conservation department. It describes the fundamental shift that has occurred in design moving away from the purely utilitarian and commercial approach toward a more contemporary artistic culture. In addition it deals with new computer-based technologies, in particular rapid prototyping. This article demonstrates how these changes are reflected in the new survey methodology. The risks that could prevent the objects' future exhibition and preservation are addressed, and examples from the SFMOMA collection are presented to demonstrate the new survey approach.

KEYWORDS
survey, contemporary design, conceptual design, designer intent, light bulbs, rapid prototyping

INTRODUCTION
The undertaking of conservation surveys of artwork has a long tradition in the conservation field. Surveys are used as a starting point to understand the needs of a collection prior to the actual treatment, display and long term preservation issues. Since 1986, the San Francisco Museum of Modern Art (SFMOMA) has carried out five item-by-item surveys of objects within its collection. The 2005 survey of the museum’s Media Arts holdings demonstrates the importance of revised survey methods and templates for contemporary art to better address the care of the 20th and 21st century objects often made with unorthodox materials and with complex implications. Results of a general conservation survey of the Architecture and Design (A&D) collection confirmed that a similar, but distinct, shift in approach is necessary for its item-by-item survey, particularly for mass-produced furniture and design objects containing consumable parts, and installation-based works. The three-dimensional objects in the A&D collection are the last of SFMOMA’s significant holdings to be surveyed on an item-by-item level. In 2009 the SFMOMA Elise S. Haas Conservation Studio received an Institute of Museum and Library Services (IMLS) grant to undertake a survey of the three-dimensional objects in the A&D collection. This survey is at its starting point, thus this article will focus on the thinking and decisions that went into shaping the survey.

SAN FRANCISCO MUSEUM OF MODERN ART
SFMOMA was founded in 1935, and from the outset has championed the most innovative and challenging art of its time. The museum continues to exhibit and collect work by both modern masters and younger, less-established artists and designers. The collection emphasizes experimental work in a broad range of traditions and a variety of media, including: painting, photography, sculpture, installation, video, and digital art. In total, SFMOMA owns over 30,000 objects; about 4,500 belong to the A&D collection, and about 1,100 of those are three-dimensional.

THE ARCHITECTURE AND DESIGN DEPARTMENT
Even before the A&D department was officially founded in 1983, SFMOMA provided an active forum for examining issues of architecture and design related to modern and contemporary art. It was the first for a West Coast museum, and is one of very few in the United States to do so. The department was established with an emphasis on West Coast and Pacific Rim regional design and architecture, and has since become one of the foremost repositories of California’s modern, contemporary...
architecture and design. Its growing collection represents con-
temporary thinking and design methodologies throughout Cal-
pography, posters, models, furniture, lighting, and electronic ap-
pliances, as well as motor vehicles.

Since the late 1990s, SFMOMA’s A&D department has ex-
panded its scope to include digital projects such as websites, and
pliances, as well as motor vehicles. Other well-known designers representing this movement are
Humberto and Fernando Campana, whose furniture depicts
Brazilian shanty towns and the gap between rich and poor. Very
influential designers are Anthony Dunne and Fiona Raby from
Dunne and Raby design firm, who create objects that do not ful-
il a function, but measure behavioural reactions. Anthony
Dunne first used the term ‘critical design’ in his book *Hertzian Tales, Electronic Products, Aesthetic Experience,* and *Critical Design* (2006). Here design should provoke new ways of think-
ing and reflections about objects and challenge our preconcep-
tions and expectations.

Similarly tendencies occur in the architecture field. For ex-
ample, the Blur Building at Lake Neuchâtel in Yverdon-les-Bains, Switzerland, was commissioned in 2002 for the Expo, and was
designed by Diller + Scofidio. This pavilion contains thousands of
jet nozzles that dispense a continuous mist around itself. The
resulting fogboth conceals and reveals the structure: a scaffold-
ing with no physical building.

These changes in design are also tightly linked to develop-
ments in new materials and new technologies and processes.

Since the early 1990s computer-aided technologies like rapid
prototyping (RP) and laser cutting (CN), as well as digital tech-
nologies like social networking and open-source collaborations
have transformed the design process from Apple’s iPhone and
iPad to social networking like Facebook and Flickr, including
the new ‘blogging’ culture to name only a few. For the latter ex-
amples, the user becomes the designer and the designer’s chal-
lenge is to create the most user-friendly platform.

**CHANGES IN CONTEMPORARY DESIGN**

“I believe we are in the third major phase of modern design his-
tory: an era of relationally-based, contextually-specific design…

It explores more open-ended processes that value the experien-
tial and the participatory and often blur the distinctions between
production and consumption….” This new phase is preoccupied
with design effects—extending beyond the design object and
even its connotations and cultural symbols.” writes Andrew
Blauvelt, design director and curator at the Walker Art Center
in Minneapolis (Blauvelt 2006). This shift in design manifests itself
by moving away from a solely utilitarian and commercial direc-
tion to becoming more experimental, contextual, abstract, and
performative, and has a strong similarity to conceptual and in-
stallation art.

An important milestone in design was the launch of the
Dutch design firm Droog in 1993. Droog added a strong con-
ceptual aspect to design objects, which seemed to be functioning
more and more at an artistic level (Williams 2006: 112). Pieces
were created which address issues, explore ideas and express
thoughts. A well known example is the *Tree Trunk Bench* by
Jurgan Bey first made in 1999. He creates hybrids of found ob-
jects (in this case, the tree trunk) and Victorian chair-backs, and
criticizes our culture’s obsession with newness and novelty.

The new post-modernism challenged the modernist orthodoxy: the third phase of modern design, which we are in today, has
had to respond to the new ‘blogging’ culture, user-generated con-
tent and new technologies to extend beyond the design object.

**THE A&D SURVEY**

The Elise S. Haas Conservation Studio at SFMOMA, one of the
largest and most active conservation departments devoted to
modern and contemporary art in the United States, was estab-
lished in 1971. Since then, the museum has made many distin-
guished contributions to the conservation field. The staff’s specialties are in objects, paper painting and photography con-
servation. The studio has an open space design to encourage the
collaboration necessary when addressing contemporary art, which
often defies such categorisation. The SFMOMA conser-
vation department has a long standing history in training in con-
servation of contemporary art due to its acknowledgment of the
shifts that have occurred in the art making process since the mid
20th century with untraditional materials and processes.

**THE A&D SURVEY**

The IMLS grant received in 2009 supports a two-year item-by-

item survey of the 1108 three-dimensional works in the A&D col-
lection. Traditionally, conservation surveys are mainly concerned
with assessing the physical condition of an object in order to in-
form its treatment. However, with these significant changes in con-
temporary design as described above, an understanding of the
other key qualities of these contemporary works is essential for
their preservation and future display. In addition to the assessment of
the condition of an object, it was concluded that the following
key information and needs also need to be addressed in the survey:

1. Obsolescence of consumable parts
2. Missing instructions/manuals
3. Intent of designer
4. Packaging: a design object in itself or part of the object?
5. Degradation of materials

As a result the new survey methodology includes traditional
topics combined with new inquires:

1. Record and document consumable and electronic components like light bulbs, the components’ specifications and availability, and provide recommendations for alterative components.
2. Record whether instructions and manuals are available for design installation, and evaluating whether sufficient information exists to exhibit and preserve this piece.
3. Examine the physical condition of objects to provide recommendations that address handling, treatment, display and packing issues.
4. Photo-document object details like ionery, hardware, and labels that will help to date objects with long production histories and provide a comprehensive photographic library when the physical object is not at hand.
5. Conduct designer interviews to learn about objects with regards to materials, processes, manufacturing and the designer’s intent, and to enhance the collection beyond the physical object.
6. Bring expert consultants to SFMOMA to provide specialised advice on contemporary architecture, design fabrication and materials’ conservation. For example, a textile conservator, who specialises in synthetic upholstery or a model maker, who is knowledgeable in identification of rapid prototyping techniques.
7. Research on history, production and manufacturing processes on pieces of the A&D collection conducted by a curatorial intern.
8. Meet twice a month with the curatorial staff to discuss surveyed objects regarding issues like intent of designer, packing and installation.

Microsoft ACCESS was chosen as the database for collecting the
survey information due to its strong search function, and ease of
use, in addition to the institutional support by the SFMOMA
Informative Systems and Services (ISS) department. Further-
more it allows for easy export and import of data from the internal
SFMOMA database EmbARK. Due to the large variety

![Figure 1](image-url)
of objects in the A&D collection in terms of construction and materials, five different databases were developed prior to the actual survey: furniture, lightings, design objects, architectural models and textiles. The assessment time of each object and its housing as well as detailed photography was estimated for an av-
tual survey: furniture, lightings, design objects, architectural erage of 2 hours. An extra day per week was calculated for down-
loading images, researching and processing the data collected.

NEW SURVEY METHODOLOGY EXEMPLIFIED
ON OBJECTS FROM THE SFMOMA COLLECTION
The five risks, that are crucial to consider for the future display and preservation of contemporary A&D objects are exemplified in the following case studies.

OBSOLESCENCE OF CONSUMABLE PARTS
The Chandelier 85 Lamps (1993) by Rody Grauman (of the Dutch Design company Droog) is formed from the grouping of 85 associated sockets, cords, and bulbs, composing the chandelier (see Figure 2). The light bulbs, which are consumable compo-
nents, comprise the central element in the object. Incandescent light bulbs are a pressing issue in the conservation of lighting objects, since they will become obsolete in the future, due to the global aim to reduce greenhouse emissions. Since September 1st 2009 the European Union has started phasing out 100-watt bulbs and will be in full effect by 2012 with bans on 40- and 25-watt bulbs. Australia has already started to interdict incan-
descent bulbs and this move is closely followed by the United States, which has passed a law barring stores from selling incandescent light bulbs after 2012 in favour of more energy-effi-
cient lighting, like (compact) fluorescent lamps, high-intensity discharge lamps, light-emitting diodes (LED), and other devices (Kanter 2009). However, the more energy efficient light bulbs have the least variety of shapes and colours, and emit a very different quality of light than traditional incandescent bulbs. As conservators, we are faced with questions of how we will be able to display lamps and lighting in the future, especially on objects where incandescent bulbs are a main decorative element (as with Chandelier 85 Lamps). Does it mean stockpiling incandescent light bulbs? Or can the spiral-shaped compact fluorescent bulbs be used instead? In order to be able to answer these questions, and to truly understand this particular chandelier, it might be necessary to ask the designer, and follow up with an interview to learn what the thresholds of the piece are.

Similarly, CDs and DVDs fall in the same category of obso-
lecence of materials. These data carriers are known for their short shelf life (Byers, Lu, Starrey et al 2004). The A&D collection holds digital data like CDs, and DVDs and VHS as part of design installations like Bad Press: Dissident Housework Series (1993-1998) by Didier S, Schofield, or as explanatory DVDs of ar-
chitectural projects like R&Sie’n’s (1993-1998) by Diller + Scofidio, or as explanatory DVDs of ar-
chitectural projects like R&Sie’n’s (1993-1998) by Diller + Scofidio. Different formats and materials may be used instead? In order to be able to answer these questions, and to truly understand this particular chandelier, it might be necessary to ask the designer, and follow up with an interview to learn what the thresholds of the piece are.

OUTSTANDING ISSUES/MANUALS
As mentioned above the movement in contemporary design, towards a contemporary art culture of installations has an impact for a conservator on how to preserve these pieces. The transformation of these pieces often relies on its installation instructions. Alex Schweder’s A Sac of Rooms All Day Long (2006) is performance architecture. This piece was commissioned by SFMOMA and is made of clear sewn polyvinyl chloride (PVC). It is comprised of one main house or ‘sac’ with four separ-
rate rooms inside. The rooms are filled with air, which holds up the outside house. The four rooms are choreographed: they inflate and then deflate all individually on a 5-hour cycle at separate times. With the piece comes a sound piece in mp3 format. Alex Schweder explores with this work his in-
terest in bodies in space and the space in bodies. He investigates as he calls it “…the permeability between buildings and the bodies that occupy them” (Grauman Foundation 2009). Knowing, that PVC is not a stable material, he conceived of the work as one that could be remade in the future. He pro-
vided technical drawings for the piece with the acquisition. The exemplifies really well the major shift that has occurred in conservation: Remaking

is a fundamental change in conservation and in how these pieces are ap-
proached. No longer is the material being preserved, but the instructions of manufacturing the piece become an essential part of the acquisition, making it possible to be remade in the future by the owner.

Yet this type of acquisition is not straightforward. It re-
quires thorough discussion with the designer to understand all the details and subtle aspects of the design and installation so that future iterations will be in keeping with the designer’s intent for the work. During the one-week installation we compiled thorough instructions notes with Schweder, with key informa-
tion to augment the technical drawings:

• The assembly of the house and its rooms inside.
• The programming of the computer that controls the four fans and the sound piece.
• The specifications of the four fans and programmer in case they break or need to be replaced.
• Instruction on how to repair tears (including repair materials).

In addition we have developed a relationship with Schweder. This relationship might prove essential for now unforeseeable future questions, changes and technical or material issues, as well as to ensure the successful retrieval of the artist’s intention.

INTENTION OF DESIGNER
SFMOMA has actively collected conceptual design pieces over the past years. Conceptual art was born with Marcel Duchamp’s 1917 ready-made Fountain (the famous urinal signed ‘R. Mutt’) making the idea behind a work far more important than its ex-
cution or visual aspect and thus liberating the artist from tra-
ditional formats and materials. In the design context it is more about disengaging from industry in terms of standing back from the process and dedicating time to reflection and to extend critical awareness. The Undercover Table (1999) designed by California based architect Thom Faudlers and artist Anna Rainier from Beige Design was on view at the SFMOMA exhibi-
tion Sensate: Bodies and Design (autumn 2009) (see Figure 4). In California people are aware, that an earthquake can strike
any moment, which caused the designers to rethink the furniture around them by transforming this everyday table into a survival station. The space underneath the table—usually the most forgotten—becomes the most significant part. This table has three orange storage compartments with six openings, and is wrapped with three perforated leather bands around the short dimension of the table. The bands can be detached, stuffed with material and used to lie on. In the three compartments is emergency equipment like a radio, flashlight, oxygen mask, a tent and water supply. The top can be pulled off and used as a stretcher. What is important here is the idea, not the actual objects in the compartment. Talking with Faulders, he pointed out, that it is possible to update all the emergency elements, replacing them to current standards and also adding other emergency supply like energy bars and a global positioning system (GPS). In addition the table can be dressed with as little and as many items as desired for the installations. As with all conceptual design pieces, it is crucial to understand their concept in order to be able to preserve and exhibit them appropriately. All installations and any communication, whether by interview, telephone or email, need to be recorded and thoroughly documented to ensure future display and reiterations.

PACKAGING: A DESIGN OBJECT IN ITSELF OR PART OF THE OBJECTS?

Many mass-produced objects that are collected by design museums often come into the collection with their original packaging. In most cases the objects are removed from the packaging for storage, since these materials are usually not archival. Either they are discarded, or conversely they are kept because resources and time were missing to replace them with appropriate housing. The packing of some design pieces are themselves important product design examples or are part of the object, but have not been accessioned. A good example is Marcel Wanders’ Airborne Snotty Vase (2001) made from polyamide (see Figure 5). This piece is part of a series of five vases named after five different diseases of the nasal cavities. Wanders digitally recorded minute mucus particles from a human sneeze with a three-dimensional scanner and transformed them into vases. It was acquired in 2001 by SFMOMA and with the piece came an equally well designed housing for the manual of the piece (see Figure 6). SFMOMA has only accessioned the vase but not the housing, however, this housing is still valued and handled like an artwork. Is this housing a design piece in its own right? Can it be displayed separately or only with the vase? Can it be displayed at all? If so does it have a separate inventory number and is it actually considered part of the collection? In order to help answer these questions bi-weekly meetings with the curatorial staff and registrars are included in the survey to discuss issues like packing, their historic relevance and importance within the collection.

DEGRADATION OF MATERIALS

The degradation of materials is what the conservator most often deals with: preserving the materiality of artworks. Design has always been involved in the development of new materials and technologies and has applied them by intentionally incorporating them into design objects. A new manufacturing technology is rapid prototyping (RP), which has been increasingly used by designers. Marcel Wanders’ Airborne Snotty Vase was made from this manufacturing technique. RP, first introduced in 1983, is one of the most important applied technological innovations to have an effect on three-dimensional design and due to its high cost implications it has been used increasingly only in the last ten years. This is a collection of processes including stereolithography, selective laser sintering and fused deposition modelling that creates objects from computer-aided design (CAD) drawings, thus removing the need for casting, hand modelling or moulds in between. The basic principle of RP, in the case of stereolithography for example, is that a designer creates a three-dimensional file on the computer, which is then sent to a so-called three-dimensional printer. The printer fires lasers into a container that slowly fills with fine layers of photo-sensitive resin dust and fuses and polymerises particles together in the precisely defined volumes. In essence the design itself is a computer file.
One of the enormous advantages of these techniques is that designers are no longer limited by negative space problems involved in using moulds and are suddenly liberated and able to create a variety of shapes that were previously impossible. Furthermore it allows for the production of infinite quantities of identical objects. A splendid example is Patrick Jouin’s chair SOLID C2 from its 2004 SOLID collection. It is made from epoxy resin using the RP technique stereolithography. This collection was groundbreaking in producing objects on such a large scale with RP. It has also been used by other designers such as Ron Arad, Marcel Wanders and by architects like Frank Gehry and R&Sie(n) for architectural models.

In the survey those objects made from this technology will be recorded with a red flag. Objects made from RP have been a concern in the collection; during their short life time, some of them have already become increasingly brittle resulting in breakage. Does the manufacturing process have an impact on the longevity of the resin? RP like laser cutting - as well as the use of new materials - requires more research into its longevity and treatability in order for conservators to understand the long-term implications for objects made by these new techniques. If these new processes prove to accelerate aging in resins that are otherwise more stable, then perhaps designers working with these methods will adopt an approach similar to that of Alex Schweder: they may provide the computer file with specifications for a design object at the time of acquisition into a collection.

CONCLUSION

These case studies presented in the article form the exception in the SFMOMA Architecture and Design collection. However, design museums have started to collect such pieces and will increasingly do so. A distinct shift in design towards a more artistic and philosophical approach and major changes in technology like rapid prototyping and materials development have occurred, which in response requires a shift in how these pieces are treated and preserved. As conservators we should commence to address these changes now to be able to develop long term preservation plans for those objects. This survey is a step towards addressing a new approach in how we as conservators respond to fundamental changes in design. After the completion of the two year survey, the ACCESS Microsoft database will be downloadable from the SFMOMA website with the hope that a new model of care can be discussed, critiqued and integrated by conservators of new design.

ACKNOWLEDGEMENTS

Grateful thanks are extended to: the Institute of Museum and Libraries for funding this project; Michelle Barger (Deputy Head of Conservation at SFMOMA) for her support and inspiration throughout the project and her passion for the conservation of contemporary art. Alex Schweder (architect) and Thom Faulders (designer) for being so approachable and collaborative, Lori Fujimoto (volunteer at SFMOMA) for her indispensable help with the Microsoft ACCESS databases and the SFMOMA conservation department.
ABSTRACT

Many product properties of plastics result from the fact that technical polymer materials are a complex mixture of different molecules. The chains of polymer molecules have a certain length distribution and contain irregular structures. The properties of technical materials are often modified by copolymerization, by blending, and by adding additives.

This formidable complexity of real world polymer materials gives rise to the aging processes which appear to be very similar.

The knowledge about the degradation mechanisms allows us to define strategies for the preservation of properties and the possibility for the repair of aging effects. Beside general rules and approaches, the specificity of a particular material has to be taken into account. In the paper, examples are discussed to illustrate this situation. While some of the procedures seem to be straightforward, more research is required to make others work.

KEYWORDS

Plastics, polymer, aging, degradation, storage conditions, repair

INTRODUCTION

Artificial materials have been used in a steadily growing extent for about 170 years. They penetrated into almost every part of the human life. In a certain sense, the rubber vulcanization by Charles Goodyear marks the start of this era in the year 1839. At the end of the 19th century Adolf von Baeyer and Leo Hendrik Baekeland developed the first synthesized artificial material. Phenol formaldehyde resin went into industrial production in 1909. Since that time, a large number of new materials with a wide range of properties has been produced.

In the 1920s Hermann Staudinger created the basis of a scientific view on these materials (Staudinger 1926). He identified them as polymers, which are molecules comprising a large number of small repeat units. This understanding led to the profound knowledge of the materials we have today.

Plastics, as well as many other organic materials, deteriorate when placed in storage. The reactions involved in the processes have already been investigated for many years. If we want to slow down the aging or repair the damage however, it is necessary to know what actually happens in the processes.

INTRODUCTION

This paper gives a brief overview about the composition of technical polymer materials and their degradation pathways. Then we will discuss some guidelines of slowing down the aging process. Finally, some ideas will be presented on how to reverse aging effects.

POLYMER MATERIALS

Polymers are synthesized from small molecules called monomers which are repeatedly built into large molecular chains. The names of the polymers are usually derived from the name of the monomer (see Table 1).

The molecules of the polymers are not all the same. They differ in a number of respects. Firstly, the chain lengths of the molecules of polymers are not uniform, rather they have a certain distribution. For example, a typical average molecular weight of polyethylene is approximately 10^6 g/mol. This number corresponds to a molecule which consists of more than 3500 ethylene units. The distribution of the molecular sizes is usually rather broad. A considerable fraction of the molecules is 10 times larger, but there is also a fraction of a waxy substance with a molecular mass below 1000 g/mol.

Beside the regular structure of a polymer the molecules contain structures that differ from the simple formula from which the name is derived. These irregular structures can have very different origins. Chain ends are inherent in polymers. In the case of polyolefins their concentration is in the order of parts per million. But this concentration can be as high as fractions of a percent for some polycondensation products such as PET (see Figure 1).

The polymer formation reaction runs usually with a high specificity. However, there are always side reactions e.g. due to impurities of the monomer or due to alternative reaction paths in the monomer addition to the growing chain. Branches are a typical example for the latter case. The amount of this kind of irregular structures varies with the reaction conditions as for example the type of catalyst. The concentration of these structures can be as high as several percent.

Many product properties of plastics result from the fact that technical polymer materials are a complex mixture of different molecules. In technical materials the properties of the polymers are often modified by copolymerization of two or more monomers, by blending, and by adding additives. Due to the fact that different polymers, even if they are chemically very similar like e.g. PE and PP, do not mix well, copolymerization and blending usually results in a phase separation.
Degradation of hydrocarbon polymers in dependence on the branching

Table 2

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Temperature of rapid weight loss:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene HDPE</td>
<td>420°C</td>
</tr>
<tr>
<td>Polypropylene PP</td>
<td>390°C</td>
</tr>
<tr>
<td>Branched Polyethylene-LDPE</td>
<td>380°C</td>
</tr>
<tr>
<td>Poly(isobutylene)</td>
<td>350°C</td>
</tr>
</tbody>
</table>

Considering the hydrogen-carbon bonds in Figure 1 it is evident that a relatively small variation in the branching structure can result in notable differences in the bond strength. This kind of difference translates directly into the stability against degradation, as it is shown in Table 2. The polyolefins listed there are distinguished only by the amount of branching. The branching weakens the structure and results in a degradation at a lower temperature.

These data illustrate that weak structures largely determine the ability of a material to withstand the degrading effect of an energy input. Besides the branches, groups which contain atoms of e.g. oxygen and nitrogen, such as ethers, esters, and amides, must be considered as weak structures. Polymers comprising such structures are usually less stable than hydrocarbons. Weakly bonded groups can also be located at the side of the polymer chain. For example, the chlorine atoms in the case of the poly(vinyl chloride) (PVC) tend to split off as hydrogen chloride (HCl), leaving a double bond (see Figure 3).

The carbon chloride bond just beside the double bond is even weaker than the one in an intact chain. More and more chlorine atoms are cleaved and the conjugated double bonds form a chromophore, which absorbs in the blue wavelength region. The HCl abstraction is accompanied by a discoloration of the material. Then the double bonds can undergo further degradation by cross-linking and oxidation.

Small molecules in the environment of the material can initiate or promote the degradation. The most prominent example of such a molecule is oxygen. The molecular oxygen in the atmosphere has the electronic structure of a biradical, which makes it very reactive. Light is able to increase this reactivity even further by exciting the molecule into the singlet state or by splitting the molecule into two oxygen atoms. Many polymer materials can be attacked by these factors. But also in a case where a bond in a polymer is broken by the action of an oxygen atom, light, heat, energetic radiation, or any other mean the radical formed this way reacts very rapidly with an oxygen molecule. With respect to material degradation, it is important to note that this radical recombination is the starting point of a chain reaction. As a result many oxygen atoms are incorporated into the polymer after a series of reactions that started at a single initiation site (see Figure 4).

Beside oxygen, water is a very abundant substance in our environment. Water is not as reactive as oxygen. But for some materials and in a long term exposure it can cause degradation by hydrolysis. In the case of a material that has this kind of group in a side chain, such as PMMA, the loss of a few side groups does not alter the material properties a great deal. However, if the group is a part of the polymer backbone the hydrolysis results in chain scissions and a reduction of the molecular mass. A typical example for such a material is PET (see Figure 5).

In the previous chapter, it was stated that some of the properties of polymer materials are largely determined by additives. In these cases, the loss or the consumption of the additives results in a loss of the desired properties. For example, radical scavengers are added to a material to suppress oxidation reactions as described above by reacting with a radical and forming an unreactive product. In the course of action this additive is consumed and at a certain point in time there is nothing left to do the job. The degradation can continue at a much higher rate. Some additives degrade by themselves. For example dyes and pigments can be bleached by light or oxygen.

Other additives like plasticizers are added in large amounts of up to several percent. Plasticizers are meant to separate the polymer molecules from each other and make them move more easily. Thus the material becomes softer and more flexible. Compared to the polymer molecules the plasticizer molecules are small and tend to evaporate from the surface of the material. The decreasing content of plasticizer causes the material to become increasingly harder and more brittle. Moreover, the loss of a part of the material results in a smaller volume. The material shrinks and forms wrinkles. PVC is the most prominent material that can degrade in this way.
The rate of most chemical reactions depends on the temperature; an increase by 10 degrees roughly doubles the reaction rate. Moreover, the evaporation rate are lower at lower temperature. For this reason, the storage would be beneficial, as the vapour pressure and, consequently, the evaporation rate are lower at lower temperature. The evaporation can be minimized by a saturated atmosphere around the material or by a coating which forms a barrier for this kind of substance. Such a coating can be as thin as 10 nm and reduce the loss of the plasticizer by several orders of magnitude while it is not visible and does not alter the tactile properties of an object.

The rate of most chemical reactions depends on the temperature; an increase by 10 degrees roughly doubles the reaction rate. Moreover, the evaporation rate are lower at lower temperature. For this reason, the storage would be beneficial, as the vapour pressure and, consequently, the evaporation rate are lower at lower temperature. The evaporation can be minimized by a saturated atmosphere around the material or by a coating which forms a barrier for this kind of substance. Such a coating can be as thin as 10 nm and reduce the loss of the plasticizer by several orders of magnitude while it is not visible and does not alter the tactile properties of an object.

**REVERSE AGING**

Once a material has aged and degraded it is extremely difficult to reverse the effects. This applies in particular if there is a multitude of different degradation reactions and pathways. The previous chapter illustrate this situation. For example, a material which is convinced to be brittle material can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration années and some variables are the parameters which are investigated. In this section the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.

At the moment the additives were added to the original material it was in a molten state and machines were used for the production. During conservation or restoration, the dependence of temperature on the reactions is discussed. For example, a material which has become brittle due to the lack of a plasticizer can be made soft again by increasing the concentration of the plasticizer to the original value. A baked material can be repaired by re-adding a dye.
ABSTRACT

This paper reports on the further development of a plasma pen, designed for small-scale improvements of the bondability and coatability of non-polar plastics used in modern and contemporary art and design. With regard to conservation and restoration applications the plasma pen was successfully fine-tuned for effecting a minimal thermal load during pre-treating thermoplastic polymer surfaces. The effectiveness of this temperature-tuned plasma for enhancing the bondability of poly(ethylene) [PE] and poly(propylene) [PP] has been proved by testing the tensile shear strength of untreated and plasma pre-treated adhesive joints. With regard to improving the adhesion of retouchings, changes in the coatability of PP, PE and poly(styrene) [PS] were quantified by performing pull-off tests. Through plasma pre-treatment the breaking strength of all tested adhesive joints were significantly enhanced and the application of mechanical resilient water-based and water-removable gouache retouchings became possible. Furthermore, by testing adhesive joints two and a half years after pre-treating and bonding, results can be taken as an indication that the affected adhesion improvements are long lasting. As is well known, surface oxidation initiated by free radicals is an essential chemical mechanism during plasma pre-treatment. First results of long-term monitoring changes in oxidation stability, performed on untreated and plasma treated PE-LD, will be presented.

KEYWORDS

Plasma, Retouching, Bonding, Polyethylene, Polyproplylene, Polystyrene

INTRODUCTION

Non-polar plastics in modern and contemporary art and design are well known to have insufficient adhesion properties in contact with nearly all adhesives and coatings. They are difficult to wet, their adhesive bonds have only limited tensile strength and applied coatings do not possess mechanical resilience. In consequence of these unfavourable adhesion properties, long-lasting conservation treatments (e.g. paint layer consolidation, bonding or retouching) are often not applicable or limited to art and design objects made of non polar plastics. A well known reason for their insufficient adhesion properties is a lack of surface polarity. Surface polarity is an important contributor to strong adhesive forces between plastics and adhesion partners (e.g. adhesives or coatings). This is due to the strong intermolecular forces between polar materials and the fact that they support strong adhesive attraction (Kinloch 1987). To overcome this lack of surface polarity before paint layer consolidation, bonding or retouching, a pre-treatment of the polymer surface is necessary to provide it with an artificial polarity. It is well known, for example from large-scale industrial applications, that plasma technology offers an opportunity to enhance the surface polarity of plastics, hereby improving their wettability and coatability (Gatenholm et al. 1990; Morra et al. 1990; Brewis and Mathieson 2002). Under specific operational conditions plasma can gain high chemical reactivity that can be used for chemical surface modifications. Hereby plasma pretreatment can introduce polar chemical groups in non polar polymer surfaces, for example by incorporating oxygen in the polymer’s hydrocarbon chains. Such changes in surface chemistry were observed by various authors by using surface-sensitive analytic methods (e.g. Gerenser et al. 1985; Wang et al. 2008; Leroux et al. 2009). Chemical modification depths were usually limited to the top few molecular layers of a polymer surface, for example depths at about 50 - 500 Angstroms are reported (WU 1982: 298). The goal of this research study was to develop a miniaturised atmospheric plasma pen specially designed for small-scale improvements of the bondability and coatability of non-polar plastics in modern and contemporary art and design. This paper reports on the process of designing, fine-tuning and testing of the plasma equipment, a process which started in early 2006. After describing the functionality and setup of this tool, a successful tuning of the operation conditions for minimising plasma temperature will be reported. Afterwards, today’s state of knowledge concerning the temperature-tuned plasma’s effectiveness for enhancing the bondability...
and coatability of poly(ethylene) (PE), poly(propylene) (PP) and poly(styrene) (PS) will be presented. Furthermore, by testing plasma treated adhesive joints two and a half years after bonding, first insights into the long-term effectiveness of the plasma pre-treatment were gained and the findings will be reported. Finally, first results of long-term monitoring the oxidation stability of plasma treated PE-LD, will be presented.

**SET-UP OF THE PLASMA PEN**

The plasma pen was designed to meet the following demands: a) The plasma should be locally applicable within a millimetre range at atmospheric pressure, thereby allowing small-sized and localised surface modifications. b) At the same time the plasma should achieve a homogeneous, reproducible and effective improvement of the polymer’s adhesive qualities. c) The load, which is caused by the plasma, should be kept on an adequate low level on thermoplastic surfaces. d) The pre-treatment should cause a minimal intervention into the artwork’s materiality, especially concerning undesirable changes in the long-term ageing properties of the pre-treated polymers and the surrounding materials (e.g. paint layers). In addition to these demands the plasma equipment should be as low-priced as possible, by maintaining at the same time a high durability of the used materials. Finally the plasma operating conditions should be as variable as possible, thereby enabling the fine-tuning of the plasma source with regard to a minimal negative impact on the materials present in works of art.

The plasma pen works under atmospheric pressure and produces a plasma jet with a sphere of action in the millimetre range (see Figure 1). The instrumental setup for operating the plasma is schematically depicted in Figure 2.

A variable AC transformer, coupled to a matched, low cost high-voltage circuit serves as power supply (1). The main part of the pen shaped plasma source (3) is an alumina capillary (4), within which the plasma is generated. A cross-section through the capillary (5) shows the used concentric electrode configuration (a-d). If adequate high-voltage is applied, electrical discharges are formed in this capillary in the gap between two electrodes (b/d). The primary high-voltage electrode (b) is a thin metal wire, mounted coaxially in the centre of the capillary. A metal mesh (d) serves as secondary grounded electrode. The alumina capillary (c) on its part acts as dielectric layer between these two electrodes and prevents hot and non homogeneous arcing. An operating gas (e.g. pure helium or helium with chemically reactive particles. This high chemical reactivity, for example caused by free radicals, can be used for chemical surface modification.

**TUNING THE PLASMA PEN FOR REDUCING TEMPERATURE LOAD**

With regard to conservation and restoration applications it is an essential necessity to be able to control the temperature load caused during plasma treatment. The effective thermal load was evaluated by performing infrared-pyrometric surface temperature measurements, using an infrared pyrometer with double laser aiming (CT laser, optris). The measurements were carried out on a specially prepared poly(propylene) foil according to the experimental set up described in endnote 2.

Especially with regard to consolidation treatments near thin paint layers with high thermal sensitivity, a minimal thermal load seemed to be an essential demand. It was found out that the plasma temperature can be minimised by changing different operation conditions like gas composition, gas flow velocity or high-voltage input. At first a reduction of the temperature load was achieved by tripling the helium flow rate (see Figure 3b). A further reduction was attained by additionally reducing the high-voltage input (see Figure 3c). Under the applied test conditions, it was possible to minimise the thermal load of the pre-treated surface down to at about 30 - 40 degrees Celsius. If not otherwise specified, all sample pre-treatments reported in this study were performed with the temperature-tuned plasma that caused a minimal thermal load in the pre-treated surfaces (see Figure 3c).1

**EFFECTIVENESS FOR IMPROVING BONDABILITY**

The effectiveness of the temperature-tuned plasma for enhancing the bondability of high density poly(ethylene) (PE-HD) and PP has been proved by tensile shear testing of untreated and plasma pre-treated adhesive joints. Tensile shear tests were performed on commercially extruded homopolymers, cut into a size of 70 × 10 × 5 mm and cleaned with propan-2-one. Polymeric samples were bonded with the acrylic resin Paraloid B-72, while maintaining an overlapping area of 10 × 10 mm. The acrylic resin was dissolved in toluene (1:1 parts by weight) and applied with a film drawing device (wet film thickness: 100 μm). After letting the sample joints dry for one month under constant pressure (267 g/cm²), the extent of the adhesion improvement was quantified using the tensile testing equipment as specified in endnote 4. The sample joints were pulled until the point of failure (testing speed 50 mm/min) and the adhesion improvement was quantified by comparing the breaking strength of the untreated with the plasma treated adhesive joints. For each test series at least eight identically treated samples were tested. The results were evaluated statistically as described in endnote 5. The adhesion qualities of PE-HD and PP were noticeably improved after plasma pre-treatment (see Fig.-
The breaking force necessary to separate the PE-HD adhesive bonds showed a significant increase from 26.17 ± 10.43 N/cm² to 197.26 ± 22.43 N/cm². In the case of PP, a significant augmentation from 26.62 ± 15.14 N/cm² to 169.16 ± 56.49 N/cm² took place. To obtain reproducible pre-treatment speeds, sample pretreatments were carried out using a computer-controlled, step motor driven x-y plotter. This plotter, fitted with a sample platform, moved samples along the x- and y-axis within a pre-treatment area of 10 × 10 mm. For all experiments reported in this study, after pre-treating the sample surface for one second, a forward movement of one millimetre took place. During pre-treatments the plasma pen was mounted rectangularly to the moving sample and was kept (deposited layer) within the same type of experiment) at operating distances of three, six or nine millimetres.

**Effectiveness for Improving Coatability**

With regard to improving the adhesion of retouchings, the effectiveness of the temperature-tuned plasma for improving the coatability was examined using pull-off tests. Untreated and plasma treated PE-HD, PP and poly(styrene) (PS) plates were coated with gouache paint as sample preparation. Polymer plates (PE-HD and PP; 70 × 10 × 5 mm, PS; 70 × 10 × 4 mm) were coated with the gouache paint (wet film thickness: 50 μm), again by using the film drawing device. The coatings were left to dry one month in controlled museum climate conditions. After that period of time, a metal stub (contact area 10 × 10 mm) was adhered on each coated sample surface by using a highly viscous cyanocrylate adhesive (see Figure 4a). In order to prevent that the used adhesive might falsify the results of the pull-off tests, the choice of an adhesive with low penetration capability was necessary. The acceptability of different adhesives was examined in preliminary tests. 24 hours after the metal stub applications, the force required to pull off the coatings was measured with the tensile tester (see Figure 4b). For each of the test series, at least seven samples with identical pre-treatment were tested. As shown in Figure 4c, all applied gouache coatings gained a considerable adherence onto the plasma pre-treated surfaces. Without pre-treatment a very low stress was already obtained (HDPE: 7.60 ± 2.94 N, PE-HD: 20.97 ± 14.73 N, PS: 2.76 ± 5.50 N). Contrary to this, on the plasma pre-treated surfaces the gouache coatings gained a significantly higher mechanical strength (PP: 83.65 ± 35.54 N, PE-HD: 116.03 ± 46.55 N, PS: 149.32 ± 48.66 N). Even though all coatings adhere very strongly to the plasma pre-treated surfaces, they can be removed easily using water. Plasma treatment opens hereby a new way to apply water-based and water-removable retouchings on hydrophobic plastic surfaces. A surprisingly strong adhesion improvement was reached through plasma pre-treatment on PS. On the untreated samples, gouache coatings began to lift off from the PS surfaces already after one week of storage.

**LONG-TERM EFFECTIVENESS OF THE ADHESION IMPROVEMENT**

To check the long-term effectiveness of the adhesion improvement, untreated and plasma treated adhesive joints (HDPE and LDPE) were stored two and a half years under controlled museum climate conditions. At least nine identically treated samples were prepared and tensile shear tested in the same manner as already described. Two and a half years after bonding with Paraloid B-72, the plasma treated adhesive joints kept their significantly higher mechanical strength (see Figure 5, on the left). To evaluate the long-term mechanical resilience of the gouache coatings on PS, untreated and plasma treated samples, prepared as described before, were stored as well under museum climatic conditions. Their optical appearance will be periodically checked with regard to paint layer separations. As can be seen in Figure 5 on the right, on the sample surfaces that were not plasma pre-treated, all coatings were lifted off within the first seven months of storage. In contrast to this all plasma pre-treated samples remained undamaged until now.

**MINIMAL INTERVENTIONS TO THE ARTWORK'S MATERIALITY ASSURED?**

Plasma treatment initiates chemical changes in the pre-treated polymer surfaces. An introduction of oxygen containing carbonyl groups takes place, as analysed for poly(propylene) with infrared spectroscopy in attenuated total reflection (ATR-IR). After plasma pre-treatment the most notable changes were found in the IR-absorbance range at about 1380-1550 cm⁻¹, known as the absorption region of carbonyl stretch vibrations. The detected carbonyl compounds are well known re-action products of polymer oxidation (Sheirs 2006, 416). It seems to be a relevant question, whether this surface oxidation accelerates the further autoxidative degradation of the pre-treated surfaces and surrounding materials (e.g. paint layers) or not. Concerning this question, a long-term observation of the future oxidative aging of plasma pre-treated polymers was started in summer 2008.

Untreated and plasma treated polymer samples are stored in the dark under museum climate conditions. Sample pre-treatments were made with the non-temperature-tuned plasma (see Figure 3a) as well as with the temperature-tuned plasma (see Figures 3b and 3c). Over the next years the samples will be periodically checked with regard to changes in oxidation stability. Oxidation behaviour of the samples is monitored by performing chemiluminencescence analysis (CL). CL is a very sensitive method for testing the oxidative stability of organic polymers. This analytical method benefits from the fact, that organic polymers emit light during oxidation processes. The emitted light, too weak to be visible to the naked eye, can be detected using light sensitive analytical equipment (Käser et al. 2007). Significant changes in the light emission of the samples can be used as an indicator for changes in their oxidation stability (Jacobson et al. 2004). Figure 6 represents one example of the CL-emission data gained after 68 weeks of long-term monitoring. These chemiluminescence measurements were performed on additive free PE-LD sheets (sheet thickness: 230 μm), the used measurement conditions are described in endnote 8. After 68 weeks of monitoring, the samples that were pre-treated with the non-temperature-tuned
introduced damages (e.g. stress crazing and cracking) during the application and removing of retouchings. It is expected that the bonding strength to other polar adhesives and coatings than those tested here can also be elevated, given that their dried films have an adequate cohesive strength. The reported long-term tests, performed on adhesive joints two and a half years after bonding, indicate that the adhesion improvement is long lasting. The plasma temperature is now tuned, thus causing a minimal thermal impact on the pre-treated materials. The long-term monitoring of oxidation behavior will be continued and future CL-measurements will expand the knowledge about the question whether plasma pre-treatment effects undesirable changes in the long-term aging properties of the pre-treated polymers present in modern and contemporary art and design.

ACKNOWLEDGEMENTS

The author would like to thank the workgroup of Dr. Ch. Holenstein (Plasma Physics Research Centre CRPP, Swiss Federal Institute of Technology, Lausanne) for the infrastructure support and for all the inspiring technical discussions. Special thanks also go to Dr. Jean-Luc Doriez, Dr. Alban Sublet and Dr. Samantha Pavon. In particular the author likes to thank Marc Eggert, Fabian Käser and Dr. Stefan Wülfert (Berner University of Applied Science, Bern University of the Arts) for their valuable collaboration. Further thanks go to Dr. Walter Caseri (Swiss Federal Institute of Technology, Zürich) for providing the infrastructure for the chemical surface analysis. Last but not least, the author thanks the workgroup of em. Prof. Dr. Döbele (Institute for Laser- and Plasma Physics, University of Duisburg-Essen), especially Dr. Stephan Reuter. This project could not have been completed without the financial support of the Berne University of Applied Science.

ENDNOTES

(1) Unless diffusion processes are involved. Adhesive bonds gained via diffusion processes (e.g. during welding or solvent bonding) are not reversible.

(2) During measurements, the plasma jet was aimed rectilinearly at a 4 μm thin PP foil that was fixed onto an aperture plate. On its backside, the PP foil was fitted with a self-adhesive film of a defined infrared emission ratio (emission ratio: 0.95). The pyrometer was positioned opposite the plasma source so that its laser aimed through the aperture opening onto the PP film's backside. The laser of the infrared pyrometer marked the centre of the pre-treatment area with a spot sized as small as 1.4 mm. Temperature values during pre-treatment were recorded during 100 s with a recording resolution of 500 ms. The procedure was performed at a fixed operating distance of 3 mm, while the plasma operation conditions like the voltage input and the gas flow rate were varied during the test runs. For each operation condition 7 temperature measurements were performed as displayed in figure 3.

(3) Except the long-term tensile shear tests reported in this paper. In this case sample pre-treatments were carried out with the non-temperature-tuned plasma (Fig. 3a) and were performed with an operating distance of 3 mm.

(4) Tensile testing equipment: Zwick 1120, Zwick GmbH & Co. KG, 89073 Ulm, Germany.

(5) All measurement data reported in this study were evaluated on the basis of calculated averages and standard deviations and they are displayed with confidence intervals of 95 per cent.

(6) Different adhesives were left to dry on carrier-free gouache films (wet film thickness 50 μm) and the chemical composition of the films backside was analyzed with infrared spectroscopy in attenuated total reflection (FTIR-ATR). The samples coated with the varnish/cyanacrylate showed no accordant IR-absorencies on their backside.

(7) Infra-red spectra were obtained six hours after plasma pre-treatment using a Fourier transform infrared spectrometer Vertex 70 from Bruker (2 cm⁻¹ resolution, 64 scans). For the semi-quantitative evaluation peak intensities were normalised by adjusting the intensity of the symmetric CH₂-stretch vibration of the used adhesive.

(8) Chemiluminescence data were gained by using an apparatus developed by Käser et al. 2006. The measurements were performed for each test series in triplicate using the same pre-treatment, storage and measurement conditions (measurement gas: oxygen 60 ml/min, non-isothermal experiment from 35 - 110 °C, heating rate: 0.2 °C / min). In the case of the CL-emission data presented in figure 6 sample pre-treatment was performed with the non-temperature-tuned operation mode (Fig. 3a).
ABSTRACT
In the mid 1950s polyethylene (PE) plastic bags were developed. Films for plastic bags differ in quality and durability, however, they all suffer from oxidation when exposed to (UV-) light during exhibition.

In the series Bicycles made by the artist Andreas Slominski since 1991, it was observed that plastic bags can decay within less than 20 years. Constant load, daylight and UV radiation cause embrittlement and some bags handles, seams, and bottoms are torn open. Thus far the conservation of plastic bags has not been an issue for conservators and there is a lack of research. Methods for their preservation have not been established.

For this study, samples of old and new PE bags were artificially light aged. Fourier transform infrared spectroscopy (FTIR) was used to follow photooxidation by measuring the carbonyl absorption during ageing. Differential scanning calorimetry (DSC) gave insight into the composition and crystallinity of aged and unaged plastic bags. Test inks for industrial testing of surface activities were used to quickly check the wetting of adhesives. The tensile strength of bonds between Japanese paper, an aged plastic bag and acrylic adhesives was tested. A plastic bag was treated using lens tissue and Lascaux acrylic adhesive 360 HV.

KEYWORDS
Polyethylene (PE) bags, surface energy, acrylic dispersion, artificial ageing, FTIR, DSC

INTRODUCTION
In the mid 1950s polyethylene (PE) plastic bags were developed. Ten years later they were widespread throughout Europe and the USA. It did not take long until art collectors started to collect them and only a few years ago, the first museum for plastic bags was established. Polyethylene bags also find their way into museums by their use in applied arts and fashion design. However, plastic bags seem to have not yet attracted the interest of conservators. Plastic bags are almost exclusively made of high- or low density polyethylene (HDPE, LDPE). Polyethylene readily suffers from photooxidation, resulting in embrittlement, cracking, darkening, loss of gloss and decrease in molecular weight. Films used for plastic bags are all or partly made of recycled material, which is particularly sensitive to UV radiation. When exposed to mechanical stress, PE films oxidise more. PE films for plastic bags differ in quality and durability and they can contain decomposition agents, which proceed to decompose when left in the dark after an initial exposure to daylight.

In the series Bicycles made between 1991 and 2005 by the German artist Andreas Slominski, it was observed that in a museum environment plastic bags can decay within less than 20 years. The bicycles are loaded with filled plastic bags, suitcases and many other items. Due to constant load, daylight and UV radiation some of the bags have become brittle and handles, seams and some of the bottoms are torn open. Before mounting the bags on the bicycle, Andreas Slominski made them look worn: he stained and scratched the bags, pulled holes into them and mended them with tape. Thus the bags differ from plain found objects and cannot be replaced by newer ones. Instead, it was decided to look into the possibility of a conservation treatment for the existing bags. New polyethylene is non-polar and has insufficient adhesion properties. If adhesion to polyethylene is required, the surface needs to be activated before applying any sort of coating. Activation can be achieved by several methods of which the build-in of atmospheric oxygen is the most common technique. The oxygen uptake during natural ageing of plastic bags has a comparable effect on the surface activity: both industrial surface activation and oxygen uptake during ageing increase the polarity and improve wettability of PE surfaces. A liquid wets a surface if the surface tension of the liquid is lower than or equal to the solid surface.

In the field of conservation some research on the polarity of PE surfaces has been done. In the field of conservation some research on the polarity of PE surfaces has been done. (van Oosten 1996; Comiotto 2003, 2007; Haider 2008) Guidelines for the conservation of
plastic bags have not been readily developed. In order to con-
serve the plastic bags of the **Bicycles** it was necessary to study the
ageing of plastic bags, to find out if aged PE bags can be adhered and
which adhesive is most suitable.

**PHOTOOXIDATION OF POLYETHYLENE**

The degradation of polyethylene has been researched and
described intensively. The most important degradation process
is light and UV radiation induced oxidation, so called photooxi-
dation, and occurs in the presence of chromophores in the
polymer. These can be internal or external impurities such as hy-
derperoxide, carbonyl groups, pigment and catalyst residues in-
troduced in the polymer during polymerisation, processing and
storage. The oxidation process is initiated and accelerated by
UV radiation. (Lemarie 1988)

The UV stability of a product depends on the structure of
the polymer (crystallinity, impurities that are added to the polymer and on the properties imparted during production and its pro-
cessing. As a result of low penetration of UV radiation into the poly-

cidal blocks) and the presence of oxygen, the de-

**EXPERIMENTAL**

Simultaneously, during ageing, the carbonyl index increases
due to the formation of carbonyl absorption during aging.
The ratio between a specific absorp-

**DIFFERENTIAL SCANNING CALORIMETRY (DSC)**

Differential scanning calorimetry measures the thermal effects
on polyethylene as it is heated and undergoes thermal transitions. The
DSC instrument analyses and quantifies the glass transition
(%) melting point(s) and crystallisation of the ma-

**TEST INKS**

When surfaces are cleared or cleaned in industrial processes, the
surface energy (in mN/m, formerly in dyn/cm) is measured af-

**RESULTS AND DISCUSSION**

**ARTIFICIAL LIGHT AGEING**

The history of the PE test bags is not known, nor their com-
pounding at manufacturing. The behaviour during artificial light
aging was observed and severe discoloration of dyes and break-

**CONDITION OF A PLASTIC BAG OF UNTITLED (1992)**

A plastic bag from the Slominski bicycle Untitled (1992), which
was attached to the bicycle, had separated from the body of the
car. The body of the bag was torn open along both edges and partially on the bottom, and the material had separated from the body. The body of the bag was torn open
and which adhesive is most suitable.
ylene bags were recorded and showed, in addition to the well-known peaks of ethylene (2900-2800, 1460 and 720 cm^{-1} of the C-H stretching, deformation and rocking modes of C=H groups respectively), carbonyl (C=O), hydroxyl (C-OH) and ester (C-O-C) functional groups (see Figure 3). The small peak at 1715 cm^{-1} can be attributed to a ketonic group. Simultaneously with carboxyl formation, double bonds change and chain scission and cross-linking occur.

At different intervals, during aging, test samples were examined to detect changes. For polyethylene test samples, the increase of photooxidation was determined by calculating the relative absorbance (A1715/A1850), which is the intensity of the carbonyl absorption peak at 1715 cm^{-1} (A1715) divided by background at 1850 cm^{-1} (A1850), where no absorption peaks are present. The degradation due to photooxidation of all PE test samples, expressed as the relative absorbance (A1715/A1850), is plotted against aging in hours (see Figure 4). After 600 hours of aging PE bag number 6 had a carbonyl index of 3.6, and some cracks were apparent. After 700 hours of artificial light aging the carbonyl index was 10.2 and the plastic bag was totally brittle. At 1000 hours of light-aging, bag 5 and bag 7 showed brittleness and were easily broken. For HDPE polyethylene bags without specific additives, a carbonyl index above the value 6 embrittlement occurs (see Table 3).

The black HDPE polyethylene bag has a carbonyl index higher than 6, but due to difference in composition observed at DSC, it can be concluded that this bag shows higher resistance to light-aging, probably due to the black coloured additive, which has a stabilising effect.

**DIFFERENTIAL SCANNING CALORIMETRY**

The DSC graphs of new and artificially light-aged polyethylene bags were recorded and melting points and crystallinity were determined. On the basis of data of melting points and crystallinity of various polymers from literature (see Table 2), it could be concluded that some of the polyethylene bags were composed of various polymers, and some polyethylene bags were made only of HDPE or LDPE.

After artificial light aging all plastic bags show increase in crystallinity, and according to literature, crystallinity of HDPE is more affected by light, showing higher increase in crystallinity than the increase in crystallinity of LDPE (see Table 3).

**TEST INKS**

A difference in the surface tension of aged and unaged bags could be measured. The insides of plastic bags have lower surface energies than the outsides, which were exposed to light. The lowest surface tension of 30-34 mN/m was observed on the insides of the bags, a value which is close to new polyethylene (approx. 30-32 mN/m). The highest surface energy was found on the outsides of artificially light-aged plastic bags (52 mN/m). The average for the outsides of the artificially aged bags was 47.5 mN/m and 37.5 mN/m on the insides.

The fragment of the Slominski bag was wetted on the outside with the inks with 44-46 mN/m and 36-38 mN/m on the inside. The plastic bag used for testing the adhesives in a mock-up situation was wetted with test ink with a surface tension of 38-40 mN/m on the inside, a value similar to the bag from the artwork that should be conserved. For industrial printing on PE foils, surface tensions of 38-42 mN/m are required. (Kappelhoff 1978:25-26) Also for adhering support material on the inside of plastic bags an increased surface activity on the inside is necessary. After 1000 hours of artificial light aging not all of the bags fulfill these minimum requirements: surface tensions for the insides of light-aged bags vary between 32 and 45 mN/m. Three samples that showed a clear loss in mechanical properties after artificial light-aging (sample 5, 6 and 7) were only wetted with 30-34 mN/m inks on the insides.

The critical surface energy of the bags (represented by the ink with the lowest surface tension that still wettens the surface) can be compared with given surface tensions of adhesives (see Table 4). Lascaux acrylic adhesive type 360 HV has a surface tension of 36 mN/m, type 498 HV of 44mN/m. Thus Lascaux 498 HV should be more compatible with the Slominski bag than 498 HV.

**APPLICATION OF ADHESIVES ON MOCK-UP**

Plexot D 360 and Plexot D 498 are low viscosity aqueous dispersions. They are soaked up by the paper and cause swelling of the fibres. For these two adhesives deformation of the plastic bag was observed, caused by shrinkage of the paper during drying and its resulting tension. Plexot D 360 and D 498 penetrate the paper and create a film on the reverse side. Adhesive films on both sides of the paper patches are unwanted as dust particles accumulate on the adhesives. The deformation of the bag could be reduced by allowing the adhesives to partly dry on the paper before adhering them. In the mock-up situation it was additionally possible to apply weight, which also helped to reduce deformations. Lascaux 360 HV and 498 HV are thickened with an acrylic butyl ester. Due to their high viscosity they neither show any visible shrinkage nor create an adhesive film on the reverse side of the patches. Plexot D 360 and Lascaux 360 HV have a lower glass transition temperature than the two 498-type adhesives and are thus stickier at room temperature. If Plexot D 360 and Lascaux 360 HV were allowed to dry almost completely before attaching them to the bag, the patches could be applied in a way similar to adhesive tape, using the pressure sensitive quality of the dried adhesive.

**TENSILE STRENGTH**

The tensile strength tests showed, that Evacon-R™ and the polar Medium for Consolidation adhere insufficiently to the plastic bag test strips. Nearly all bonds could be opened the same day. Most of the bonds with Plexot D 360 D and Lascaux 360 HV opened during the third week. Specimens adhered with Lascaux 498 and Plexot D 498 were stable for four weeks. No difference in stability between the two products of the same type was observed. The above mentioned lower glass transition temperatures of Plexot J 360 and Lascaux 360 HV could explain that all bonds made with the 360-type adhesives failed in the third week where higher room temperatures were measured.
CONSERVATION TREATMENT OF A PLASTIC BAG OF UNTITLED (1993)

The application of adhesives on the dummy showed that Lascaux 360 HV is most suitable for conserving the bag of Untitled (1992). Also the comparison of surface tensions suggested that the 360-type adhesives wet the surface better than the 498-type adhesives. Even though the 498-type adhesives showed better results regarding the tensile strength, Lascaux 360 HV was used for the conservation of the original bag because in the tensile strength tests higher loads were used than required for the original plastic bag. Most of the 360-type bonds failed, most likely due to high temperatures in direct sunlight and thus are not realistic for the artwork.

Instead of Japanese paper, Lascaux less tissue L2 (9 g/m²) was used for laminating the cracks in the Slominski plastic bag. It is a thin, soft and long-fibred acid-free material used in paper adhesives. Even though the 498-type adhesives showed better results regarding the tensile strength, Lascaux 360 HV can be heat-sealed, no heat was used in order to avoid thermal ageing of the bag. A new plastic bag that matched in size and look was placed into the conserved body of the Slominski bag and the seams of the original bag were partly attached to the new supporting bag. The conserved bag was then attached to the bike using the new handles. They were hidden under the original handles still attached to the bicycle.

CONCLUSION

In this study HDPE, LDPE and their various mixtures in the fabrication of plastic bags were investigated in order to understand how they age. Text tests to measure surface tensions without any analytical apparatus were found to be a useful method for quickly checking polarity of plastic bags for estimating their degree of oxidation. Possibilities to adhere cracks in a damaged plastic bag were tested and a damaged plastic bag of the artwork Untitled (1992) by Andreas Slominski was conserved.

Using FTIR analysis, the carbonyl index was established. It can be used for comparison of the degree of photooxidation of different plastic bags. DSC was used to determine the crystallinity of plastic bags and to gain insight into the composition and additives as well as the thermal history affect the ageing of LDPE, and HDPE plastic bags. For HDPE, which is more crystalline than LDPE, exposure to light is more devastating than for LDPE bags. The photostability of polymers cannot be evaluated by the formation of oxygenated products and changes in crystallinity. Polymer structure, composition and additives as well as their outer surface before printing. Thus it can be assumed that all printed plastic bags have had such pre-oxidation treatment and therefore will oxidize faster than polyethylene that is not activated. Information on the polarity of a plastic bag allows conclusions to be drawn regarding its degree of oxidation. Measuring surface tension of polyethylene bags provides good insight into which adhesive could be used for a conservation treatment. Until now, test inks have only been applied on dummies or on parts of the original that could not be preserved. After several

The torn edges and cracks in the body of the bag were laminated with a maximum overlap of 15 mm on each side of the cracks and tears, depending on their size and shape (see Figure 5). Since the body of the bag had come off the bicycle, it was possible to partially apply weight during conservation. Even though Lascaux 360 HV can be heat-sealed, no heat was used in order to avoid thermal ageing of the bag. A new plastic bag that matched in size and look was placed into the conserved body of the Slominski bag and the seams of the original bag were partly attached to the new supporting bag. The conserved bag was then attached to the bike using the new handles. They were hidden under the original handles still attached to the bicycle.

CONCLUSION

In this study HDPE, LDPE and their various mixtures in the fabrication of plastic bags were investigated in order to understand how they age. Text tests to measure surface tensions without any analytical apparatus were found to be a useful method for quickly checking polarity of plastic bags for estimating their degree of oxidation. Possibilities to adhere cracks in a damaged plastic bag were tested and a damaged plastic bag of the artwork Untitled (1992) by Andreas Slominski was conserved.

Using FTIR analysis, the carbonyl index was established. It can be used for comparison of the degree of photooxidation of different plastic bags. DSC was used to determine the crystallinity of plastic bags and to gain insight into the composition of the material. The research showed, that the increase in car- bonyl absorbance and crystallinity and therefore the increase in embrittlement are direct results of the exposure to light/UV radiation. Polymer structure, composition and additives as well as the thermal history affect the ageing of LDPE, and HDPE plastic bags. For HDPE, which is more crystalline than LDPE, exposure to light is more devastating than for LDPE bags. The photostability of polymers cannot be evaluated by the formation of oxygenated products and changes in crystallinity alone. Also, changes in average molecular weight should be monitored using e.g. high temperature size exclusion chro- matography in order to establish the loss of mechanical properties up to the point of embrittlement. Still the condition of a plastic bag can be estimated using the carbonyl index and taking into account the crystallinity. To complete the data from the FTIR and DCS, tensile strength tests on the aged and unaged samples, are necessary.

By the use of test inks it proved that photooxidation of plastic bags goes along with changes in surface polarity and the wetting behaviour. Wettability is the key for any application of an adhesive. As mentioned above, plastic bags are activated on their outer surface before printing. Thus it can be assumed that all printed plastic bags have had such pre-oxidation treatment and therefore will oxidize faster than polyethylene that is not activated. Information on the polarity of a plastic bag allows conclusions to be drawn regarding its degree of oxidation. Measuring surface tension of polyethylene bags provides good insight into which adhesive could be used for a conservation treatment. Until now, test inks have only been applied on dummies or on parts of the original that could not be preserved. After several

The torn edges and cracks in the body of the bag were laminated with a maximum overlap of 15 mm on each side of the cracks and tears, depending on their size and shape (see Figure 5). Since the body of the bag had come off the bicycle, it was possible to partially apply weight during conservation. Even though Lascaux 360 HV can be heat-sealed, no heat was used in order to avoid thermal ageing of the bag. A new plastic bag that matched in size and look was placed into the conserved body of the Slominski bag and the seams of the original bag were partly attached to the new supporting bag. The conserved bag was then attached to the bike using the new handles. They were hidden under the original handles still attached to the bicycle.

CONCLUSION

In this study HDPE, LDPE and their various mixtures in the fabrication of plastic bags were investigated in order to understand how they age. Text tests to measure surface tensions without any analytical apparatus were found to be a useful method for quickly checking polarity of plastic bags for estimating their degree of oxidation. Possibilities to adhere cracks in a damaged plastic bag were tested and a damaged plastic bag of the artwork Untitled (1992) by Andreas Slominski was conserved.

Using FTIR analysis, the carbonyl index was established. It can be used for comparison of the degree of photooxidation of different plastic bags. DSC was used to determine the crystallinity of plastic bags and to gain insight into the composition of the material. The research showed, that the increase in carbonyl absorbance and crystallinity and therefore the increase in embrittlement are direct results of the exposure to light/UV radiation. Polymer structure, composition and additives as well as the thermal history affect the ageing of LDPE, and HDPE plastic bags. For HDPE, which is more crystalline than LDPE, exposure to light is more devastating than for LDPE bags. The photostability of polymers cannot be evaluated by the formation of oxygenated products and changes in crystallinity alone. Also, changes in average molecular weight should be monitored using e.g. high temperature size exclusion chro- matography in order to establish the loss of mechanical properties up to the point of embrittlement. Still the condition of a plastic bag can be estimated using the carbonyl index and taking into account the crystallinity. To complete the data from the FTIR and DCS, tensile strength tests on the aged and unaged samples, are necessary.

By the use of test inks it proved that photooxidation of plastic bags goes along with changes in surface polarity and the wetting behaviour. Wettability is the key for any application of an adhesive. As mentioned above, plastic bags are activated on their outer surface before printing. Thus it can be assumed that all printed plastic bags have had such pre-oxidation treatment and therefore will oxidize faster than polyethylene that is not activated. Information on the polarity of a plastic bag allows conclusions to be drawn regarding its degree of oxidation. Measuring surface tension of polyethylene bags provides good insight into which adhesive could be used for a conservation treatment. Until now, test inks have only been applied on dummies or on parts of the original that could not be preserved. After several
days the inks were still wet and could easily be wiped off with cotton swabs and no change of the surface was noticed by visual examination. Test inks seem to be a convenient technique to quickly check surface compatibility of plastics or metals with adhesives, binders or solvents, but possible drawbacks still need to be researched. A drawback of the method is that the readings of the ink have to be done in the first 2 seconds after application. For the most part the readings are done by the person performing the test and are thus subjective.

By measuring the surface tension of aged polyethylene bags it was possible to pre-select adhesives for the conservation of Untitled (1992). Lascaux 360 HV and 498 HV and Plextol D 360 and D 498 were tested in uniaxial tensile strength tests. The tests showed that adhered bonds of aged plastic bags with a sufficient strength can be created. However, these findings are limited to tensile stress parallel to the adhered bond. As previous research has shown, the shear- and peel off strength of adhered bonds on polyethylene sheets is poor. (Haider 2008) Since the cracks and tears in the original bags on the bicycles neither require shear nor peel off strength, they can be adhered using one of the tested adhesives. The theoretical minimum surface tensions for printing and adhering PE bags refer to high-performance industrial applications and cannot be applied to requirements in conservation.

The application of these adhesives on a dummy showed that the viscous adhesives 360 HV and 498 HV are more suitable for laminating plastic bags than Plextol D 360 and Plextol D 498, because they cause less dimensional change of the paper patches during drying. Also, they do not create an adhesive film on the reverse side of the patch that could accumulate dust. The cracks in the damaged plastic bag of Untitled (1992) were laminated using Lascaux 360 HV and lens tissue. After the conservation the bag was reinserted into the artwork. The completely degraded handles of the plastic bag could not be treated because they were too brittle.

ACKNOWLEDGEMENTS

I would like to thank the art collectors Sabine and Hans-Jochen Waitz for their hospitality and Katharina Roeck for establishing the contact. I owe special thanks to Erwin Emmerling, Heike Stege, Andreas Burmester and Alexandra Czarnecki for fruitful discussions.

ENDNOTES

ABSTRACT
Many publications by conservation professionals describe visual assessment as the primary evaluation technique for cleaning. This may be due to the lack of analytical equipment available in museums, the speed and simplicity of visual examination or to the great importance of appearance of museum objects. Although it is relatively simple to examine surfaces by eye, it is complex to convey the results to others and it is unlikely that two independent evaluators can achieve identical results. Optical microscopy provides qualitative results concerning the intensity and density of scratches induced when cleaning and the presence of residues left by cleaning agents. Gloss measurements are relatively easy to perform and provide information about the presence of any physical changes to surfaces. However, when examining transparent plastics, measurements are disturbed by the multiple reflections within the bulk of material. Contact angles are relatively easy to perform and show changes in surfaces often before they can be detected by eye or optical microscopy. Contact angles relate to the type of change including the introduction of residues or of scratches, although it is not simple to attribute causes. Contact angle measurements can offer a reproducible and quantitative alternative to visual appearance for conservation professionals.

KEYWORDS
cleaning, PMMA, optical microscopy, contact angle, microfiber cloth, scratch

INTRODUCTION
Although all surveys of the condition of plastics conducted in museums in the United Kingdom and Scandinavia since the 1990s conclude that approximately 75% of collections require cleaning, few treatments have been developed (Shashoua and Ward, 1995). This is mainly due to the high risk of damaging plastics mechanically or chemically with an invasive cleaning treatment. Plastics with a glass transition temperature close to ambient, including polyethylene and plasticised polyvinyl chloride (PVC), are readily abraded by contact with brushes, cloths and sponges. Solvents and detergents applied either alone or as part of mixtures in commercial cleaning products can extract additives from flexible plastics such as PVC or induce environmental stress cracking in rigid plastics such as poly styrene, poly carbonate and polymethyl methacrylate (see Figure 1).

Despite the high risks, removal of oily fingerprints, carbonaceous dirt or crystalline degradation products from museum objects or artworks comprising plastics is necessary to maintain their significance, chemical stability and commercial value. Polymethyl methacrylate (PMMA), known widely by its commercial name Plexiglas or Perspex has been used commercially to manufacture designer furniture, aircraft windscreens, mathematical instruments, contact lenses and dental appliances as well as artworks. As a result, PMMA is found in industrial, modern history, design and art collections. Although the amount of literature discussing conservation of PMMA is sparse, specialist commercial cleaning products and procedures have been developed as aftercare for industrial products constructed from the plastic (Lucite International, 2005).

An extensive literature search of academic and commercial publications since 2000 made by Yvonne Shashoua and Esther Rapoport, suggested that cleaning practices for plastics could be divided into the following groups:

• Mechanical Includes microfibre cloths, natural fibre cloths, washing leathers, sponges, cotton wool, brushes, tissues and paper towels
• Aqueous Includes water, anionic detergents (eg Orvus WA paste) and non-ionic (eg Synperonic A7) detergents, water-based commercial blends based on aqueous solutions of detergents (eg W5 Synthetic material spray and Brillianize Plastic Cleaner)
• Solvent Includes pure solvents such as acetone, ethanol and iso-propanol and commercial blends based on solvents (eg W5 cockpit spray and Vinyl Makeup)
Optical Microscopy

Examination of surfaces by optical microscopy offers increased resolution, contrast and magnification compared to the naked eye. Increased magnification facilitates detection of micro-scratches and etching of surfaces. The technique is available in most museums and therefore was examined here. No preparation of samples is necessary. Polar and other filters may be introduced to enhance certain aspects of the image.

Gloss

Gloss has been proposed by the plastics industry as a convenient quantitative measurement system which would be an alternative to appearance. Gloss is the ability of a surface to reflect specular light which is incident from a particular direction. The factors that influence gloss are the reflective index of the material, the angle of incident light and the surface topography. Materials with smooth surfaces appear highly reflective (glossy), while very rough surfaces reflect no specular light and therefore appear mat.

Gloss is determined by shining a known amount of light at a surface and quantifying the reflectance. Gloss is measured using a glossmeter which directs a light at a specific angle to the test surface and simultaneously measures the amount reflected. The angle of incident light is determined by the type of surface being examined. Highly glossy surfaces are usually measured using an incident angle of 20° while mat surfaces require a higher angle. Glossmeter results are related to the amount of reflected light from a black glass standard with a defined refractive index and not to the amount of incident light. The measurement value for this defined standard is equal to 100 gloss units. For transparent materials such as PMMA, values can be higher than 100 gloss units due to multiple reflections in the bulk of the material (Glossmeter, 2009).

To compare any changes induced by cleaning from information given by optical microscopy, gloss and contact angle, a selection of cleaning techniques were applied to new, extruded PMMA and surfaces investigated by all three techniques before being examined. Highly glossy surfaces are usually measured using an incident angle of 20° while mat surfaces require a higher angle. Glossmeter results are related to the amount of reflected light from a black glass standard with a defined refractive index, and not to the amount of incident light. The measurement value for this defined standard is equal to 100 gloss units. For transparent materials such as PMMA, values can be higher than 100 gloss units due to multiple reflections in the bulk of the material (Glossmeter, 2009).

All publications found in the literature search which involved conservation professionals described visual assessment as the primary evaluation technique. This may be due to the lack of analytical equipment in many museums, the speed and simplicity of visual examination or to the great importance of appearance of museum objects on exhibition. Although it is relatively simple to train conservators to rate surfaces by eye, the results are rarely expressed quantitatively. It is complex to convey the results to others and it is unlikely that two independent evaluators can achieve identical results. The purpose of this investigation was to examine whether simple, non-invasive techniques could offer an alternative to visual examination in evaluating the changes in surface structure induced by cleaning PMMA. The simple, non-invasive evaluation techniques investigated were optical microscopy, gloss and contact angle of water on PMMA.

Optical Microscopy

Examination of surfaces by optical microscopy offers increased resolution, contrast and magnification compared to the naked eye. Increased magnification facilitates detection of micro-scratches and etching of surfaces. The technique is available in most museums and therefore was examined here. No preparation of samples is necessary. Polar and other filters may be introduced to enhance certain aspects of the image.

Gloss

Gloss has been proposed by the plastics industry as a convenient quantitative measurement system which would be an alternative to appearance. Gloss is the ability of a surface to reflect specular light which is incident from a particular direction. The factors that influence gloss are the reflective index of the material, the angle of incident light and the surface topography. Materials with smooth surfaces appear highly reflective (glossy), while very rough surfaces reflect no specular light and therefore appear mat.

Gloss is determined by shining a known amount of light at a surface and quantifying the reflectance. Gloss is measured using a glossmeter which directs a light at a specific angle to the test surface and simultaneously measures the amount reflected. The angle of incident light is determined by the type of surface being examined. Highly glossy surfaces are usually measured using an incident angle of 20° while mat surfaces require a higher angle. Glossmeter results are related to the amount of reflected light from a black glass standard with a defined refractive index, and not to the amount of incident light. The measurement value for this defined standard is equal to 100 gloss units. For transparent materials such as PMMA, values can be higher than 100 gloss units due to multiple reflections in the bulk of the material (Glossmeter, 2009).

To compare any changes induced by cleaning from information given by optical microscopy, gloss and contact angle, a selection of cleaning techniques were applied to new, extruded PMMA and surfaces investigated by all three techniques before being examined. Highly glossy surfaces are usually measured using an incident angle of 20° while mat surfaces require a higher angle. Glossmeter results are related to the amount of reflected light from a black glass standard with a defined refractive index, and not to the amount of incident light. The measurement value for this defined standard is equal to 100 gloss units. For transparent materials such as PMMA, values can be higher than 100 gloss units due to multiple reflections in the bulk of the material (Glossmeter, 2009).

All publications found in the literature search which involved conservation professionals described visual assessment as the primary evaluation technique. This may be due to the lack of analytical equipment in many museums, the speed and simplicity of visual examination or to the great importance of appearance of museum objects on exhibition. Although it is relatively simple to train conservators to rate surfaces by eye, the results are rarely expressed quantitatively. It is complex to convey the results to others and it is unlikely that two independent evaluators can achieve identical results. The purpose of this investigation was to examine whether simple, non-invasive techniques could offer an alternative to visual examination in evaluating the changes in surface structure induced by cleaning PMMA. The simple, non-invasive evaluation techniques investigated were optical microscopy, gloss and contact angle of water on PMMA.

Mechanical and aqueous

Includes various combinations of groups 1 and 2

Mechanical and solvent

Includes various combinations of groups 1 and 3

Chemical

Encompasses materials that clean by reacting chemically with the plastic or with the dirt (eg hydrogen peroxide)

Encompasses materials that clean by reacting chemically with the dirt (eg hydrogen peroxide)

Includes various combinations of groups 1 and 2

Includes various combinations of groups 1 and 3
Cleaning agents investigated in project

<table>
<thead>
<tr>
<th>Cleaning agent</th>
<th>Applied concentration</th>
<th>Description</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biflavone Plastic Cleaner</td>
<td>as supplied</td>
<td>based on detergent solution without silicone</td>
<td>Brilliante Inc., 4923 Industrial Way, Benicia, CA 94510, USA; <a href="http://www.brilliante.com">http://www.brilliante.com</a></td>
</tr>
<tr>
<td>Syntex AF®</td>
<td>1% in distilled water</td>
<td>nonionic detergent</td>
<td>American Roentgen Ray Society, <a href="http://www.conservationresources.com">www.conservationresources.com</a></td>
</tr>
<tr>
<td>Orange WA paste</td>
<td>as supplied and in distilled water</td>
<td>amionic detergent</td>
<td>as above</td>
</tr>
<tr>
<td>MS Cyclone spray</td>
<td>as supplied from spray can</td>
<td>solvent based without silicone</td>
<td>Luff UK, Graft, 17 Wyrple Road, London SW7 4EE, England; <a href="http://www.britsol.com">www.britsol.com</a></td>
</tr>
<tr>
<td>Organic material</td>
<td>as supplied from spray can</td>
<td>contains aliphatic hydrocarbons, terpene hydrocarbons, oxime derivates, dibasic, oxime, diglycolylester, oxime</td>
<td>as above</td>
</tr>
<tr>
<td>allulose on</td>
<td>as supplied</td>
<td>98% alcohol</td>
<td>&amp; Berthiou A3, Sandvika, %, Sandvika, NK-0210 Norway</td>
</tr>
<tr>
<td>PMMA</td>
<td>as supplied</td>
<td>general purpose, reagent quality</td>
<td>as above</td>
</tr>
<tr>
<td>PE teflon</td>
<td>as supplied</td>
<td>general purpose, reagent quality</td>
<td>&amp; Berthiou A3, Sandvika, %, Sandvika, NK-0210 Norway</td>
</tr>
<tr>
<td>PMMA, PMMA sheet</td>
<td>as supplied from Rias, the contact angles formed between distilled water and PMMA, both immediately after removing the protective film</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>as supplied</td>
<td>prepared by the authors as required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>as supplied</td>
<td>prepared by the authors as required</td>
<td></td>
</tr>
</tbody>
</table>

EXAMINATION BY OPTICAL MICROSCOPY

PMMA was examined for changes in surface appearance immediately after cleaning with a Carl Zeiss Jena, NEOPHOT 32 stereo-optical microscope in bright field, under crossed Polaroid filters and in dark field at magnifications of x 70 and x 300 before and after cleaning. Experience showed that if a period longer than 10 minutes passed between cleaning and examination, accumulated dust and other particles disturbed the surface image. Micrographs were taken of test areas before and after cleaning. Samples were examined for any disruptions in the passage of light through test areas after cleaning in the form of scratches, crazing or deposits and photographs were taken.

GLOSS MEASUREMENTS

Gloss of test substrates before and after cleaning was determined using a Minolta multi-gloss 268 meter. The glosmeter was calibrated so that the amount of reflected light from the black glass standard tile supplied with the instrument was 100 gloss units. Calibration was repeated every 10 minutes during measuring. It was possible to determine gloss at angles of illumination or geometries of 20°, 60° and 85°. Poorly reflective surfaces are recommended to be examined at an angle of reflection of 85°, semi-glossy surfaces at 60° and highly reflective surfaces at 20° (Minolta, 2009). Initially, all geometries were used to examine new test substrates but because values obtained from 85° were very low and poorly repeatable, measuring at that angle was discontinued.

Because the PMMA used as a test substrate was transparent and therefore likely to exhibit multiple reflections from the inside surfaces, a grey, mat card was placed directly under it in an attempt to reduce extraneous reflections. The measuring area of the Minolta mini-gloss 268 was approximately 1.5 cm x 1.5 cm. All gloss measurements on new test substrate were greater than 100 gloss units, which can be attributed to the presence of multiple reflections in the bulk of the PMMA. The grey mat card placed underneath the test substrate was replaced with both black and white cards in an attempt to reduce reflection from the lower surfaces. Changing the colour of cards did not significantly change gloss measurements, so the grey card was used. The error between measurements was calculated from the percentage gloss determined at 20 different positions on a new PMMA sheet immediately after the protective plastic had been removed and was found to be ±2 gloss units.

Three gloss measurements were taken for each test substrate area before and after cleaning (2 cm x 2 cm) by repositioning the glosmeter randomly between readings. The mean value was calculated. In order to investigate the extent to which the presence of scratches and crazing in PMMA had any influence on gloss, they were deliberately induced in the test substrates. Silicone carbide paper, grit 1200 (fine), was applied using backwards and forwards motion five times and a circular motion 5 times to produce patterns of scratches on an area of PMMA which measured 2 cm x 2 cm.

EXAMINATION BY CONTACT ANGLE

There are several ways to measure the contact angle of surfaces including the Wilhelmy plate method, captive air bubble method and the capillary rise method. The static sessile drop method was selected for this investigation because of the simplicity of the equipment required and the straightforward measurement procedure.

The static sessile drop method involves using an optical system to capture the profile of a pure liquid on a solid substrate. The angle formed at the liquid/solid interface and the liquid/vapour interface is the contact angle. Traditionally, a microscope optical system with a back light has been employed but high resolution cameras and software are used today to capture and analyse the contact angle. In order to determine whether cleaning had induced changes in surface energy of test substrate PMMA from Rias, the contact angles formed between distilled water and PMMA, both immediately after removing the protective film from its surfaces and 24 hours after cleaning were measured. In order to investigate whether the presence of scratches and crazing in PMMA had any influence on the contact angle, they were deliberately induced in the test substrate. Silicone carbide paper, grit 1200 (fine) was applied using backwards and forwards motion five times and a circular motion 5 times to produce patterns of scratches on an area of PMMA which measured 2 cm x 2 cm. The contact angles made by distilled water on these surfaces was determined immediately after they were produced.

EXAMINATION OF CONTACT ANGLE

PMMA was not rinsed after applying cleaning agents, as would be the case when conserving museum objects, so that the effect of the cleaning agent and application technique could be the focus of the examination. After cleaning, test areas were allowed to dry in air at 20 ± 2˚ C and 50 ± 2% relative humidity for 24 hours prior to examination.

Cleaning agent | Applied concentration | Description | Supplier |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biflavone Plastic Cleaner</td>
<td>as supplied</td>
<td>based on detergent solution without silicone</td>
<td>Brilliante Inc., 4923 Industrial Way, Benicia, CA 94510, USA; <a href="http://www.brilliante.com">http://www.brilliante.com</a></td>
</tr>
<tr>
<td>Syntex AF®</td>
<td>1% in distilled water</td>
<td>nonionic detergent</td>
<td>American Roentgen Ray Society, <a href="http://www.conservationresources.com">www.conservationresources.com</a></td>
</tr>
<tr>
<td>Orange WA paste</td>
<td>as supplied and in distilled water</td>
<td>amionic detergent</td>
<td>as above</td>
</tr>
<tr>
<td>MS Cyclone spray</td>
<td>as supplied from spray can</td>
<td>solvent based without silicone</td>
<td>Luff UK, Graft, 17 Wyrple Road, London SW7 4EE, England; <a href="http://www.britsol.com">www.britsol.com</a></td>
</tr>
<tr>
<td>Organic material</td>
<td>as supplied from spray can</td>
<td>contains aliphatic hydrocarbons, terpene hydrocarbons, oxime derivates, dibasic, oxime, diglycolylester, oxime</td>
<td>as above</td>
</tr>
<tr>
<td>allulose on</td>
<td>as supplied</td>
<td>98% alcohol</td>
<td>&amp; Berthiou A3, Sandvika, %, Sandvika, NK-0210 Norway</td>
</tr>
<tr>
<td>PMMA</td>
<td>as supplied</td>
<td>general purpose, reagent quality</td>
<td>as above</td>
</tr>
<tr>
<td>PE teflon</td>
<td>as supplied</td>
<td>general purpose, reagent quality</td>
<td>&amp; Berthiou A3, Sandvika, %, Sandvika, NK-0210 Norway</td>
</tr>
<tr>
<td>PMMA, PMMA sheet</td>
<td>as supplied from Rias, the contact angles formed between distilled water and PMMA, both immediately after removing the protective film</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>as supplied</td>
<td>prepared by the authors as required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>as supplied</td>
<td>prepared by the authors as required</td>
<td></td>
</tr>
</tbody>
</table>

PMMA was not rinsed after applying cleaning agents, as would be the case when conserving museum objects, so that the effect of the cleaning agent and application technique could be the focus of the examination. After cleaning, test areas were allowed to dry in air at 20 ± 2˚ C and 50 ± 2% relative humidity for 24 hours prior to examination.

Cleaning agent | Applied concentration | Description | Supplier |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biflavone Plastic Cleaner</td>
<td>as supplied</td>
<td>based on detergent solution without silicone</td>
<td>Brilliante Inc., 4923 Industrial Way, Benicia, CA 94510, USA; <a href="http://www.brilliante.com">http://www.brilliante.com</a></td>
</tr>
<tr>
<td>Syntex AF®</td>
<td>1% in distilled water</td>
<td>nonionic detergent</td>
<td>American Roentgen Ray Society, <a href="http://www.conservationresources.com">www.conservationresources.com</a></td>
</tr>
<tr>
<td>Orange WA paste</td>
<td>as supplied and in distilled water</td>
<td>amionic detergent</td>
<td>as above</td>
</tr>
<tr>
<td>MS Cyclone spray</td>
<td>as supplied from spray can</td>
<td>solvent based without silicone</td>
<td>Luff UK, Graft, 17 Wyrple Road, London SW7 4EE, England; <a href="http://www.britsol.com">www.britsol.com</a></td>
</tr>
<tr>
<td>Organic material</td>
<td>as supplied from spray can</td>
<td>contains aliphatic hydrocarbons, terpene hydrocarbons, oxime derivates, dibasic, oxime, diglycolylester, oxime</td>
<td>as above</td>
</tr>
<tr>
<td>allulose on</td>
<td>as supplied</td>
<td>98% alcohol</td>
<td>&amp; Berthiou A3, Sandvika, %, Sandvika, NK-0210 Norway</td>
</tr>
<tr>
<td>PMMA</td>
<td>as supplied</td>
<td>general purpose, reagent quality</td>
<td>as above</td>
</tr>
<tr>
<td>PE teflon</td>
<td>as supplied</td>
<td>general purpose, reagent quality</td>
<td>&amp; Berthiou A3, Sandvika, %, Sandvika, NK-0210 Norway</td>
</tr>
<tr>
<td>PMMA, PMMA sheet</td>
<td>as supplied from Rias, the contact angles formed between distilled water and PMMA, both immediately after removing the protective film</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>as supplied</td>
<td>prepared by the authors as required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>as supplied</td>
<td>prepared by the authors as required</td>
<td></td>
</tr>
</tbody>
</table>
setup and a mean contact angle calculated. The angle of water on test surfaces was repeated 3 times for each ing edge of the droplet. The process of determining the contact selected the horizontal baseline, which met the slope of the lead- could be seen in real time. The MicroCapture software was also Examination of new test substrate samples before cleaning RESULTS AND DISCUSSION Polar filters revealed the presence of scratches induced by applying PMMA after a new piece of PMMA

Figure 3 Optical microscopy was used to examine PMMA for scratches after cleaning

Figure 4 The 20° gloss of PMMA after cleaning was dependent both on the cleaning agent used and the technique by which it was applied

Figure 5 Cleaning of PMMA resulted in both improved and reduced wetting by distilled water

Figure 6 Cleaning of PMMA with ethanol was effective in reducing the contact angle

croscope prevented the risk of camera shake. Video films were also made of the water drop so that any spreading after contact could be seen in real time. The MicroCapture software was also used to measure contact angle on the images, which showed the drop making initial contact with the test substrate. The operator selected the horizontal baseline, which met the slope of the lead- ing edge of the droplet. The process of determining the contact angle of water on test surfaces was repeated 3 times for each setup and a mean contact angle calculated.

RESULTS AND DISCUSSION

Examination of new test substrate samples before cleaning showed no scratches or other surface disturbances that were visible to the naked eye, magnification x 70 or x 300. All cleaning techniques induced scratches on PMMAs surfaces when applied dry, that is, without cleaning agents; they could all be clearly seen at magnification x 300. The intensity and density of the scratches varied by technique. Microfibre cloth produced both the most intense and the highest density of scratches, followed by kitchen roll, natural fibre brush and synthetic fibre brush (Figure 3). Lens tissue produced the least change in surface appearance.

Adding cleaning agents reduced the intensity and number of scratches, probably because they act as lubricants and reduced friction between the tool used and the PMMA surface. Other researchers have obtained similar findings when cleaning the PMMA component of face-mounted photographs (Sen Lights Cor- poration, 2009). Some commercial cleaning agents deposited a visible residue, which persisted on surfaces after drying. After applying W3 Cockpit spray, a highly glossy, only residue remained regardless of how it was applied. Application of W3 Synthetic mat- terial care containing silicone also resulted in the formation of residues that were more highly glossy than those produced in the product without silicone. Orvus WA paste, an anionic de- tergent, also left a shiny residue. Neither ethanol, isopropanol, acetone nor white spirit left a visible residue after evaporating.

Gloss measurements made at 20° and 60° showed identical trends for a series of readings and therefore only those made at 20° are discussed here. New, untreated PMMA had a mean gloss of 138 gloss units. After applying cleaning agents, the gloss ei- ther remained unchanged or increased, that is, more than the ±2 gloss units attributed to error. Both the cleaning agent used and the technique used to apply it were factors in the resulting gloss. To illustrate this point, it was seen that acetone applied by microfi- bre cloth, paper tissue and synthetic fibre brush did not change the gloss of new PMMA whereas application by cotton bud, lens tissue, kitchen roll, or cotton bud. Contact angles formed by water on PMMA after cleaning with microfibre cloth and water (72º) and the lower image shows the effect of cleaning with microfibre cloth and water (72º).

In common with gloss measurements, both the cleaning agent used and the technique used to apply it were factors in the resulting contact angle.

For example, the contact angle of distilled water on PMMA after cleaning with ethanol applied with a synthetic fibre brush was 46°, compared to an angle of 66° when ethanol was applied with a cotton bud. Contact angles formed by water on PMMA after clean- ing with acetone, Brilliance plastic cleaner, Orvus WA paste and W3 Synthetic material care with silicone all applied by cotton bud were 64°, 49°, 63° and 52° respectively. These findings agreed with those of other researchers who have found that the presence of hydrophilic contamination increases the ability of water to wet surfaces (Sen Lights Cor- poration, 2009). The introduction of a material that is more hy- drophilic than PMMA on a surface, therefore results in a reduction in the contact angle with water compared to the angle achieved between water on an otherwise identical but clean sur- face. In the present research, such hydrophilic contaminants are most likely to be detergents. Optical microscopy suggested that
residues were present after cleaning with Orvus WA paste. In contrast to gloss measurements where cleaning resulted only in a reduction in gloss units, some treatments resulted in an increase in contact angle. The contact angles of distilled water on PMMA treated with Brilliance and Orvus WA paste applied with kitchen roll were 71˚. The contact angle of distilled water on PMMA after treatment with distilled water applied with microfibre cloth was 72˚. The increase in contact angle could be accounted for by the deposition of a hydrophobic contaminant during cleaning which reduced the ability of water to wet surfaces. In the present research, such hydrophobic contaminants are most likely to be silicones. However, because distilled water, which also resulted in an increased contact angle when applied with microfibre cloth, does not contain silicones, an alternative explanation was sought. Optical microscopy of PMMA after application of dry microfibre cloth and kitchen roll showed the presence of scratches. Although the intensity of the scratches was reduced when a cleaning agent was used in conjunction with microfibre cloth and kitchen roll, they remained visible at magnification ×300.

Scratches induced by applying fine grit silicone carbide paper to new PMMA increased the contact angle markedly from 68˚ for new, untreated substrate to a maximum of 114˚ when the silicone carbide paper had been applied in a backwards and forwards direction and 91˚ when it was applied in a circular motion. The ability of water to wet rough or inhomogeneous surfaces is more complicated to predict than for homogeneous surfaces because it is dependent on the pattern described by the roughness and the portion of the surface that is wet. Contact angles for droplets placed on a rough surface that wet only a portion of the surface, are larger than those made by droplets that wet the surface more completely (Ryan and Poduska, 2008). The formation of air pockets between a rough surface and a droplet contributes to a reduced surface area available for contact and wetting.

Contact angles of water on PMMA immediately after cleaning and drying provided information about whether changes had been induced at surfaces by the treatment. A significant reduction in contact angle suggested that hydrophilic contaminants were present as a result of the cleaning process. A significant increase in contact angle suggested either that hydrophobic contaminants may have been deposited on surfaces by treatments or, a more likely possibility, that the PMMA surface had been scratched by the cleaning technique and this had increased the hydrophobicity of the plastic.

CONCLUSION
Visual appearance has been widely used to evaluate cleaning by conservation professionals. Although it can provide useful information about the cleaning process, it is highly subjective and poorly reproducible from person to person.

Optical microscopy provides qualitative results concerning the intensity and density of scratches induced when cleaning and the presence of residues left by cleaning agents. When examining transparent plastics, the addition of filters, especially crossed polar filters, accentuated scratches and other surface features induced by cleaning. Gloss measurements were relatively easy to perform but the results were disturbed by the multiple reflections within the bulk of transparent PMMA. Circular scratches reduced gloss more than linear symmetrical ones. This finding suggests that the use of a circular motion to apply cleaning agents is more damaging than back and forwards motion.

Equipment to determine contact angle by the sessile drop method can be readily and cheaply obtained. A USB microscope (×400) was found to provide sufficient resolution and cost 45 Euro or US$ 66 in November 2009. Contact angles are relatively easy to determine and the results show changes in the surface energy of the surface studied often before it can be detected by eye or optical microscopy. Contact angles are related to the type of change induced by cleaning including the introduction of residues or of scratches, although it is not such a simple process as to attribute causes with certainty. With further developments, it seems likely that contact angle measurements can be a more reproducible and quantitative alternative to visual appearance for conservation professionals.

ACKNOWLEDGEMENTS
The authors would like to thank Bent Eshøj of the Royal Danish Academy of Fine Arts, School of Conservation, Copenhagen for help with gloss measurements.
ABSTRACT
The study presented here provides the theoretical and experimental basis for repairing a breakage damage on the Poly(methyl methacrylate) (PMMA) sculpture *Construction in Space: Crystal*, created by Naum Gabo in 1937. To find a suitable bonding strategy, especially to prevent stress crazing and cracking during bonding, different experimental setups were applied. First, stresses present in the sculpture were detected by performing a photoelastic examination and the feasibility of stress releasing by annealing was evaluated. Further, the stress crazing and cracking promoting action of different adhesives was evaluated performing bent-beam tests, whereby different joint geometries and long-term loading were simulated. Finally the breakage damage was documented using photogrammetry. The respective measurement data were used to make physical replicas of the damaged areas of the sculpture. Bonding treatments were applied on these dummies using the acrylic resin Plexigum PQ 611 (dissolved in isooctane) and the load-bearing strength and optical appearance of the adhesive joints were monitored over several months. In the end the bonding operation was carried out successfully on the original sculpture. Until this day, three years after bonding the original sculpture, the adhesive joint has kept a sufficiently high mechanical strength and is not affected by craze or crack formation.

KEYWORDS
Poly(methyl methacrylate), bonding, stress, annealing, crazing, Gabo

INTRODUCTION
The initial point of this study was a breakage damage on the poly(methyl methacrylate) (PMMA) sculpture *Construction in Space: Crystal* created by Naum Gabo in 1937. The sculpture (see Figure 1) is a remarkable early artwork integrally made of PMMA.

Naum Gabo got to know this new synthetic material in 1937 during a visit to the Imperial Chemical Industries (ICI) factory in Welwyn Garden City. Reportedly he was enthused because of the high clarity of PMMA and its capacity to be twisted and bent into curved planes, so he ordered acrylic sheets from ICI in July 1937 (Hammer and Lodder 2000: 251). *Construction in Space: Crystal* was exhibited for the first time in 1937 in the Jeu de Paume of Louvre. At that time PMMA was anything but an ordinary material for artists to use. Only three years earlier, in 1934, ICI had made their patent application for the manufacture of cast acrylic sheets (Tattersall 1934) and had registered the trade name Perspex.

In 2003 the sculpture *Construction in Space: Crystal* was severely damaged. Due to an external mechanical impact, a solvent bonded glue line was partially broken, causing the separation and relaxation of one of the parts (see Figure 2).

To restore the sculpture’s original appearance it was necessary to re-bend the relaxed element to its original position and to re-bond it with its counterpart. As is well-known, bonding treatments on stress loaded PMMA involves the risk of crazeing or cracking, therefore suitable bonding strategies to prevent such damages had to be found.

The theoretical and experimental part of this study was realised from summer to winter 2005. The bonding of the breakage damage was carried out in summer 2006 and results of long-term testing were evaluated recently in 2009.

MATERIALITY AND MANUFACTURING TECHNIQUE
*Construction in Space: Crystal* (1937) is made of seventeen clear, cell-casted PMMA parts. Their materiality was determined on micro samples by Fourier Transform Infrared Spectrometry (FT-IR), whereby also small amounts of an aromatic ester additive (e.g. phthalate plasticiser) were indicated. Scratched lines bear analogy to the insertion of tensed poly(amide) filaments, a technique applied by Naum Gabo in...
other sculptural works. Some of the PMMA sheets were thermoformed, as can be observed by their irregular shape (see Figure 3b). Others were cold bent into curved planes without thermoforming. Naum Gabo's daughter Nina Williams considers that for the thermoforming he used the oven in the kitchen of his apartment in London, where he lived in 1937. She assumes that after heating the sheets in the oven he moulded them by hand. Very likely Naum Gabo bonded the sheets using solvent; Nina Williams remembers that he applied Acetone for this purpose.3

PRECONDITIONS FOR CRAZE AND CRACK FORMATION DURING BONDING OPERATION

Crazing disturbs the transparency of glassy, amorphous polymers by the formation of silvery shining hairlines. The loss of transparency is caused by a change in the polymer’s morphology, whereby crazing is a mode of local plastic deformation (Lammas 2003: 307). As a consequence of yielding, the polymer chains get stretched and form a void-filled fibrillar structure (Ehrenstein 1999: 103). This structure has a lower refractive index than unaffected surrounding areas, therefore crazes become visible to the eye (Wright 1996: 35). The basic preconditions for craze formation are tensile or flexural stress and strain. Stress and strain can be induced by externally applied mechanical loads, for example if PMMA sheets are bent cold in a curvature without thermoforming, as done by Naum Gabo. Internal stresses can result from cell-casting or thermoforming, especially if too low thermofoming temperatures are used (Yueneg and Esser 1975: 432; Warbuton Hall and Russell 1949: 12).

Furthermore internal stresses arise from local heating during mechanical processing (e.g. sawing, sanding, drilling and polishing) as well as from solvent bonding. Several authors observed that under long-term loading at room temperature a minimal stress or strain level must be applied to initiate crazing (e.g. Bartning et al. 1996; Menges et al. 2002). For uniaxial loaded PMMA critical strain values at about > 0.5 - 0.9 per cent are reported (Menges et al. 2002: 207; Brüller et al. 1977: 283). Even though crazing can be initiated due to high stress and strain alone, in most cases this kind of damage is drastically facilitated when PMMA is additionally in contact with low molecular liquids or vapours (Wright 1996: 3). Their absorption leads to a local plasticisation of thermoplastics, whereby crazing becomes possible under drastically lower levels of stress and strain. Such craze-promoting substances can be present in adhesives as for example solvents, monomers, hardeners, catalysts or plasticizers. How strongly they assist in crazing depends on the one hand on their chemical composition, their molar volume and on the concentration in which they are absorbed by the polymer (Wright 1996: 5,110). On the other hand, how long the low moleculars stay in an adhesive joint and consequently how long the plastic is exposed to them also plays a crucial role. High solvent and monomer concentrations, long setting times and long-time retention of solvents in the adhesive bond can therefore assist in craze formation. In addition high stresses in the joint parts as well as high room temperature and relative humidity facilitate craze formation during bonding operation (Wright 1996: 10). Because low moleculars (e.g. solvent and monomer residues) can stay in cured adhesive joints over long periods of time, time-delayed crazing can also occur and does not necessarily appear shortly after adhesive application. Localised plasticisation of stressed PMMA by e.g. solvent or monomers can not only result in craze initiation, but can also be a precursor to subsequent crack formation and fracture (Sheirs 2000: 549). The transition from a craze to a crack is accompanied by ruptures of fibrils and a loss of the craze’s load-bearing capacity (Ehrenstein 1999: 103).

EVALUATING THE STRESS LOADING OF THE SCULPTURE

Cold bent and thermoformed planes of the acrylic sheets, their sawed edges and bond seams were assumed to be stress loaded zones, susceptible to crazing and cracking during bonding treatments. These stresses were visualised in a non destructive way by performing a photoelastic examination of the sculpture. The experimental set-up is shown in Figure 4a. Due to changes in birefringence, stresses become visible as bright zones (Hering and Triemel 2003: 99) between two crossed polariser filters. On the one hand, stress patterns were identified in the relaxed sheet as well as in its cold bent counterpart (see Figure 3a, b).
Figure 4b. On the other hand additional stresses were expected to build up during re-bending operation, as shown in Figures 4c - d on a dummy shaped true to the original. During the re-bending of the relaxed element to its original position, the applied external mechanical load causes new stresses around the glue line (visible under magnification in Figure 4e). Based on these observations, the risk for adhesive promoted crazing and cracking was estimated to be high. It is interesting to note that the detached sheet and its cold bent counterpart were obviously subjected to loads below the critical strain level of PMMA. This conclusion can be drawn due to the observation that after being fixed 66 years under external tension, no craze formation due to mechanical loading took place in these elements.

EVALUATING THE FEASIBILITY OF STRESS RELIEVING

In industrial production annealing is widely used to release stresses in PMMA before bonding operations. Annealing is typically done at temperatures near but sufficiently below the polymer’s glass transition. Today annealing temperatures are recommended at about 70 – 90°C (ICI 1999). Annealing of cast acrylic sheets was patented by the Bell Telephone Laboratories in New York already in 1945 (Baker 1945). In the patent note Process for Inhibiting Cracking of Polymeric Bodies stress reliving is described by slowly heating amorphous thermoplasts at 5 – 20°C below glass transition, for example by heating flat cell-cast sheets at 60°C for three hours. Unfortunately, severe risks of damage were to be expected with regard to annealing the thermoformed, stress loaded acrylic sheets of Construction in Space: Crystal. Annealing at too high temperatures can activate the well-known plastic memory of thermoplastics (Rosato et al. 2001: 138), whereby thermoformed sheets tend to go back to their original flat shape. Furthermore heating stress loaded PMMA too near and especially above its glass transition can also result in shrinkage due to stress relaxation (Ebrenstein et al. 2003: 211; Ebrenstein 1999: 141). Longitudinal shrinking and subsequent increase in thickness up to four percent are reported if the PMMA is not absolutely stress free and fully pre-shrinken during previous heat treatments (Veneg and Eser 1975: 363). Distinctive thermal-induced shrinking is to be expected if stresses induced by the casting process are not released already prior to sheet manufacture. During the 1930s (5b) Normalizing, typically done above glass transition temperature, was likely to have not been applied on the acrylic sheets which Naum Gabo constructed his sculpture in 1939, published as Process of Treating Cast Polymeric Sheets (Bartoe 1939). The stress loaded elements of the sculpture were considered to be predestined to deform and shrink, and evaluating a safe annealing temperature seemed to be equivalent to walking a tightrope. Only a very precise knowledge of the glass transition temperature of the acrylic sheets used by Naum Gabo could help to minimise the risk of shrinking and deformation damages during annealing. Gaining such a precise knowledge about glass transitions is complicated by the fact that glass transition temperatures of thermoplastics are not well-defined, material-specific values (see Figure 5). They occur typically over a broad temperature range and can be influenced by several factors, for example by the presence of residual monomers and plasticizers and by stress level (Dudek and Lohr 1965; Warburton Hall and Raval 1949: 3; Ebrenstein 1999: 99). Without doubt, the experimental determination of glass transition temperature by Differential Scanning Calorimetric Analysis (DSC) could expand the amount of knowledge about the heat sensitivity of the acrylic sheets used by Naum Gabo. But as can be seen in Figure 5 with the example of DSC measurements performed on historic PMMA samples, the determination of glass transitions has strong limitations as well. In the first place, glass transition temperatures could only be analysed using sample weights of not less than about 1 mg, because the DSC-signal intensity depends on the sample weight. This seemed to be an unjustifiable size of a sample to be taken from the original sculpture. Secondly, experimental results gained by thermo analysis can be influenced by the chosen measurement method and respective measurement parameters (Lampmann 2003: 118). Taking into account the afore-mentioned limitations, stress relieving by annealing was definitely considered to be out of the question.

EVALUATION OF ADHESIVES WITH MINIMAL CRAZE AND CRACK PROMOTING ACTION

Regarding the impossibility of stress releasing the evaluation of adhesives with minimal craze- and crack promoting action came to the foreground. To pre-assess the risk of crazing and cracking during bonding operations, as well as over the following days by visual observation. If a test series was unaffected after a period of one week in all three sample geometries, these samples were left in the three-beam device for long-term observation over a period of three years. The tested adhesives are listed and specified in Table 1.11 The acrylic resin Plexigum PQ 611 was applied because of its good solubility in aliphatic hydrocarbons, a solvent class known to have low craze and crack promoting action, at least in short-time contact to PMMA (Wright 1996:10, 102). Based on the same consideration the mixture of Paraloid B-67 and Par-
When applied to non-annealed, stress loaded PMMA, especially F-10, as developed and successfully tested by Sale (Sale 1993) and already applied in conservation practice (Lorre 1999; Wolf 2005), was utilised. In both cases, solvent concentrations were kept as minimal as possible, as specified in endnote 12.12. The light curing acrylic resin Delo Photobond PB 493 and the cyanoacrylate Cyanolit 201 were tested because they represent very fast curing adhesives with polymerisation times of only a view seconds.13 Both adhesives were tested with regard to preventing crazing and cracking by keeping exposure times to monomers as short as possible. The solution adhesives Acrifix 116 and Acrifix 117, as well as the light curing adhesive Acrifix 192, are commercial products recommended for bonding PMMA in industrial and handicraft applications. Low molecular concerning these adhesives (e.g. ethyl acetate, nitro ethane and methyl methacrylate) are known to promote stress crazing and cracking in combination with long exposure times. Together with the acrylic resin Paraloid B-72 (dissolved in Toluene, solid content 30 percent by weight) these adhesives were tested to visualise a worst case scenario.

As expected, all Acrifix adhesives effected a strong craze and crack formation in all tested sample geometries (see for example Figure 7). Paraloid B-72 caused no crazing or cracking if applied, like in sample geometry ‘i’, without bonding a counter-part. Whereas in geometry ‘ii’ and ‘iii’ a strong craze and crack formation took place due to evaporation hindrance (see Figure 7). Bonds performed with Cyanolit 201 and Delo Photobond PB 493 were affected by craze and crack formation as well, except where the adhesives were applied very sparsely in geometry ‘ii’. The best test results were achieved by using Flexigum PQ 611 in isooctane, as well as by using the mixture of Paraloid B-67 and Paraloid F-10. In both cases no crazing and cracking took place in any sample geometries or on any tested samples, even after three years of long-term loading. These adhesives are thus evaluated as a promising option to consider, although the tested PMMA can only approximately represent the materiality (e.g. molecular weight, residual monomers and aromatic ester additive) of the acrylic sheets used by Naum Gabo in 1937.

**SIMULATION OF THE BONDING OPERATION USING DUMMIES TRUE TO THE ORIGINAL**

As last step of the experimental part of this study the breakage damage was documented using photogrammetry. The respective measurement data were used to make physical replicas of the damaged area of the sculpture (see Figure 8).

First, a replica of the relaxed acrylic sheet was made by generating a virtual three-dimensional (3-D) model using the software Photo Modeler Pro 4.0. The 3-D model (data format: Initial Graphics Exchange Specification) was based on seven digital images (resolution: 3072 x 2048 pixels), taken from the damaged area of the sculpture. After having solvent bonded the acrylic sheet with its cold bent counterpart, the bonding zone was partially broken again, according to the glue joint geometry of the damaged sculpture. Five dummies were produced according to these manufacturing steps (see Figure 8). These dummies were used for testing the following operations:

- a) Bending back the detached element in its original position and evaluating the risk of further opening of the glue line.
- b) Set in a reversible manner by applying a dot matrix on electrostatic adherent polypropylene foils (see Figure 9a).
- c) Attach the two dummy parts with the Glue joint geometry of the damaged sculpture (b) set in a reversible manner by applying a dot matrix on electrostatic adherent polypropylene foils (see colour plates, p. 164).
- d) Bending back the detached element in its original position and evaluating the risk of further opening of the glue line.
- e) Set in a reversible manner by applying a dot matrix on electrostatic adherent polypropylene foils (see Figure 9b).
- f) Fabricate a mould as basis for thermoforming. The mould was made of medium density fiberboard (MDF) and was milled using computer numerically controlled equipment (CNC) (see Figure 9c). The replica of the relaxed sheet was then thermoformed using cell cast PMMA, heated in a hot air circulating oven at 160°C. In the rubbery state the sheet was laid over the MDF mould and loaded during cooling with a plaster counter-mould. After cooling, the thermoformed element was mounted in an MDF frame, constructed as well true to the original geometry of the sculpture. After having solvent bonded the acrylic sheet with its cold bent counterpart, the bonding zone was partially broken again, according to the glue joint geometry of the damaged sculpture. Five dummies were produced according to these manufacturing steps (see Figure 8a). These dummies were used for testing the following operations:

- Figure 3: Craze and crack formation in contact to the light curing adhesive Acrifix 192 and in contact to Paraloid B-72.
- Table 1: Tested adhesives: chemical composition and curing mechanism.

<table>
<thead>
<tr>
<th>Product name</th>
<th>Solid content</th>
<th>Low molecular content</th>
<th>Curing type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraloid B-67</td>
<td>poly (iso-butyl methacrylate-co-2-ethyl heptyl methacrylate)</td>
<td>isooctane</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Paraloid F-10</td>
<td>poly (iso-butyl methacrylate-co-2-ethyl heptyl methacrylate)</td>
<td>isooctane</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Paraloid F-10</td>
<td>poly (iso-butyl methacrylate-co-2-ethyl heptyl methacrylate)</td>
<td>isooctane</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Delo Photobond PB 493</td>
<td>poly (iso-butyl methacrylate-co-2-ethyl heptyl methacrylate)</td>
<td>isooctane</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Acrifix 116</td>
<td>poly(ethyl methacrylate)</td>
<td>ethyl formate, nitroethane</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Acrifix 117</td>
<td>poly(ethyl methacrylate)</td>
<td>ethyl formate, nitroethane, 2-phenoxyethanol</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Acrifix 117</td>
<td>poly(ethyl methacrylate)</td>
<td>ethyl formate, nitroethane, 2-phenoxyethanol</td>
<td>solvent evaporation</td>
</tr>
<tr>
<td>Paraloid B-72</td>
<td>poly(ethyl acrylate-co-ethyl methacrylate)</td>
<td>ethyl acrylate</td>
<td>solvent evaporation</td>
</tr>
</tbody>
</table>

Figure 8: Dummies (a and c) shaped true to the original, according to the glue joint geometry of the damaged sculpture (b) (see colour plates, p. 164).
Figure 9

Reconstructing steps for the fabrication of the mould used for thermoforming the relaxed element:

a) Auxiliary construction used for the re-bending operation
b) Auxiliary construction displayed under magnification
c) Controlling stress levels by photelastic examination
d) Fixing the re-bent PMMA element during bonding operation

ENDNOTES

(1) For a picture of the sculpture during this first exposition in 1937 see (Naeh and Merker 1965: 65).
(2) The main parts of the bent-beam devices are three bright steel rods, labeled as x, y and z in Figure 6 (Ø x = 10 mm; Ø y = 10 mm; Ø z = 20 mm). Rod x and y are mounted on a level with each other with a distance L = 160 mm.
(3) The strain level at the most bent sample surface is defined by the level difference between the rods x, y and rod z. This level difference is referred to as deflection D. To induce a maximum strain level of 0.5 per cent in the sample surface, rod z had to be mounted with a deflection D = 7 mm. Deflection D was calculated according to the following formula:

\[ D = \frac{rL^2}{6d} \]

where \( r \) = strain (unit: m/m) and \( L \) = distance of 20 cm.

(4) At the glass transition amorphous polymers change from the glassy to the rubbery state. As a result of the higher polymer chain mobility changes in their material properties take place (e.g. higher thermal expansion, higher polymer chain mobility changes in their material properties take place (e.g. higher thermal expansion, higher strain level is expected to decrease during long-term testing by relaxation processes.

(5) Efficient annealing must be performed under controlled and uniform heating by using for example an air circulating oven with precise temperature control. After upholding the annealing temperature for a sufficient time (dependent on sheet thickness) the plastic has to be slowly cooled back to room temperature in order to avoid the occurrence of new internal stresses. For a detailed description of annealing procedures see (ICI 1999).

(6) Furthermore significant changes in glass transition temperatures were reported for PMMA when exposed to heat and UV radiation (Ebrenstein et al. 2003: 90; Colom et al. 2003).

(7) DSC-Measurement equipment: Mettler Toledo DSC 822; temperature program data: dynamic heating from 30 °C to 150 °C; number of runs: 2; measurement gas: Nitrogen, 30 ml/min; sample pan: Aluminiun 40 μl.

(8) The main parts of the bent-beam devices are three bright steel rods, labeled as x, y and z in Figure 6 (Ø x = 10 mm; Ø y = 10 mm; Ø z = 20 mm). Rod x and y are mounted on a level with each other with a distance L = 160 mm.

(9) Before testing the samples were stored for 72 hours at 60 percent relative humidity and 19 °C and were then tested under the same climatic conditions.

(10) Additionally an untreated sample was clamped in direct vicinity of each test series. This control sample was used as an indicator as to whether solvent or monomer vapours were falsifying the results. None of these control samples showed craze or crack formation during bonding and long-term testing.

(11) Chemical compositions in Table 1 are specified according to (Osete-Cortina and Domenech-Carbó 2006 and Chiarenti and Lazzari 1996) and the accordan\n
technical data sheets.

(12) Plexigum PQ 611 was dissolved in isooctane (solid content 30 percent by weight). Paraloid B-67 was dissolved in petroleum spirit (boiling range of 100 °C to 140 °C) with a solid content of 30 percent by weight. Paraloid F-10 was applied in a solution supplied by the manufacturer (monomer content 40 percent, mineral spirits / aromatic 150 at a solvent ratio 9:1).

(13) Delo Photoluid PB 493 polymers were immersed about 20 seconds, if exposed to electromagnetic radiation in the wavelength range of 120 - 450 nm. Adhesive bonds were cured for 60 seconds using a hand-held UV-A light unit from Höhnle (UVHAND 250), mounted rectangularly to the sample surface at a distance of 20 cm. Subsequently...
ABSTRACT
Research into adhering broken transparent unsaturated polyester (UP) objects started when two artworks made of cast transparent polyester resin, seriously damaged and yellowed, were submitted to the Cultural Heritage Agency of the Netherlands (RCE) in order to investigate a suitable conservation treatment. The two artworks, both untitled, made by the Dutch artist Mathilde ter Heijne in 1993, are part of the art collection of the company Océ.

Investigation into the best suitable adhesive has led to the investigation into the refractive index, applicability and performance of the epoxy adhesives Hxtal NYL-1, Fynebond and the acrylic adhesive Paraloid B72. The selected adhesives were tested for applicability and appearance on new polyester as well as naturally aged yellowed polyester, similar to the two yellowed polyester frames of the artworks. These naturally aged yellowed polyester objects, paperweights with objects cast inside, were collected in order to serve as dummies.

Tensile strength tests were performed on adhered joints and in all aspects, epoxy adhesive Fynebond performed best. Fynebond will be finally tested on a polyester study object with a comparable size and weight as the two artworks to be restored. When successfully applied, this will give good insight into how adhering broken pieces of yellowed transparent polyester will return the object to its original state so that it can be appreciated as it was originally meant. Finally the adhesive will be used for the restoration of the two artworks of Mathilde ter Heijne.

KEYWORDS
Transparent unsaturated polyester (UP), refractive index, epoxy adhesive, adhering, plastics

INTRODUCTION
In 1993 Océ Company acquired two works of art (untitled, 1993), made by the artist Mathilde ter Heijne, for their art collection. Both works consist of two parts: a drawing on paper made with mixed media, covered by a rectangular transparent unsaturated polyester resin (UP) cast frame.

In 2007 the condition of both artworks showed that the polyester frames were broken into several pieces as a result of mechanical damage. Moreover, both artworks have yellowed considerably, however this discolouration is not the most significant problem. The overall damage includes broken and missing parts, chipped off polyester, cracks and scratches, all influencing the aesthetic value of the artworks negatively. The polyester frame plays an important role in the visual characteristic of the artwork and therefore the artworks have to be restored to bring back the original intention of the artist.

The aim of the research is to find a good adhesive and a suitable application method for repairing broken transparent unsaturated polyester works of art by achieving a strong joint with a good appearance. In order to develop an application method for adhering broken transparent polyester art works, a survey among glass conservators was done and based on their experience a selection of different adhesives could be made.

ART WORKS
The two artworks consist of a drawing on paper covered by a transparent unsaturated polyester frame. The technique of the drawings is mixed media, including pencil, fluorescent markers, watercolour and collage on paper. Each drawing is inserted in the frame and fixed with tape. Cardboard backing supports the drawing. The frames of the artworks, called ‘polyester bricks’, are rectangular shaped. The frames (2 cm thick) were casted by the artist, and both have nearly identical sizes; one is 47.9 × 35.1 × 5.3 cm and has a weight of 6 kg and the other is 48.1 × 35.3 × 5.5 cm with a weight of 7 kg. After moulding, the frames were polished, which is visible as minor circular scratches on the surface, with exception of the inside corners of the front of the frames. Moreover, both frames show air bubbles in the inner side of the front, resulting from mixing the polyester resin and the catalyst when making the frames. The frames with the air bubbles, yellowing and the scratches from the polishing altogether play an important role and determine the visual characteristics of the artworks.

The drawings of the artworks are in good condition; both frames are yellowed and seriously damaged. The main conservation problem is the mechanical damage: the chipped polyester...
To study the adhering of transparent unsaturated polyester resin objects, test samples were prepared according to the manual of the supplier. All test samples were prepared with 99% polyester resin (Poly-Pol PS 230) mixed with 1% of Peroxan ME-50 L. Three different sized shape samples were made: heart shaped ice cube dummy (3,2 × 2,7 × 1,2 cm), thick round shaped dummy (4,5 × 2 cm) and flat thin rectangular shaped (12,2 × 4,5 × 0,2 cm) test samples.

**NATURALLY AGED TEST SAMPLES**

The cast polyester resin paperweights, bought at flea markets or donated by a private conservator, served as naturally aged, ‘yellowed’ dummies. The cast frames are not just a protection but original and unique signs of the artist’s work and technique.

**ARTWORK FROM RCE STUDY COLLECTION**

The study collection of RCE consists of works of art that cannot be exhibited or restored anymore, but still can function as part of conservation studies. Using the adhesive first on a polyester study object with comparable size and weight will give better information on how adhering broken pieces of the yellowed transparent frames and will archive a satisfactory result for the artwork itself. Therefore a study object (49 × 39 × 28 cm) that is broken into six pieces, has been chosen (see Figure 2).

**POLYESTER RESIN**

Unsaturated polyester resins (UP resins) are made from aromatic di-acids and polyalcohol and refer to a large variety of products, all containing reactive double bonds in their polymer chain. Double bonds give UP resins the ability to crosslink with monomers, generally the styrene solvent, forming a three dimensional polymer network (Kessler et al 2004). Unsaturated polyester resin is often used by artists for its transparency, good workability, easiness to colour and its ability to cure at room temperature. Moreover, polyester has good resistance to most organic solvents and weathering. Unsaturated polyester resin is also known for its yellowing, which is one of the most obvious degradation phenomena related to the composition of the polyester. When styrene is used as a co-polymerization component, the yellowing is particularly intense (Watteng 2008).

Polyester is also well known for its low-impact strength, which is the reason why it is generally reinforced with glass fibre or other reinforcing materials. The tensile strength of unfilled saturated polyester resin can range from 10-123 MPA (1-123 N/mm²), while with glass fibre reinforced polyester has tensile strength ranging from 7-621 MPA (7-621 N/mm²). Polyester without reinforcement breaks more easily (www.matweb.com, as at October 2009).

**BREAKING POLYESTER DUMMIES**

In order to gain experience in adhering polyester artworks, it was necessary to reproduce the damage found in the artworks in the polyester dummies. Breaking polyester was performed by using a chisel and a hammer.

**ADHESIVES**

A suitable adhesive for the restoration of transparent polyester resin should have the following properties: be able to adhere polyester without dissolving the polyester resin; have enough strength; have a comparable refractive index to that of polyester; have an appropriate viscosity; have a suitable working time to adhere rather large surfaces without air bubbles, preferably non-yellowing and reversible; and be chemically and physically stable (Skene, 1977, Down 1996, Davidson 2003).

Due to lack of literature describing adhering transparent unsaturated polyester objects, and due to similarity to adhering transparent glass objects, experience of glass conservators was considered. Therefore Hxtal NYL-1, Fynebond and Paraloid B72, as regularly used in glass conservation, were selected to be applied on polyester test dummies. Hxtal NYL-1 and Fynebond are both crystal clear epoxy resins with excellent properties: transparency, non yellowing qualities and high adhesion strength. Fynebond, as well as Hxtal NYL-1, are both non reversible and can only be removed mechanically. Paraloid B72, an acrylic adhesive, was selected for its transparency, versatility and reversibility (Down 1996). Moreover, Paraloid B72 was also tested as an interface barrier to provide a probable reversibility in epoxy joints adhered with Fynebond and Hxtal NYL-1 (Padam 2003).

**ADHESIVE TESTS**

Flat thin polyester test samples were used to test the tensile strength of adhesives. Each test sample had been broken into two pieces. Test samples were scratched in the middle using a ruler and a sharp scalpel. After scratching, tension was applied by hand close to the incision until breaking. Broken test samples were adhered with the five adhesives systems selected: Hxtal NYL-1, Fynebond, Paraloid B72 40% in toluene/isopropanol (1:1), Hxtal NYL-1 with a Paraloid Interface, Fynebond with a Paraloid Interface. Paraloid 5% in toluene/isopropanol (1:1) was used as interface. The best method of applying the adhesive on the flat, thin test samples was the method used in glass repair procedures. Strips of paper tape were placed on the surface to be joined to provide a temporary support. The adhesive was applied by capillary action with a needle until the void was completely filled. It is important to understand that capillary action does not work as well with polyester as it does with glass.
Adhesion tests performed on the thick heart shaped and the thick round dummies were useful to understand which application method would be the best in adhering transparent thick polyester objects. Due to the thickness, the capillary action was not working properly. Therefore the adhesive was directly applied to one side of the break. When adhering, the problem was mainly the formation of air bubbles in the joint. To avoid air bubble formation, it appeared particularly useful to position one broken part horizontally and place the other one on top of it, in order to have a constant pressure, making use of the weight of the material itself. The adhered part could be placed in a horizontal position using polyethylene foam as a support.

**FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)**

Samples from adhesives and the artworks were submitted to Fourier transform infrared spectroscopy (FTIR) to verify materials composition. Spectra were recorded from 4000 to 600 cm⁻¹, with 40 scans at a resolution of 4 cm⁻¹ using a Perkin Elmer Spectrum 1000 FTIR Reflectance accessory (ATR, Graseby spectrometer combined with a Golden Gate single Reflection Diamond Attenuated Total Specac, sample size 0.6 mm²).

To investigate yellowing and potential changes in tensile strength of adhered joints, the adhered flat, thin dummies were artificially light aged using a Xenotest, Alpha High Energy (Atlas®), and exposed to the radiation of a filtered Xenon-Arc-lamp (105 Klx, T 50°C, 40 % RH) for up to 140 hours to induce photo-oxidation. 140 hours Xenotest equalises 35 years in museum condition at 200 lux.

**REFRACTIVE INDEX**

When repairing broken glass objects the main objective is making an invisible joint. Light raking an interface between two materials with different refractive index will show reflection (Davison 2003). To avoid reflection from the surface of a break and to have an invisible repair, the refractive index of the adhesive needs to match the refractive index of glass preferably by n=0.01. When the difference is n=0.04, the joints are visible (Tennent 1984, 1984a). To verify if a comparable refractive index is also needed when adhering polyester, the refractive index of new, naturally aged samples and the polyester of the two frames of the broken artworks was measured using a refractometer. All samples were measured using a Rayner illuminated Dialdex refractometer (see Table 1).

<table>
<thead>
<tr>
<th>OBJECT/adhesive</th>
<th>nD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presse papier, heart</td>
<td>1.548</td>
</tr>
<tr>
<td>New polyester, Round dummy</td>
<td>1.548</td>
</tr>
<tr>
<td>Art Work, Mathilde ter Heijne</td>
<td>1.542</td>
</tr>
<tr>
<td>Fynebond</td>
<td>1.548</td>
</tr>
<tr>
<td>Presse papier, fruit</td>
<td>1.541</td>
</tr>
<tr>
<td>New polyester, Flat test sample</td>
<td>1.541</td>
</tr>
<tr>
<td>Paraloid</td>
<td>1.620</td>
</tr>
<tr>
<td>Hxtal NYL-1</td>
<td>1.320</td>
</tr>
<tr>
<td>Paraloid</td>
<td>1.49</td>
</tr>
</tbody>
</table>

**RESULTS**

**TENSILE STRENGTH**

The tensile strength that is applied on an adhered joint until the joint collapses was measured in Newton (N). Hxtal NYL-1 formed the strongest joints of about 1386 N and Fynebond was comparable with 1359 N. The strength of the Paraloid joints is 75 % lower and was measured as 356 N. After light ageing the adhered joints using Hxtal NYL-1 and Paraloid are shown in Table I. Refractive indices of the selected adhesives were collected from literature and data sheets (Augerson 1993, Messenger 1989).

**FTIR**

For the identification of all materials used and for the polyester artworks FTIR analysis was performed. FTIR spectra of arts-

works, study objects and naturally aged polyester dummies show similarity in polyester composition (see Figure 3).

**REFRACTIVE INDEX**

The results of the refractive index measurements of the polyester artworks and all polyester dummies, new and naturally aged, are shown in Table 1. Refractive indices of the selected adhesives were collected from literature and data sheets (Augerson 1993, Messenger 1989).
HALF FYNEBOND, HALF HXTAL NYL-1
To investigate whether a fracture can influence the performance of adhesives, a break in a polyester dummy was adhered, half with Fynebond and the other half with Hxtal NYL-1. The surface of the large break is still visible where adhered with Hxtal NYL-1, while invisible when using Fynebond. This experiment confirmed that the most important property that determines the final result, when adhering polyester, is the refractive index.

PARALOID
Adhering several polyester dummies, both new as well as naturally aged, using Paraloid B72, showed that the adhesive did not perform very well. It was difficult to apply without introducing bubbles, mainly due to solvent evaporation in the joint. Making the adhesive more concentrated could have been a solution; however, this would result in inadequate viscosity when adhering rather large breaks. Moreover, the main reason for this unattractive joint is the incompatibility of its refractive index of $n=1.49$ compared to that of polyester $n=1.548$.

APPLICABILITY AND VISUAL OBSERVATION

PARALOID
Adhering several polyester dummies, both new as well as naturally aged, using Paraloid B72, showed that the adhesive did not perform very well. It was difficult to apply without introducing bubbles, mainly due to solvent evaporation in the joint. Making the adhesive more concentrated could have been a solution; however, this would result in inadequate viscosity when adhering rather large breaks. Moreover, the main reason for this unattractive joint is the incompatibility of its refractive index of $n=1.49$ compared to that of polyester $n=1.548$.

FYNEBOND
The workability of Fynebond is good. No air bubbles were present in the joint and the transparency is perfect; the fracture became invisible (see Figure 5). Only the breaking line remains visible. However, a breaking line will never disappear completely, as it also does not disappear when adhering glass. The refractive index of Fynebond is 1.365, which matches the refractive index of the polyester by 0.02. Moreover, Fynebond is very easy to apply and has a good curing time of about 40 hours at room temperature.

HXTAL NYL-1
The workability of the very fluid Hxtal NYL-1 was good, even applied on large and broad breaks. No air bubbles were shown; however, the joint was still visible. The surface of the break was still visible after adhering (see Figure 4). Hxtal NYL-1 has a refractive index of 1.520 which comes close to that of polyester ($n = 1.548$), but obviously not close enough. The long curing time of at least one week might be a disadvantage.

CONCLUSION AND DISCUSSION
When adhering polyester objects, either new or aged, the main property to deal with, in order to have an invisible joint, is the refractive index. Of the tested adhesives Paraloid B72, Fynebond and Hxtal NYL-1, Fynebond matches the best with polyester regarding the refractive index. The refractive index of Hxtal NYL-1 was not close enough to that of polyester and the refractive index of Paraloid B72 did not match at all.

Testing Paraloid B72 as an interface for Fynebond or Hxtal NYL-1 in order to make the adhered joint reversible would not have been successful due to the mismatching of the refractive index.

Fynebond and Hxtal NYL-1, both having low viscosity, are easy to apply without introducing air bubbles, while the solvent based adhesive Paraloid B72 is more difficult to work with and solvent bubbles are inevitable. Curing time of Fynebond and Hxtal NYL-1 are both appropriate for adhering rather large and broad breaks.

Both Hxtal and Fynebond will give sufficient strength when joining broken parts of the artworks. Epoxy adhesives other than Fynebond and Hxtal NYL-1 were not tested because only Fynebond and Hxtal NYL-1 are typically used for glass and are quality controlled. The waxy materials on the surface of the study object of the RCE collection derives either from a release agent or from a maintenance treatment using wax. For restoration all aspects of the two artworks and their context will be discussed with the artist and the owner of the artworks. Even if the decision to cast new frames will be the final outcome, the method investigated will be used first on the RCE study object and then on the frames of the work of art.

ACKNOWLEDGEMENTS
Thanked for providing the artworks is the curator of the Océ collection, Mrs Claudine Hellweg and thanked for their advice about glass conservation are Norman Tennent, Liya Bicaci, Kate van Lookeren-Campagne, Eva Wolfs and Emmy van der Vos all from the University of Amsterdam (UVA). Our colleagues at RCE who helped with the tensile strength tests are Suzan de Groot, Frank Ligterink and Ron Kieverts (RCE) and Richard Schoevaart (conservator and private collector), provided us with the naturally aged dummies.

Figure 4

Figure 5

Figure 6

(see colour plates, p. 142)
ABSTRACT

Two case studies are presented as an example of projects undertaken in the Conservation Department of Die Neue Sammlung - The International Design Museum Munich - concerning the conservation of modern materials. The first project features the conservation of a polyvinyl chloride coated fabric. The Throw Away sofa was designed by Willie Landels in the early 1960s. The structure of the sofa consists entirely of soft expanded polyurethane (PU) foam on a hard polystyrene base. The PU foam is covered with a polyvinyl chloride coated textile. The method of filling losses in the original material is described. The second project deals with losses in a coating of a high-gloss polyester resin and their filling. This varnish was applied to a "Home Entertainment Center" from around 1961/62 – the so called Kuba Komet – produced by Kuba Tonmöbel und Apparatebau in Wolfenbüttel, Germany. Different methods of compensating for losses in the degraded materials were tested and the implemented procedure is described. Both projects were assisted by students from Cologne and Paris.

KEYWORDS
polyvinyl chloride coating, polyester resin, Kuba Komet

INTRODUCTION

This article will focus on two projects which were conducted in the Conservation Department of Die Neue Sammlung during the past three years and which are still in progress. Both projects are representative of a series of similar case studies that were carried out over the course of the last few years concerning the conservation of modern materials. Due to their specific aging properties over a relatively short period of time, these complex material compositions pose new challenges for conservation treatment. In this field we often explore new paths as a part of our workday routine. This article will be about some of the challenges we faced in our treatment of new materials and also about situations in which we reached the limits of our knowledge.

The first project deals with the conservation of a polyvinyl chloride (PVC) coated fabric used as a sofa cover. The Throw away sofa entered the holdings of Die Neue Sammlung in 2004 (see Figure 1). Its dimensions are 1500 x 750 x 550 mm (length x width x height).

Designed by Willie Landels, the sofa has been in continuous production by the Italian manufacturer Zanotta since 1965. Landels designed his first pieces of furniture, which he made for his own use, in the 1960s. His interest in new materials led him to work with inexpensive materials such as foam rubber. As the story goes, in 1963 he had just designed an armchair made of large foam cushions held together by glue when the Italian furniture manufacturer Aurelio Zanotta visited him at home and saw this homemade piece of furniture. Zanotta promptly commissioned a sofa from Landels, which the latter designed very quickly and which would become the Throw Away (Poletti 2004). It was a breakthrough for Landels as a furniture designer and also for Zanotta as an industrial manufacturer. Established in 1954 by its founder Aurelio Zanotta, the company had previously produced handmade furniture, particularly seating pieces, using traditional materials. Not until Landels’ Throw Away did Zanotta use a brand-new artificial material – expanded polyurethane foam – in a modern industrial serial production process. The structure of the sofa consists entirely of soft expanded polyurethane foam on a hard polystyrene base. The PU foam is covered with PVC. The sofa and armchairs were produced in different heights and different PVC colours: pink, black, white, red, yellow, lilac, pale blue and orange; Zanotta also mentioned green (Casciani 1984). Because of the integral foam structure a solid wooden or steel construction is not necessary, and the seats are extremely lightweight and easy to han-
sive and the strength of the backing fabric. Two kinds of cotton fabrics were chosen: a woven fabric, strong and non-elastic, and a knitted, rather elastic jersey.

The samples were prepared according to the ISO Standard 9664:1993, “Adhesives: Test methods for fatigue properties of structural adhesives in tensile shear”. All in all 18 samples were prepared. For the test the tensile strength machine “Zwick Materialprüfung 1445” at the Chair for Materials Technology and Mechanics at the Technical University of Munich was used.

After measuring the tension level needed to break the original material, all of the tests were conducted with the prepared samples. Prolongation, force and time were measured. It became evident that in the samples using the woven cotton fabric, the original PVC broke first. In the samples using the jersey fabric, the elasticity of the fabric showed its importance by taking away the stress from the PVC. One particular adhesive ultimately revealed itself to be most suitable for the conservation treatment: the acrylic dispersion Lascaux® 498 HV. Because of these results the inlays were fixed using the jersey fabric and the acrylic dispersion. The final product was described as minimalist and perfectly executed – a lightweight, cheap article, easy to clean (by using water and soap) and quick to produce. Its name “Throw away” refers to the growing number of cheap plastic articles for daily use: after using them you throw them away.

When the sofa came to the museum in 2004, the PVC cover already showed traces of degradation such as fine cracks and two bigger tears (see Figure 2). They continued to grow slowly but constantly. In the summer of 2006 we started a conservation project. Besides detailed research into the construction of the sofa and the materials used, the aim of the project was to strengthen the damaged PVC cover. It quickly became clear that in view of the dimensions of the cracks, caused by the brittleness of the aging PVC, the best decision was to close the tears with inlays. Fortunately we were able to utilize an identical loose sofa cushion as a material “supplier”. The greatest challenge was to find the most suitable means of closing the cracks, fulfilling the following requirements:

- Achieve a strong but slightly flexible connection between the inlay and the original PVC to avoid mechanical stress and further cracks.
- Avoid contact between the inlay and the foam interior.
- The deformed edges of the original PVC had to be brought to the level of the “new” inlay.
- When applying the inlay, minimal mechanical stress and non-invasive solvents had to be used.
- The conservation treatment had to be reversible.

After developing a theoretical system, we performed a series of tests on samples. The original PVC-coated fabric should be backed with a lining as a supporting structure for the inlay. The main questions were related to the search for a suitable kind of fabric lining and an adequate adhesive. Nine different adhesives were tested. In addition to all of the requirements concerning the applicability, viscosity and appearance of the adhesive, we needed to know if the adhesive would break before the original material in case of any stress or tension. Two parameters needed to be considered: the strength of the adhesive and the strength of the backing fabric. Two kinds of cotton fabrics were chosen: a woven fabric, strong and non-elastic, and a knitted, rather elastic jersey.

The samples were prepared according to the ISO Standard 9664:1993, “Adhesives: Test methods for fatigue properties of structural adhesives in tensile shear”. All in all 18 samples were prepared. For the test the tensile strength machine “Zwick Materialprüfung 1445” at the Chair for Materials Technology and Mechanics at the Technical University of Munich was used. After measuring the tension level needed to break the original material, all of the tests were conducted with the prepared samples. Prolongation, force and time were measured. It became evident that in the samples using the woven cotton fabric, the original PVC broke first. In the samples using the jersey fabric, the elasticity of the fabric showed its importance by taking away the stress from the PVC. One particular adhesive ultimately revealed itself to be most suitable for the conservation treatment: the acrylic dispersion Lascaux® 498 HV. Because of these results the inlays were fixed using the jersey fabric and the acrylic dispersion. During the restoration work it was not always possible to even up the levels between the original PVC and the inlay. Consequently, small remaining gaps were filled with party – a mixture of Lascaux 498 HV, lycopodium and pigments. After finishing this work the sofa went back into the in-house storage area, which has optimal environmental conditions. Still perfect after three months, there was good as well as bad news after five months. Fine gaps had appeared, fortunately between the original PVC and the inlay (see Figure 4). This means that the ideas and practical realization turned out to be in the right direction, but with no long-term stability. The immediate idea of using a stronger adhesive or the non-elastic fabric next time was rejected, because the risk of new gaps would increase due to the deterioration of the original material with its increasing inherent tension. Since party had already been used to fill the small gaps, the new ones could be treated in the same way. For the moment we are monitoring further changes, due to our awareness of this problem in the conservation of PVC-coated fabrics.
The second “work in progress” also deals with loss compensation, specifically with filling losses in a coating of high-gloss polyester resin varnish. This varnish was applied by using the casting technique. A closer look represented more than a year’s wages for an average worker. The fabrication number of the museum’s Komet is 279005. The Kuba Corporation manufactured the Komet only from 1957 to 1962, and it was regarded as the “Mercedes” among Kuba products. The museum’s particular Komet has a fabrication number of the museum’s Komet is 279005. The Kuba Corporation manufactured the Komet only from 1957 to 1962, and it was regarded as the “Mercedes” among Kuba products. The two-part corpus is made of chipboard with maple and wenge veneer. The upper section rotates, allowing the viewer to swing the black and white television and speaker system in the desired direction. Opening the door of the lower cabinet reveals the rest of its properties. It is very glossy, very thick, still transparent, slightly yellowish, and shows no traces of surface cracks. The cross-section shows two transparent layers with a remarkable thickness of the upper layer (see Figure 6). The results of the gas chromatography-mass spectroscopy (GC-MS) and infrared-spectroscopy (IR) showed that the upper layer is an oil free polyester resin based on phthalic anhydride. In the course of a workshop at the University of Applied Sciences in Cologne, Thea van Oosten analyzed the thin underlayer as cellulose nitrate using Fourier transform infrared analysis (FTIR). These components and the thickness of the lacquer led to the assumption that the varnish was applied by using the casting technique. A closer look into the technical literature for painters and varnishers showed that the casting technique was used especially for polyester varnishes (Nutsch 1984). To produce this kind of lacquered surface, a layer of cellulose nitrate already containing the catalyst was applied onto the wooden board. After two to three hours the second layer, a solution of polyester dissolved in styrene, was applied. The chemical reaction with the catalyst (contained in the primer) causes the resin to cure and harden into a rock hard, crystal clear coating. After hardening, the surface was polished by hand-operated machines.

Secondly, we were interested in the damages to the surface which had accumulated over the course of time: scratches, a few cracks, parts where the varnish had come off, but mainly loss of varnish on the edges. Next to cleaning, the consolidation of the coating losses was the main conservation task, which will be focused on in the present article. The evaluation of suitable filling materials involved films made from several types of synthetic resin, with the aim of reproducing the transparency, colour and thickness of the original coating and its degree of gloss.

Further demands were a non-invasive method of application (concerning solvents, heat or mechanical stress), easy applicability regardless of whether the loss was in a vertical or horizontal position, long-term stability and reversibility.

Materials tested included different types of synthetic resins such as Paraloid B 72, Regalrez or a polyester resin.

Matching the thickness of the original varnish was a difficult task. Most of the tested synthetic resins showed strong bubbling or it took too much time to reach a similar thickness of the coating. As a next step natural resins like shellac, sandarac and mastic were included in the evaluation process. Shellac proved to be the most suitable material in the test series. The material has several advantages: the natural yellow colour of shellac blond matches the colour of the aged polyester resin almost perfectly. Shellac is also easy to dye if necessary. When crushing shellac to a fine powder, it can be applied using a heating spatula. Step by step the loss can be filled without using solvents – to any necessary level and with a perfect fit (see Figure 7). This work must be performed with great precision; otherwise tiny air bubbles
remain in the shellac. Nevertheless a relatively quick working process is possible. To achieve an even surface with the new shellac – and this is the greatest disadvantage of the material – one must use mylar/melinex and a sizeable heating spatula like a flat iron. Using this technique the heat reaches the original varnish. Visible changes could not be detected but we have had an uneasy feeling about it. Most problematic were the parts where losses larger than 1.5 square centimetres had to be filled in. To achieve a perfectly even surface, it was necessary to use a heating spatula with a heating shoe approximately three or four times larger than the size of the loss. Therefore only the small losses were filled using the shellac technique.

In summer 2009 the testing series was continued. Again an evaluation of suitable filling materials was started and our main attention was directed to the technical aspect of how to apply a new resin. Finally a procedure for the fillings was developed consisting of the following steps:

- Manufacturing a full-scale sample with the size and form of the original corpus edge
- Manufacturing a four-layer silicon/PMMA form
- Preparation of this form for the filling process: positioning of the holes for air leakage and for pouring the epoxy
- Pouring the epoxy with a syringe
- Removal of the form after hardening

It took a lot of testing until it became clear how to deal with the air bubbles, how to achieve a perfectly smooth surface, how many air channels were needed, how thick the silicon layer had to be and so on. In addition to this intensive examination, different types of synthetic resins were tested again. In the end an epoxy resin from R&G GmbH was used as a filling material. The result was a perfectly even, bubble-free and high-gloss surface, which almost perfectly matches the original varnish. For the larger losses in particular, the surface quality of the filling is much more convenient. Apart from this, the edges of original varnish are not exposed to any thermal or mechanical influences. Initial concerns regarding the reversibility of the new method could easily be allayed. If the loss was prepared with a thin layer of Re-galrez, a light impact removes the inlay without any trouble.

But even with this success in mind there were still some problems left unsolved. The main problem is the question of the colour and long-term stability of the resin used for the filling. The colour of most epoxy resins, like Araldite 20/20 or similar types, changes to yellow over the course of time, sometimes even after a few weeks. Yellowing was also the reason for not considering polyester as a suitable material. The varnish samples made of new polyester resin showed a considerable change in colour after only six months. For the fillings, an epoxy resin described as “water-clear cast resin” was used. No long-term studies with this material have been carried out yet, and in view of our experiences a change of colour is expected. Apart from this the colour of the original varnish has changed to yellow with time. For a perfect filling the epoxy has to be stained, or either the underlying wooden surface or the top of the newly applied varnish must be retouched. In this particular case the wooden surface was retouched with “Horadam” watercolours by Schmincke. But staining the new resin may be more successful and even easier. So far only one crack has been treated with the epoxy resin on the original varnish of the Kuba Komet. The difficult task of reproducing the original yellowed colour of the varnish by staining as well as maintaining this colouring has not yet been solved.

CONCLUSION
Both projects, the Kuba Komet and the Throw Away sofa, are not yet finished and might be completely finished. A broader exchange of experiences, precise monitoring and further tests in combination with new materials and technologies will guide the way to finding suitable solutions for these kinds of challenging problems.

ACKNOWLEDGEMENTS
The author would like to thank all those who participated in these projects, especially Clementine Bollard, Carsten Henselmann and Françoise Dubouchet for the investigations and conservation of the objects as part of their internships at the Conservation Department of Die Neue Sammlung; Friederike Waentig and Andreas Krupa at the University of Applied Sciences in Cologne for their support; Ursula Baumer and Thea van Oosten for the identification of the materials.
A collaboration between the newly founded Triennale Design Museum of Milan (TDM) and the Politecnico di Milano, a leading university for design has been established to tackle different aspects of the conservation of the large collection of twentieth century industrial objects. Various objects from the TDM collection, well known design icons, have been selected for study in order to assess the condition of those objects which are believed to be at risk; objects have been examined with the aim of producing condition reports and careful analysis of constituent materials as well as the assessment of degradation patterns.

In this article a case study focussing on the Taraxacum™ and Fantasma™ lamps by FLOS™ is presented. The two lamps are manufactured in poly(vinylacetate) (PVAc). Samples of the two objects, coming from the surfaces of the light diffuser, were collected and examined by optical microscopy, micro-FTIR and UV fluorescence spectroscopy. Analyses allowed the assessment of the degree of polymer degradation, highlighting different degradation phenomena and chemical modification of the polymer fibres. FTIR spectra were examined in comparison with the standard unaged PVAc sample, and three different deterioration pathways have been recognized, which correspond to the different local condition of the polymer. Similarly, differences among collected samples have been pointed out by fluorescence spectroscopy, where different chromophores are evident in samples coming from different areas.

KEYWORDS
interior design, polymer degradation, FTIR spectroscopy, fluorescence spectroscopy, poly(vinylacetate), PVAc

INTRODUCTION
A recent collaboration between the Politecnico of Milan and the Triennale Design Museum (TDM) has been established on the basis of complementary competences and resources, with the aim of studying the twentieth century objects of the museum collection and promoting a better understanding of some of the problems related to the preventive conservation and treatment of objects made of plastic. The interdisciplinary collaboration is devoted to uniting different experts: polymer scientists, conservation scientists, architects and designers.

The Triennale Design Museum, directed by Silvana Annichiarico, is the first museum of Italian design and it represents the multiplicity of expressions of Italian design. The museum is extremely dynamic, able to renew itself and offer to its visitors unusual, different outlooks, points of view and trails: a museum that is not only scientific and rigorous but also emotional and riveting. A lively, ever-changing body, it can also dispute, contradict and question itself.

The Triennale Design Museum “stages” Italian design through a sequence of plays that change every year, with different key themes, scientific approaches and layouts. Thanks to its innovative formula, the Triennale Design Museum aims at providing an answer to the following question: What is Italian Design?

The first interpretation is: “The Seven Obsessions of Italian Design”. The “obsessions” are cultural categories often responding not to real needs of the market or to technical requirements, but to the design criteria and methods of a culture which addresses the contemporary while preserving connections with old tradition and memory.

The second interpretation: Series, Off Series is dedicated to the relationships existing between Italian Design and industry. The title indicates two poles of a circuit, where industrial production is nourished by spontaneous experimentation, and this, in turn, takes place within an open industrial system.

The museum has a permanent collection, which is made up of a unit from the permanent Italian design collection, from Alessandro Mendini’s sketches and from the Giovanni Sacchi and Alessandro Pedretti collection, but it also manages a vast network of “layerings” present throughout Italy (private collections, company museums, specialised collections and small themed museums) with which it has established a close collaborative relationship. Triennale Design Museum is also characterized by the presence of a conservation studio, dedicated to the “memory of modernity”, but also to the experimentation of new technologies, which aims at becoming an international point of
Great number of polymers have been reported of surface coatings and protection. (PVC) suspended in ketone solvents. It is used in a wide variety of formulations by a different coating produced by Andek in a wide number of less and flexible membrane that sprays cobweb-like filaments that form a continuous, jointed network. The main objective of the work is to set up a significant and careful protocol for the examination and analysis of fine atmospheric dust covers the fibers, which has led to a general grey appearance of some areas. Procurement and processing of fine atmospheric dust is complex. One of the most relevant problems in the conservation of plastics is that once initiated, most degradation processes cannot be stopped. The main factors which initiate or accelerate degradation of the TDM collection are: heat, oxygen, and is definitely the most common reaction of degradation naturally occurring on exposed surfaces, and may result in changes in gloss and color, cracking and chalking, all consequences of the interaction of the molecular structure of the polymer or its physical properties. The main vibration groups in PVAc. The main vibration groups in PVAc. The main vibration groups in PVAc. Table 1

<table>
<thead>
<tr>
<th>Wave number (cm⁻¹)</th>
<th>Assignments</th>
<th>Intensity of bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC–H</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>νC=O</td>
<td>Weak</td>
<td></td>
</tr>
</tbody>
</table>
It is known that PVAc degrades with the quantitative elimination of acetic acid and the formation of polyene (El-Din, 1993; Vaidergorin et al., 1987). Recent studies suggest that thermal degradation of PVAc proceeds with a series of different reactions (Holland and Hay, 2002): the elimination of acetic side chain leads to the formation of C=C double bonds, both along the carbon backbone with chain termination; furthermore this process leads to the formation of ketone groups inside the main chain. The rate of loss of acetic side groups was found to increase as degradation proceeds, due to the migration of C=C double bonds into side group positions; an effect of auto-catalysis is therefore occurring.

All the collected spectra show the fingerprint of PVAc with some of the typical vibrations of the polymer, even if the FTIR analysis revealed three different degradation patterns.

The first group of spectra is the closest to standard PVAc, therefore corresponding to the less deteriorated material. Only a partial deacetilation is detectable from FTIR spectra, where the signals from ester carbonyl and C-O-C group decrease (see Figure 1). Deacetilation involves the removal of acetic acid and in the FTIR spectra this is ascribed to the reduction of characteristic bands ν C=O ester and the associated 1375 cm⁻¹ δ C-H, 945 cm⁻¹, γ C-CH₃, 1243 cm⁻¹ and C-O-C. Furthermore the process of deacetilation leads to the formation of shoulders at 3020, 1600 and 1073 cm⁻¹ (ν H=CC=CH in cyclic compounds and along the chain) caused by an initial formation of C=C unsaturation of the chain.

The second group of spectra are associated with partial deacetilation and a distinct decrease of the ester carbonyl absorption peak (1740 cm⁻¹), the presence of the peak relative to ketonic carbonyl vibration around 1728 cm⁻¹ in the polymer chain occurs. The formation of alcoholic side chains following deacetilation is evident in the broad band at 3355 cm⁻¹, typical for OH groups in the polymer chain. Further confirmation of the formation of alcoholic side chains comes from the increase in the bands corresponding to ν CH-OH at 1058 cm⁻¹ and the broad bands at 1161 and 1112 cm⁻¹. The spectra show a broad peak between 1560 and 1670 cm⁻¹, caused by wide signs of unsaturation occurring in the chain with formation of double bonds and numerous bands of aromatic structures which overlapped in the same area of the spectra. The polymer is completely deacetilated and degradation has led to the formation of a new molecular pattern.

The discussion of FTIR data is related to the changes observed in the vibrational modes characteristic of PVAc; further research will be dedicated to assign and study the ageing behaviour of some minor vibrations which may be related to the presence of additives.

**FLUORESCENCE EXCITATION EMISSION SPECTROSCOPY (FEES)**

Spectrofluorimetry was carried out in order to assess whether there are detectable differences between samples taken from different areas from the lamps, and spectra were recorded from the entire fibre sample and are representative of the bulk material. Investigations using fluorescence spectroscopy highlight differences in the optical properties of the polymers employed in the two lamps, and hence the results from spectrofluorimetry are presented for each case separately. While the fluorescence observed cannot be ascribed to specific fluorophores, the fluorescence of the samples studied is significantly different to that of reference PVAc, which is non fluorescent, suggesting that the fluorophores present cannot be ascribed to specific fluorophores, the fluorescence
Figure 6: Stereo microscopy images of the morphology of the polymer in Fantasma and Taraxacum (see colour plates, p. 166).

Owing to the presence of the fluorophores in aged PVAc or in additives, the observed differences in EE spectra may be ascribed to differences in the degree of degradation of the polymer, and degradation in this case may be related to light exposure, which may vary between the surfaces of the lamp. Among the differences in the observed fluorescence, the samples studied may be related to degradation of the original material, as well as to the presence of additives. Analysis of samples taken from the Taraxacum and Fantasma lamps using fluorescence excitation emission spectroscopy (FEES) highlights the presence of different groups of fluorophores from different samples; these fluorophores are located in different areas of the EE spectra with excitation/emission bands at approximately 300:365, 345:390 and 370:425. The relative intensity of the three bands varies depending on the location of the sample and differs in the two lamps. This suggests that, while the polymer may be similar for both lamps, the modification in the EE spectrum in this case may also be due to differences in the chemical composition and degradation of the polymer.

While the three fluorescence emissions described cannot be ascribed to specific fluorophores in aged PVAc or in additives, fluorescence spectroscopy may still provide diagnostic information regarding the ageing or degradation of the polymer and hence investigations related to the modification of the fluorescence spectra as a function of ageing are underway.

CONCLUSIONS

The analyses carried out for the two lamps by FLOS, Taraxacum and Fantasma, highlight differences in the polymer condition. Three different degradation patterns have been described based on analysis of micro samples using FTIR. Degradation is probably related to the different exposure to light, as the significantly different morphology of the polymeric material evidences. From FTIR it is clear that the typical deacetylation and deterioration process of the PVAc has begun and these changes may be reflected in EE spectra. It is not possible to qualify the exposure conditions which may have favoured the process of degradation. Moreover this is complicated, as deterioration patterns are heterogeneously distributed on the lamp surfaces. Only few polymeric fibres are completely deteriorated.

The well known autocatalytic process of the PVAc degradation is particularly significant for preventive conservation. A careful set-up for the conservation of the two lamps is in progress at the conservation studio of the TDM in Milan, while further studies on the specific additives of the polymer mixture will be carried out with the aim of establishing new post-stabilization procedures.

ACKNOWLEDGEMENTS

Authors would like to acknowledge the Triennale Foundation’s support for this research and wish to thank the conservator of the conservation department of the museum, Ms Roberta Vertieramo, for her help and assistance during the examination of the lamps.
Lecture 011
Preservation of the GDR-Culture of Everyday-Life made of Plastics
By Friederike Waentig, Stephanie Grossman and Christoph Wenzel

Abstract
Lack of natural resources forced the German Democratic Republic (GDR) from its early days on to rely heavily on the production of plastics. Based on the local coal industry, plastics like melamin resins, polyester or PVC substituted scarce materials - especially metals - in the production of consumer goods. In the 1960s the production of plastics soared but unlike in the capitalist West, attempts to school the consumer in the handling and care of these new materials were coordinated by the state and not by privately run companies. The goal was not to boost sale numbers but to shed their aura of ersatz. Plastics were promoted as the proof of socialism’s technological progress and moral superiority. Soon after the fall of the Berlin Wall twenty years ago, previously omnipresent household items started to vanish from every day life. Factories were dismantled and plastic objects reached the end of their natural life spans - if they were not discarded earlier as unwanted relics of the past. This paper will summarize the project and present some interesting aspects.

Keywords
Plastics, GDR, preservation-conservation, design, objects of daily life, plastics industry

Introduction
The interdisciplinary research project titled Preservation of the GDR-Culture of Everyday-Life made of Plastics (Bewahren der DDR-Alltagskultur aus Plastik) started in June 2009 and will end in May 2012. It is a cooperation between the Centre of Documentation of the GDR Everyday-Life in Eisenhüttenstadt (Dokumentationszentrum Alltagskultur der DDR) and the Cologne Institute for Conservation Sciences, state-aided by the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung). The aim of the project is to contribute to the preservation of plastic objects made in the GDR between 1945 and 1989 as they represent the every day life of this particular period in German history.

Historical Background
In the aftermath of World War II Germany was divided by the Allied Forces into four occupation zones with the Soviet Zone becoming the GDR in 1949. War damage and removal of entire plants as part of reparations had a devastating effect on the East German industry and economy. Furthermore the transformation of formerly privately owned companies – mostly heavy industry - into Soviet Public Companies (Sowjetische Aktiengesellschaften - SAGs) in 1946 intensified the massive shortage in the supply of necessary goods and services for the East German population. The main aim of production was the retrieval of reparation payments and the production of goods - especially machinery - for the Soviet Zone. It was not until 1954 when the East German government bought back the SAGs for 3.5 billion Marks that the production of consumer goods for the domestic market and for export could be expanded. But even after the former SAGs were transformed into People’s Enterprises (Volkseigene Betriebe, VEBs) sufficient production, especially of consumer goods, was constrained by several factors. The foundation of the COMECON Council for Mutual Economic Assistance (Rat für gegenseitige Wirtschaftshilfe, RGW) in 1949 was intended to economically assist the weaker economies of the Eastern Bloc – like Bulgaria, Romania, Cuba, Mongolia and Vietnam. For the members with stronger economies of the COMECON this meant production had to be streamlined and aimed at the demands of the weaker partners instead of producing and exporting goods for domestic use or markets outside the COMECON.

History only external factors hindered the growth of the local industry and the production of consumer goods. Until the late 1930s the East German government invested primarily into...
heavy industry, especially engineering and chemicals industry, as those sectors built the necessary foundation for light manufac-
turing industries and the production of consumer goods. The nationalisation of private businesses – starting as early as 1946 – and the centrally planned economy with five-year-plans and later seven-year-plans also affected the development neg-
atively, as a rigid economic system was created which was un-
able to respond to the developing and changing needs and demands of the people.4 Furthermore due to a lack of foreign currency the GDR was unable to substitute needed supplies of
necessary goods with imports, which added to the general feel-
ing of dissatisfaction with the government. The economic and political situation in East Germany contrasted especially harshly with the evolving economic miracle (Wirtschaftswun-
der) in West Germany. The resulting so-called Republikflucht - the term used to criminalise attempts to flee or otherwise leave the country without a valid exit visa - posed a huge prob-
lem for the East German state as hundreds of thousands left the country for the West, reducing the workforce significantly. In the 12 years between the establishment of East Germany in 1949 and the construction of the Berlin Wall in 1961, over 2.7 million East Germans fled to West Berlin. The Berlin Wall was therefore built by the GDR with support of the Soviets to pro-
vide a physical barrier between East Berlin and West Berlin in order to stop the migration.4

But even after the Berlin Wall was built the numbers of the population of the GDR were constantly declining until the col-
lapse of the state in 1989 (see Figures in Table 1). For compar-
sion, the population in West Germany rose between 1950 and 1989 by 23 % whereas the population in East Germany de-
clined by 10,6 %. Demographic factors therefore also posed a huge problem for the East German economy, as the government had to face a constantly shrinking workforce.5

CHEMICAL INDUSTRY

Most of the East German chemical industry was – and still is – located in what is known as the Chemical Triangle (Chemiedreieck). The term describes the region between Halle, Merseburg, Leipzig and Bitterfeld, an area that has been the site of chemical plants from the early days of the chemical revolution due to its rich lignite and salt deposits. Lignite was the base for electricity generation as well as for the production of chemical and industrial feedstock. Ammonia, nitrogen, pigments, paints, synthetic rubber and gasoline were, among others, products generated for domestic markets and export until the beginning of World War II. Germany’s pre-war strive for autarchy as a means of war preparation led to massive financial investments in the chemical industry of the Chemical Triangle with an emphasis on the production of gasoline by coal hydrogenation. Though – as already men-
tioned – war damage and reconstruction took massive toll on infrastructures, once more the region provided the basis for autarchy in the post-war period.6 It wasn’t until 1963 that crude oil became available to East Germany’s chemical indus-
try. At the 10th session of the COMECON in 1958 the con-
struction of a pipeline was decided, which would provide East Germany among other states of the Soviet Bloc with crude oil. The construction of the so-called Friendship Pipeline took al-
most five years, with the town of Schwedt/Oder being its west-
ermost recipient. Simultaneously new plastic processing plants were built to produce plastics not only for the East Ger-
man domestic market but also for the member states of the COMECON as a way to streamline production within the Eastern Bloc.7

ORGANISATION

The 15 state holding companies (Kombinate) of the chemical sector were under the direction of the Federal Ministry of Chemical Industry (Ministerium für Chemische Industrie). The state holding companies mandated 231 People’s Enterprises with more than 1000 plant sections. There were eight divisions of chemical industry:

- Oil-producing, natural gas and hydrocarbons
- Organic and inorganic priming chemistry
- Pharmaceutical products
- Chemical and technically chemical specialty products
- Synthetic fibres
- Plastics and synthetic resins
- Rubber and asbestos
- Potash-salt and sodium chloride

Though most plastics known in the West were also produced in East Germany, the production output differed significantly. The most common plastic produced in the GDR in 1973 was polyvinyl chloride (PVC) with 31.0 % of total production whereas polyole-
fines ranked third behind amino plastics (17,7 %) and made up just 13.0 % of the total production (see Table 2).6

CONSUMERISM AND PLASTICS

The Program of Thousand Small Things (Programm der tausend kleinen Dinge) launched in 1960, aimed at the pro-
duction of consumer goods for daily life to respond to the needs and wants of the population. The Chemical Program (Chemie Programm) followed in 1961 as a result of the Chemical Con-
ference (Chemie Konferenz).

The state’s official position on consumer goods was that cheap, mass produced novelties of low quality were considered to be characteristic for capitalistic markets and therefore some-
ting to be rejected. Wasting raw materials, labour and income on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-
cialistic society. To prove the supremacy of socialism not only on the production and consumption of low quality products was branded as immoral and damaging to socialism and the so-

dard of the Chemical Triangle (Ministerium für Chemische Industrie). The state holding companies mandated 231 People’s Enterprises with more than 1000 plant sections. There were eight divisions of chemical industry:

<table>
<thead>
<tr>
<th>Year</th>
<th>Population numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945-1949</td>
<td>ca. 19 mill. (approximately 4 mill. refugees and displaced persons)</td>
</tr>
<tr>
<td>1949-1951</td>
<td>ca. 17.1 mill.</td>
</tr>
<tr>
<td>1951-1953</td>
<td>ca. 16.9 mill.</td>
</tr>
<tr>
<td>1953-1955</td>
<td>ca. 16.6 mill.</td>
</tr>
<tr>
<td>1955-1957</td>
<td>ca. 16.5 mill.</td>
</tr>
</tbody>
</table>

(See: Dietrich 2003, 18)
goods that could be sold in the West and not only within the Eastern Bloc. But convincing consumers to accept plastics was not easy in the beginning, as was experience left them eyeing plastic materials suspiciously as crotz – something without quality or value. Replacing scarce metals – as was necessary – with inadequate materials posed therefore the risk of leaving people with a feeling of shortage that would cause distrust in the state’s and system’s abilities. To create the illusion that the socialist government could provide its citizens with everything for a productive and content life, it was mandatory to produce goods that were as good - if not even better - than the same product made from traditional materials.10

The success of high quality produced objects was the core of plastics production from the beginning, as plastics in the GDR were never seen as cheap consumer goods or disposable products. Due to scarce raw materials and the immense effort necessary to produce plastics from lignite, they were considered highly valuable materials and already in the early 1960s recycling options were investigated. The GDR bought a constant (uphill) battle to avoid wasting raw materials, productivity and money but the difficulties the industry had to face in the socialist economy led to a high output of malfunctioning products causing complaints among consumers and retailers.

To form a truly socialist society it was considered indispensable to educate the citizens accordingly. Therefore the state provided guidance for all aspects of life – and it does not come as a surprise that consumer education played a vital role in establishing plastics as a truly modern material ideal for modern living. In the early 1960s schoolbooks, periodicals, journals like Jugend + Technik (Youth + Technology), and comic books like Mosaik (Mosaic) all praised the new synthetic materials and already in the early 1960s recycling options were developed. It describes a concept that is rooted in ideas first postulated in Germany within the Deutscher Werkbund but dates back to the Arts and Crafts Movement in England. Plastgerecht does not only imply the idea of form follows function, but also that the form must evolve out of the material itself. This does not come as a surprise as the leading designers of the GDR – or Formgärtner as they were called – came from a tradition influenced by the Bauhaus and the Deutscher Werkbund. They saw the opportunity to establish a culture of well designed and well manufactured goods within the new socialist society by means of state-controlled design and centralised production. Most important for the concept of socialist design was the university educated designer who would develop new modern forms in cooperation with engineers and scientists for the good of society. Berlin, Weimar, Dresden and Halle became the centres of industrial design in the GDR. The first school offering industrial design courses after the war was the Hochschule für Werkkunst at the Academy of Fine Arts (Akademie der Künste) in Dresden where Mart Stam – a former teacher at the Bauhaus – once more was appointed as vice chancellor. Under Stam’s influence the academics developed a course of studies modelled after the Bauhaus education system with preparatory classes and atelier work.

The other highly influential school was the Burg Giebichenstein in Halle. Founded as a vocational school in 1879 it was turned into a school for arts and crafts in 1913 in the spirit of the Deutscher Werkbund. After World War II it became the Bauhaus academy before the Academy for Industrial Design (Hochschule für industrielle Formgestaltung) was founded in 1958. Most of the early GDR design objects considered iconic today were developed at this school – for example the pastel-colored melamin trays and bowls. This design was actually the result of the teamwork of a group of students and teachers in response to the Program of
AIF). The example of Horst Michel, director of the Institute for Interior Design (Hochschule für Architektur und Bautechnik) in Halle, is telling: Michel was a member of the AIF's Review Panel for Materials and was responsible for the institute's participation in the AIF's exhibitions, which were considered to be of poor quality. Nevertheless, continuous efforts were made to establish a platform for the exchange of ideas and to encourage designers to uphold the quality of their work. The AIF's exhibitions, which were held in the early years of state fairs like the Leipzig Fair, provided a platform for the presentation of collections like the AIF's collection of plastics.

The AIF's exhibitions were given to a number of product categories at the Leipzig Fair in spring and autumn, with members of the AIF joining the exhibitions as selection committees. The institutions and agencies mentioned here are just a small selection of the many state-run agencies that coordinated and curated exhibitions.

The examples summarised in short here are mostly based on the archive of the AIF. The archive contains a wealth of information about the AIF's exhibitions and the quality of the products produced by the East German industry. The archives are lost, which makes it especially difficult to understand all the factors that played a role in their production. Without obvious changes, we cannot make predictions about the chemical stability of East German plastics.

The Berlin Wall fell 20 years ago and still Germans struggle with their divided past. Almost everything that was part of the daily life in the GDR has by now been replaced. Especially in Berlin – the symbol of the German divide - it takes almost archeological efforts to find traces of the GDR in public space today. Small objects that would otherwise be easily discarded can be found in private collections and state run museums today. Like most plastics, their long term preservation also poses problems. For cultural historians and design historians they are a symbol of the German divide.

OUTLOOK

The database and the handbook will be available in 2012. A conference and a summer school program on the history and preservation of plastics is scheduled for the same year in Cologne and the type and state of the art of the GDR's consumer industry. Therefore plastic objects that would otherwise be easily discarded can be found in public collections and state run museums today. Like most plastics, their long term preservation also poses problems. As little as we know about plastics conservation of Western plastics, we know even less about plastics made in the GDR or in the Eastern Bloc. Archives are lost, which makes it especially difficult to understand all the factors that played a role in their production. We have to assume that most plastics – though they might appear very similar to their Western counterparts – were produced differently. We have to expect that plastics production was even more experimental than in the West, as the factories had to fall back on substitutes to keep up production in bottleneck situations.

Aspects conservation will address in the course of the project are handling, preservation and identification of materials we find in the collections. Our aim is to develop a web-based handbook on collecting, preserving and exhibiting daily-life objects made from plastics from the GDR with additional information on their history and technology. A database with reference objects from collections like the GRASSI Museum for Angewandte Kunst, Wuppertal Kultur, and the International Design Museum Munich will be produced. This will be the first comprehensive handbook on collecting, preserving and exhibiting daily-life objects made from plastics from the GDR.

Eastern Bloc. Archives are lost, which makes it especially difficult to understand all the factors that played a role in their production. We have to assume that most plastics — though they might appear very similar to their Western counterparts — were produced differently. We have to expect that plastics production was even more experimental than in the West, as the factories had to fall back on substitutes to keep up production in bottleneck situations. Due to the fact that some items were produced over a period of thirty years or more — even in different factories but without obvious changes — we cannot make predictions about their chemical stability based on a few examples examined.

Aspects conservation will address in the course of the project are handling, preservation and identification of materials we find in the collections. Our aim is to develop a web-based handbook on collecting, preserving and exhibiting daily-life objects made from plastics from the GDR with additional information on their history and technology. A database with reference objects from collections like the GRASSI Museum for Angewandte Kunst, Wuppertal Kultur, and the International Design Museum Munich will be produced. This will be the first comprehensive handbook on collecting, preserving and exhibiting daily-life objects made from plastics from the GDR.
**ABSTRACT**

Stiletto. Double-sided problems with a self-adhering, flexible PVC-film presents an object located perfectly at the border between design and art. The non-functional wardrobe: Hüben wie drüben was designed in 1991 by the German artist Stiletto. It consists of eight doors, four on the front and four on the backside with neither shelves nor drawers or clothes rails on the inside. From a practical point of view it is not very useful as a furniture object. By decorating both sides with large-scale reproductions of the Berlin Brandenburger Tor, the designer transforms this common wardrobe into a semi-political art object and refers to the historical context of the falling of the Wall in 1989. Finally this wardrobe is walkable. Stiletto refers to this with a play on words by calling it: “Hüben wie Drüben, Die volksverbindende Schranktrennwand” (On either side, the nation connecting wall unit). Apart from the surface design the construction is quite simple and ordinary. The black laminated chipboard is connected with Minifix and SPAX screws. Because of the lack of shelves the construction is quite unstable.

For the surface design Stiletto used a traditional repro-technique. Postcards showing the Brandenburger Tor were enlarged and projected on PE-photopaper. These prints were mounted on the front and on the backside of this furniture. To protect the sensitive photo surface a transparent, self-adhesive protection film was laminated on top of it.

This paper illustrates the manufacturing process of laminated photography and focuses on the deterioration of plasticized PVC-film and its conservation treatment.

**KEYWORDS**

PVC-film, detachment, consolidation, lamination, Mowilith SDM 5, Stiletto

---

**THE ARTIST**

Stiletto by name Frank Schreiner was born in 1959 in Rüsselsheim, Germany. In 1995, after finishing his studies (1988) as a master scholar of Naim June Paik at the Academy of Fine Arts in Düsseldorf, Germany he founded the so-called ‘Stiletto DESIGNVERBRE: Unternehmung für transfunktionale Ges- tesegegenstände, transoriginales Gestesgegenlicht und refunk- tions- lotsiche Wohnraums- und Arbeitsplatzhinterleuchtung’, a distributor for furniture and interior design light objects and flashes of inspiration. His best-known work might be a slightly modified shopping trolley named: Consumer's Rest, designed in 1983 (see Figure 1). With this and other works Stiletto became one of the leading spokespeople of the New German Design in the second half of the 1980s. Furthermore he worked as an experimental Super 8 filmmaker, producing crazy short films like moped races in living rooms or falling cameras thrown down from towers.

---

**THE OBJECT**

The wardrobe: Hüben wie drüben was designed in 1991 by Stiletto (see Figure 2, 3). But to call this a wardrobe is not very precise. The object has eight doors, four on the front and four on the backside, with neither shelves nor drawers or clothes rails on the inside. From a practical point of view it is definitely non-functional and wobbly. By decorating both sides with large-scale reproductions of the Berlin Brandenburger Tor, Stiletto transforms this common wardrobe into a semi-political art object and refers to the historical context of the falling of the Wall in 1989. One side shows the Brandenburger Tor seen from the east side, the other the perspective from the west side of Berlin.

Finally it is possible to walk through this wardrobe. Stiletto refers to this with a play on words by calling it: “Hüben wie Drüben, Die volksverbindende Schranktrennwand” (On either side, the nation connecting wardrobe partition wall). Apart from the surface design the construction is quite simple and ordinary. The black laminated chipboard is connected with Minifix and SPAX screws. Because of the lack of shelves the construction is quite unstable.

Hüben wie Drüben was shown at the exhibition: “Interferences – Art from Berlin” in Riga and St. Petersburg in 1991. In 2003 it was donated to the collection of Die Neue Sammlung, The International Design Museum Munich by the artist. In a reference letter he mentioned that this object is a unique piece.
MAKING OF
The conservation treatment focused on the damages of the surface of the eight doors. Due to improper handling and storage, the transparent protection film on top of the door surfaces was damaged in large areas. To gain insight into the complexity of this special surface design and structure it is important to take a closer look at the manufacturing and the materiality of these ‘image carriers’. To realise his idea of a piece of furniture looking like a huge monument, Stiletto used a traditional repro-technique described in the following steps.

The decor images originate from two colored postcards of the Brandenburg Gate. One is showing the monument by day from the west side of Berlin, the other the east side by night. With these two postcards Stiletto went to a studio for photo reproduction. They transformed the images to a negative and finally inverted them. The inverted negatives were exposed on a large-scale photographic paper. In this regard a telephone conversation with the former technician of the photo lab who was involved in the production of this object was revealing. He supposed they had used polyethylene (PE) photo paper. In the early 1990s the classical baryta paper was no longer in use at the lab. Each large-sized photo, the Brandenburger Tor seen from east and west, was cut into four parts. Each part was mounted on a door using a double-sided, self-adhesive film. By means of a heated pressing roller, a transparent, self-adhesive plastic film was laminated on the surface. With increased temperature the plastic film becomes more flexible and expands, resulting in a close bond to the surface. The laminated film was cut with overlap, folded at the edges and attached to the reverse side.

To become familiarized with this technique a reconstruction was made in a specialized photo laboratory in Munich.

COATING MATERIALS
As well with different methods of analysis the above-mentioned technique was confirmed. Fourier transform infrared (FTIR) analysis of a small sample of the transparent protection film was performed at the Netherlands Institute for Cultural Heritage (ICN) in Amsterdam. By comparison to reference material a soft Poly (vinyl acetate) (PVC) with an adhesive layer of poly acrylic acid was detected.

Cross sections were taken and examined under visible (VIS) and ultraviolet (UV) light. Using different tinting media the stratigraphy was differentiated. According to the above-mentioned technique of photo-laminating it was expected to find the following stratigraphy (bottom-up):

- Transparent protection film (soft PVC)
- Adhesive layer of transparent protection film (poly acrylic adhesive)
- Gelatine layer (PE-photo)
- PE-film (PE-photo)
- Cellulose fibres (PE-photo)

With the magnification of the lower side of the cross section the double-sided adhesive film becomes apparent.

This resulted in a clear red layer, presumably the gelatine layer of the PE-photo paper. With a second stain test it was intended to uncover cellulose material. By treating the sample with a mixture of iodine, zinc chloride and potassium iodide, the evidence was adduced: Characteristically the cellulose fibres change color to violet.

Having this in mind the cross section of the lamination, seen under UV light, reveals more of the material structure. The following stratigraphy becomes apparent (bottom-up):

- Transparent protection film (soft PVC)
- Adhesive layer of transparent protection film (poly acrylic adhesive)
- Gelatine layer (PE-photo)
- PE-film (PE-photo)
- PE-film (PE-photo)
- Cellulose fibres (PE-photo)

With the magnification of the lower side of the cross section the double-sided adhesive film becomes apparent (bottom-up):
nCH₂ = CHCl

reaction.

merized from vinyl chloride via a free radical-induced addition

dehydrochlorination of the polymer.¹⁴

polyene systems of increasing length accompanied by dehy-

Deterioration of Plasticized PVC Film in General

The possible effects of further deterioration of the PVC-film will

DETERIORATION OF PLASTICIZED PVC FILM IN GENERAL

The possible effects of further deterioration of the PVC-film will

• Double sided adhesive layer
• Black plastic laminate
  (presumably melamine resin)

DETERIORATION OF PLASTICIZED PVC FILM IN GENERAL

The possible effects of further deterioration of the PVC-film will

• Black plastic laminate
• Double sided adhesive layer
(see colour plates, p. 167)

Stratigraphy of laminate

Flexible PVC-film is commonly plasticized with di (2-ethyl-

hexyl) phthalate (DEHP) in ranges varying from 15 percent to

50 percent by mass to modify the workability (reducing the vis-

cosity and melting temperature) and to soften the final PVC

product (flexibility and elongation).¹⁰

The degradation of PVC is mainly caused by high-energetic

radiation (UV-A, 380–315nm)¹¹ and higher temperature¹². The

degradation of plasticized PVC often becomes evident with

sticky surfaces caused by the migration of the plasticizer from

bulk to surface.¹³ The migration can be initiated by polar

solvents or elevated temperature. From the surface, DEHP

either evaporates slowly (the characteristic sweet smell of
dibutyl- and dioctyl phthalates or hydrolyzes to crystalline

phthalic acid.

The material becomes harder, shrinks and gets brittle. Later,

the PVC polymer component degrades and forms conjugated

polyene systems of increasing length accompanied by dehy-

drochlorination of the polymer.¹⁴

“Dehydrochlorination occurs at imperfections in the PVC struc-
ture and starts with the breaking of a carbon-chloride bond.

Loss of chlorine atom is followed almost immediately by ab-

straction of a hydrogen atom and a shift of electrons in the poly-

mer to form a double bond. The next chlorine becomes highly

reactive and is readily removed.”¹⁵

With the hydrochlorination of the PVC polymer, acidic con-
ditions arise. This accelerates the hydrolysis of DEHP (ph-
thalates) to form white, crystalline phthalic acid.

The conjugated double bonds shifts the absorption of light to

the visible spectrum characterized by discoloration of the poly-

mer from white to yellow, red, brown and eventually black.

DETERIORATION OF PLASTICIZED PVC FILM IN PARTICULAR

At first sight the decorated door surfaces are in a good condition.
The most severe damages like tears, abrasions, deformations,
folding, detached areas and losses originate mostly from me-

chanical stress caused by improper handling (see Figure 3).

At the time of examination none of the characteristic PVC
deterioration, like for example, discoloration, stickiness or em-

brittlement, was apparent. Only in detached areas, where the

PVC-film showed first signs of loss of flexibility, was it visible,

probably caused by a slow emission of softeners.

TEST SERIES AND THE TREATMENT

The main focus for the conservation treatment was the consoli-
dation of the detached areas. Moreover with this treatment it

was intended to recover the whole aesthetic quality of the object.
For consolidating the detached and damaged PVC film an ap-

propriate strategy had to be developed. Possible consolidants

needed to be evaluated. The consolidant should meet the fol-

lowing requirements:

• Good working properties
• Good film forming characteristics, no blisters
• No harm neither to PVC nor to the gelatine layer
• PE-photo
• Good resistance to ageing
• Average adhesive strength
• Low viscosity
• Transparency
• Flexibility
• Subsequent cleaning possibilities

For the adhesive test series 11 commercial adhesives and

seven products that are common in conservation practice were

chosen.¹⁶ To stay in the system, adhesives based on acrylate like

the adhesive layer for the transparent PVC-film were favored.
In a series of mock-ups transparency, tensile strength and peel

adhesion were checked. Furthermore the degree of deformation,

stickiness and elasticity was compared by applying different

thicknesses of layer on a PVC-film. Nine adhesives were pre-

sented and tested on simulated damages like film deformation

and blisters. The best results were obtained by three adhesives,

common in conservation practice.

• Lascaux 498 HV
• Mowilith SDM5
• Kremer PU-Dispersion

On the basis of simulated film damages Mowilith SDM5

proved to be best. Moreover it is transparent, flexible, thermo-

plastic, free from any softeners and quite resistant to aging. Al-

though Mowilith is an adhesive with a high water content of

47%, no harm to the water sensitive gelatine layer, even under

the microscope, was detected.

Depending on the damage symptoms (blister, fold) the con-

solidant was applied with a small brush or injected with a sy-

ringe. Folded parts were carefully unfolded and, using a warm

spatula (max. 45 °C), smoothened and relocated. The consoli-

dation of the front surface was very successful (see Figure 6).

The edges however were a bit more problematic. Because of

the microstructured surface of the black edge veneer the liq-
uid consolidant, which filled this structure, caused a slightly different refraction index.

**RESUMÉE**

As Shashoua wrote in 2002 about the degradation of plasticized PVC objects: “Degradation of objects was first detected within 10 to 35 years of acquisition”\(^{16}\), it must be assumed that the condition of the PVC-film will worsen in the next years. The presented treatment is an active way to deal with this kind of material failure. But what are we going to do in some years when the original substance is heavily deformed, sticky and brittle?

**ACKNOWLEDGEMENTS**

I would like to thank the following persons without whom this work wouldn’t have been possible: Anna Comiotto (Bern University of Applied Science, Berne University of the Arts, Switzerland), Company Beyer (Munich, Germany), Marc Egger (Bern University of Applied Science, Berne University of the Arts, Switzerland), Ulrike Fischer (Doerner-Institut Munich, Germany), Susanne Hofmann, Frank Schreiner (Stiletto, Berlin, Germany), Thea van Oosten (Instituut Collectie Nederlands, Amsterdam, The Netherlands) and Marien Schmidt (Munich, Germany).

**ENDNOTES**

(1)www.stiletto.de, as at 09/2009.
(3) Stiletto mentioned the photo lab Gigant Foto, Uhlandstr. 20-25, 10623 Berlin in a letter to: Die Neue Sammlung, dated October 22, 2007.
(4) Telephome call on 12/07/2007 with Mr. Weiss, former employee of Gigant Foto, Berlin.
(5) Photo lab Beyer, Analog und Digitalfoto, Dachauerstr. 233, 80637 München.
(6) FTIR research, Instituut Collectie Nederland (ICN), Amsterdam, 10/15/2007.
(11) Dolcez 1978: 5.
(14) “Already a number of 7 double-bonds per molecular chain are sufficient to cause a visible discoloration”, in: Diem 1970: 46.
(16) Commercial adhesives:

- Pattex Plastic (acrylic copolymer and vinyl acetate copolymer solved in 60-70% butyl acetate and 10-20% acetone)
- UHU allplast (acrylic ester, PVC copolymer solved in ester and ketone; ethyl acetate, acetone, butanone)
- UHU plus acrylic (two-component acrylic adhesive methyl-meth-acrylate, di-benzo periloxide)
- UHU plast special (acrylic resin dissolved in ester and ketone)
- UHU Sekundenkleber (cyanoacrylate)
- Penlog GTI (two-component acrylic adhesive)
- UHU weich PVC (polyurethane elastomer dissolved in ester, ketone and aromatics)
- UHU Alflakhele Kraft (polysolvent acetate – ethylene copolymers and polyurethane dispersion)
- Pattex Kraftkleber (polyurethane dissolved in 60-70% acetone and 10-15% n-butyl acetate)
- UHU Extra Alflakhele (polyvinyl ester dissolved in ester and alcohol)
- Rudorfer L 530 (solution of synthetic resin)

Adhesives common in conservation practice:

- Kremer Acronol 500D (anionic, unplasticized pure acrylic dispersion)
- Kremer Dispersion K 160 (pure acrylic dispersion)
- Lascasa 498 HV (dispersion of a thermoplastic acrylic polymer on the basis of methyl methacrylate and butyl acrylate)
- Mowilith S195 (unplasticised aqueous co-polymer dispersion on the basis of vinyl acetate/ethyl acrylate ester)
- Kremer PU Dispersion (Aquafox anionic polyurethane dispersion)
- Araldit 2020 (epoxy resin)
- Araldit 2026 (two-component polyurethane resin)
(17) Shashoua 2002: 927.

---

\(^{16}\) Commercial adhesives:
ABSTRACT
Cold War Modern – Design 1945-1970 was a major exhibition at the Victoria & Albert Museum in Autumn 2008, the main theme of which explored the influence this period had on contemporary design, architecture, film, popular culture and how a constant state of political uncertainty fostered new and exciting artistic developments.

This paper focuses on the examination, analysis and preparation of elements from costume ensembles by Pierre Cardin and Paco Rabanne. Establishing themselves as prominent designers of the period they were known for their use of new materials and construction techniques to create their ‘Space Age’ look. As well as an ethical discussion, raised by notions that Rabanne’s disk dress could be user-customised, this paper looks at unstable elements within both ensembles. Fourier Transform Infra-red Spectroscopy (FTIR), light microscopy and Scanning Electron Microscopy (SEM) were used to examine and analyse them. Relevant contextual information used to support the analysis also helped to interpret the damage evident and highlight treatment options available.

KEYWORDS
fashion, cellulose acetate, disk dress, polyurethane, boot, heel tip,

INTRODUCTION
The Victoria & Albert Museum’s major Autumn exhibition of 2008, ‘Cold War Modern: Design 1945-1970’, was the first to examine the influence this period of intense rivalry between the Soviet Union and America had on all aspects of design and technology. The exhibition opened with a Sputnik, an object that marked the beginning of the space race from its launch in 1957 and symbolised the hopes of people for a bright and shiny new future following the devastation of war. With over 300 exhibits, a diverse collection of objects were chosen to illustrate exhibition themes and the show included work from artists such as Gerhard Richter, designers Charles and Ray Eames, film makers such as Stanley Kubrick and architecture by Le Corbusier and Richard Buckminster-Fuller. The Cold War was a period of confrontation, in all spheres. It saw a continual state of political conflict, military tension and economic competition between the USSR and the USA following World War II. Although military forces never officially clashed directly they expressed the conflict through military coalitions, nuclear arms race, espionage, propaganda and technological rivalry.

In the art and design worlds as well different terms of reference were introduced, deliberately at the opposite extreme to those established by previous generations. Developments were also occurring in the fashion industry; the emergence of designers such as Paco Rabanne and Pierre Cardin, who focused on using new materials and construction techniques, had such a profound impact on fashion that it caused a radical change in direction. The objects discussed in the two case studies presented here aim to show not only the diverse materials used in their construction but also to consider their underlying stability issues. Analytical techniques were used to identify materials, to help interpret their condition and to provide possible solutions for treatments. Details of materials used and contextual information help to place the objects in this experimental and innovative period. They were prepared for a three month display at the V&A and a two venue tour. Therefore their preparation for travel was an important element of the overall treatment. In terms of how they could be displayed, and preventive measures that were put in place to protect vulnerable elements while in transit.

CASE STUDY 1
PACO RABANNE AND THE ‘UNWEARABLE DRESSES IN CONTEMPORARY MATERIALS’
The disk dress from the Victoria & Albert Museum’s Textile & Dress Collections was designed by Paco Rabanne in 1967 at the
A closer look at the disk dress, T.165-1983

The dress is constructed from multiple light-weight and rigid plastic disks or paillettes, which have a reflective surface due to an applied foil or an iridescent coating. The disks are composed of one thin piece of plastic, approximately 125 microns in thickness and 30mm in diameter, with the foil or coating applied to one side only. The disks are linked together by a network of brass rings. The main structure of the dress is composed of diagonally linked iridescent disks that are doubled, with holes punched evenly in four places. Three of the brass rings connect it to the next disk and so on. Due to this diagonal composition an intermittent void is created. An additional foil disk is used to fill this space, which is secured by only one ring, allowing it more freedom to move than its fixed neighbours (see Figure 1).

Our main concern was with the foil coated disks, a number of which had become detached. Their composition was unknown and in museum records the dress was referred to as ‘a mini dress with Perspex™ disks and metal chain’. Therefore one of the detached foil disks and its coating were analysed. It was not possible to test the disks with the iridescent finish.

Areas of the disk where the coating was lost were examined using FTIR (Fourier Transform Infrared Spectroscopy) and they proved to be Cellulose Acetate (CA). CA is made from wood or cotton fibres that are treated with acetic acid and acetic anhydride, processed to produce a plastic dough and injection moulded to produce sheets and rods. In this case it was injection moulded to produce sheets, from which the disks were probably formed into sheets, from which the disks were probably punched.

The coating was analysed using X-Ray Fluorescence (XRF) and appeared to be silver in composition with little or no other elements found, suggesting that it was a silver foil. It is frequently associated with silver, such as tarnishing.

Cellulose acetate is susceptible to hydrolysis by atmospheric humidity causing the release of the acetic acid, which in turn can trigger an auto-catalytic reaction. The disks themselves exhibit some problems that are typical with the degradation of this material. They were originally intended to be flat but now a larger number of the free hanging disks and some of the fixed disks have become curved. It is likely that their current condition owes much to wear in combination with the breakdown of the disks themselves. Because of the close contact these areas would have had with the wearer it is possible that hydrolysis was triggered in the disks, thereby initiating corrosion in the brass rings. Although this damage is evident, the dress does not have a strong odour or a weeping or sticky surface and the corrosion on the rings is largely localised.

CONDITION

The disks show signs of damage overall, with abrasion to the silver foil surface evident mainly on disks at the sides and reverse, appearing consistent with use and wear. However some disks appear to be positioned where they are unlikely to have received such heavy abrasion, suggesting that they were probably detached at some point and replaced without considering their new locations.

Additional local areas of loss, but where residues remain, were also tested in the hope that some information may be gained about other layers beneath the silver, such as adhesives. Unfortunately no new data was obtained. However it is likely that similar production methods were used to a patent, entitled ‘Method of Coating Plastic Films with Metal’, namely for polyesters and polyacetylenes with silver, filed in 1972. With this method the film is degreased and roughened, mechanically and chemically. The foil is applied, baked to remove excess moisture and is therefore capable of forming a very strong bond with the plastic without the use of adhesives. (Polakys et al, 1972)

TREATMENT

In total eight detached disks accompanied the dress to textile conservation for treatment and there were twenty-nine areas of loss. Losses were most notable on the front and sides, especially when highlighted against the backdrop of the dress that was chosen to cover the mannequin for the exhibition.

It is known that the replacement of detached, but associated material without clear documentation and evidence of where it came from has difficult ethical considerations. Ashley-Smith suggest that ‘the key to the problem is the quality of evidence’ (Ashley-Smith, 1994).

The evidence here therefore relies upon its origin, original construction, technology used in manufacture and information that embodies the maker’s intentions. Rabanne designed the dress with some flexibility in construction to allow the wearer to decide the arrangement. He even produced later models, in the 1980’s & 90’s, that were sold with pliers, disks and links in a box for self assembly (Rabanne, 1995).

That said, each disk bears evidence of wear, however slight, and the decision to return them without exact placement information was not taken lightly. In support of their return to the dress, once repaired, was the fact that they were designed to be fixed but slipped onto the rings and could be removed again at a later date if required. Guided therefore by curatorial support, contextual information and documentation to record new positions, work began.

As the disks are relatively thin, approximately 125 microns, it was important to avoid the creation of ridges or raised areas with the chosen support material and the combination of plastic and metal, conventional support materials such as paper and textile were not deemed appropriate. Melinex™ (polyester film), available in a variety of grades, was considered because it is a stable; translucent material of sufficient strength to support the damaged areas. Although strong, it was felt that a finer grade, such as 50 microns had the potential to fail before splitting the disk further if pressure was exerted.

The same criteria applied to the choice of an adhesive, in addition to reversibility, good ageing and working properties. It is known that CA is insoluble in acetone, therefore IMAS (Industrial Methylated Spirits, a methanol and ethanol mixture used in the UK) was mixed with low ratios of cellulose ethers, such as methylcellulose.
cellulose and Kluel G® (hydroxypropyl cellulose). The solvent was also tested with acrylic dispersions of Lascaux 360&498 HV (thermoplastic adhesive based on methyl methacrylate and butyl acrylate) as well as undiluted combinations of these. The tests were carried out on similar sized disks cut from heavy grade Melinex® to assess the application, consistency and the relative bond strength of the various ratios. The thin Melinex® support material was degreased with IMS and lightly rubbed with sandpaper to provide a key. The adhesives were thinly and evenly applied with a brush to the thin Melinex® and pieces were fixed in place on both sides of the substrate disks, taking care to remove any air bubbles. Blotting paper was placed on both sides to help absorb any excess liquid or moisture, it was weighted and allowed to dry. Before the thin Melinex® was trimmed and pierced, simple peel strength tests were carried out.

It was found that Lascaux 498HV applied undiluted satisfied all the criteria. 498HV is the more viscous of the two dispersions commonly used in textile conservation, which dries to a hard film. The same procedure was used to apply the supports to the dress disks and they were photographed (Figure 2), photographed and recorded both for the onward tour and static records held in the studio.

As the costume was difficult to dress, there was potential for further damage due to dressing and undressing at each venue. If handled incorrectly the disks can easily turn back on themselves, putting pressure on the pierced holes. Therefore a decision was taken to travel the object on its mannequin.

The main issue while in transit is vibration and as it has unfixed elements, which were of concern, a method to hold and cushion the elements was important. A quilted silk cover, fitted tightly to the object and mannequin, was prepared with Velcro™ tabs for ease of removing and replacing. A Tyvek® bag was constructed for the outer layer and the mannequin travelled in a crate standing upright, fixed at the neck and base.

CASE STUDY 2

PIERRE CARDIN & ‘THE WORLD OF TOMORROW’

Pierre Cardin developed his first ready-to-wear collections in 1950 and became well known for his avant-garde collections including his famous bubble dress. Although Cardin’s clothes are not always practical to wear, but by his own admission he was inventing ‘for a life that does not exist yet – the world of tomorrow’. (Mendes, 1990)

In 1959 Cardin developed his first ready-to-wear collections. Designed to appeal to a broader audience, they were more affordable and available to buy in department stores. By the mid-1960s he and contemporaries, such as André Courrèges, had transformed the excitement and curiosity of the Space Race into a wearable and fashionable look. These areas were no longer fixed to the heel but merely floating on the surface and when contact was made pieces became easily detached in large flakes. Beneath the tips was the very fragmentary and had suffered losses. The translucent areas appeared to be the same material but seemed to be migrating at a different rate, as they were still relatively fixed and the tip below seemed to be more complete.

It was clear that because the spigot hole in the proper right boot had weakened it overall, that it could not support itself and that this display method could not be used. The extent of the damage to the heel tips also suggested that pressure on them might cause problems and a decision was taken to support the mannequin from above, by hanging, but close enough to the ground so that it appeared to be standing.

However, the overall condition of the heels and tips were still of concern. Untreated, the vulnerable areas at the edge of the tips were likely to continue to break up and the translucent areas to deteriorate further. But why bother – can the tips be taken off and not treated, discarded even? These were all questions I was asked. Although these elements were intended to be somewhat temporary, now in their context as museum objects they are as valid to the overall design of the boots as the zips and the heels themselves. Additionally as the objects were donated by Cardin, so required, but likely that they are original to the boots and have never been re-tipped.2

The Theboots are knee length, with a high block heel, square toe and part zip openings on the inner side of each leg (see Figure 3). The back and leg sections are composed of four pieces of PVC stitched together and the sole is leather. In women’s footwear plastic soles were beginning to replace leather by 1958. It is unclear why Cardin chose to use leather here instead of plastic, considering that the rest of the boot is composed of synthetic materials. It is possible that because a thin sole was required, leather was deemed to be a longer lasting material.

The condition of the boots overall is fair. The PVC, although scratched, abrasced and worn, is in good condition. The right boot has a spigot hole, which was a popular previous display method. This has now made the boot unstable and in general it has undermined the strength of the sole. When the boots arrived for conservation the heel tips appeared to be coated with a thick waxy layer on the surface, milky white in overall appearance (see Figure 4). The surface of the coating and the heel tip visible below was generally cracked, broken and small areas of loss were evident.

COSMOS ENSEMBLE – T.35-1974

Cardin’s ‘Cosmos’ range was produced in 1967, with commemorative ensembles for women, men and children. This was one of his most commercial collections and has been described as ‘a uniform for youth’. (Farrington, 2008)

The garments were constructed from relatively hard wearing materials in bright colours and combined with plastic details in PVC, polyurethane and acrylic. The female Cosmos ensemble from the V&A’s collections was accessioned in 1974 along with a male equivalent, which was also displayed in the show but will not be discussed here.

The ensemble consists of six parts, a fine knit woolen hat, thick ribbed neck-puller and tights, all of which are black. A knitted nuno in red with a striking black PVC motif cut out and stitched to the front is worn over the tights and puller. New discreet fastenings, such as zips or Velcro®, were very attractive to designers because of their convenience and functionality, in this case Cardin used a concealed zip at the reverse. The accessories consist of a tinted acrylic visor and a pair of boots, an element of which is the main subject of this study.

THE COSMOS BOOTS

The boots are knee length, with a high block heel, square toe and part zip openings on the inner side of each leg (see Figure 3). The back and leg sections are composed of four pieces of PVC stitched together and the sole is leather. In women’s footwear plastic soles were beginning to replace leather by 1958. It is unclear why Cardin chose to use leather here instead of plastic, considering that the rest of the boot is composed of synthetic materials. It is possible that because a thin sole was required, leather was deemed to be a longer lasting material.

The condition of the boots overall is fair. The PVC, although scratched, abrasced and worn, is in good condition. The right boot has a spigot hole, which was a popular previous display method. This has now made the boot unstable and in general it has undermined the strength of the sole. When the boots arrived for conservation the heel tips appeared to be coated with a thick waxy layer on the surface, milky white in overall appearance (see Figure 4). The surface of the coating and the heel tip visible below was generally cracked, broken and small areas of loss were evident.

TREATMENT

THE HEEL TIPS – BIG DECISIONS FOR SMALL COMPONENTS

A closer examination of both heels revealed that the waxy layer had both opaque and translucent areas. These transparencies were no longer fixed to the heel but merely floating on the surface and when contact was made pieces became easily detached in large flakes. Beneath the tips was the very fragmentary and had suffered losses. The translucent areas appeared to be the same material but seemed to be migrating at a different rate, as they were still relatively fixed and the tip below seemed to be more complete.

It was clear that because the spigot hole in the proper right boot had weakened it overall, that it could not support itself and that this display method could not be used. The extent of the damage to the heel tips also suggested that pressure on them might cause problems and a decision was taken to support the mannequin from above, by hanging, but close enough to the ground so that it appeared to be standing.

However, the overall condition of the heels and tips were still of concern. Untreated, the vulnerable areas at the edge of the tips were likely to continue to break up and the translucent areas to deteriorate further. But why bother – can the tips be taken off and not treated, discarded even? These were all questions I was asked. Although these elements were intended to be somewhat temporary, now in their context as museum objects they are as valid to the overall design of the boots as the zips and the heels themselves. Additionally as the objects were donated by Cardin, so required, but likely that they are original to the boots and have never been re-tipped.2

Therefore two possible treatment paths were considered - the coating could be retained and secured in some way or removed and the tip reinforced.

The waxy coating had no artistic or visual significance to the boots and was obstructed. Because it was very likely that they would be handled, knocked and would potentially come into contact with a solid surface causing further
losses during the V&A exhibition and in two tour venues. The decision was taken to remove the plasticiser coating and reinforce the tip.

As explained, there were two distinct areas: the opaque and the translucent. The opaque came away easily but care was taken because of the brittle tip below. The translucent areas required a bit more effort and were removed mechanically with a blade. The heel tips are relatively small, approximately 10 mm in depth by 80 mm in length and a generous 0.5 grams of the coating was collected from each boot. Once the coating was removed the tips were cleaned, using a swab lightly moistened with de-ionised water, and dried to remove moisture. The tip was examined again, using light microscopy under various magnifications and SEM, in order to assess the structure.

The purpose of the treatment was to coat the tip and ensure that the cracks were filled with adhesive improving the cohesion between the fragmentary pieces and it was hoped that a consistent layer would inhibit further deterioration. An adhesive suitable for use as a consolidant with good ageing properties was required and Paraloid B72 (methyl acrylate/ethyl methacrylate copolymer) was chosen for these reasons.

Tests were undertaken to determine the thinning rate and the appropriate solvent to provide good penetration and consolidation properties. Small pieces of detached tip were tested in IMS and acetone to assess the effect of solvents on the material. It was found that the tip softened in acetone but appeared to retain its structure and firmness in IMS. Further detached pieces were coated with different concentrations of the adhesive. Solvent retention was taken into consideration and samples were left to evaporate. A 10% solution was chosen and applied to the boot with a brush (see Figure 5). Where possible loose material was returned to the tip with the aid of documentation marking their locations.

Paraloid has a high sheen when dry, which would have been more of a consideration if another section of the boot was treated, but because of the tip’s location it was felt that this was an acceptable compromise. In order to assess the penetration of the adhesive, a sample newly coated with Paraloid and a small piece that became detached during the treatment was examined using SEM. It is clear from the images that the adhesive has penetrated as required, flowing into cracks and pores (see Figure 6).

CONCLUSION

The costumes presented here are key examples from this period and clearly show the influence that technological developments during the Cold War had on the designers and the materials they chose to use. Known in the industry as the ‘metal worker’ (Kamitsis:1999), Rabanne designed the disk dress with movement in mind, intending it to follow the curves of the body. It is possible to imagine though, that this was not the most comfortable dress to wear and is probably deserving of the title ‘unwearable’, as the metal would have felt cold and the plastic sharp and abrasive. As well as avant garde costume, Cardin “the space-age designer” (Pavitt, 2008) is also credited with the introduction of unisex fashion and affordable ready-to-wear collections.

Although their designs were not always comfortable or practical to wear, both designers have left significant fashion legacies, elements of which are only now beginning to reveal themselves as problematic. The issues discussed here are representative of wider concerns with objects and collections of a similar date, material and construction within our collections.

The disk dress and Cosmos boots were examined and elements were analysed to help interpret their condition. The ensembles were prepared for safe display and to withstand the vibrations and movement during transit on the onward tour.

ACKNOWLEDGEMENTS

The authors would like to thank the Cold War Modern project team. Many thanks to Marei Hacks, Conservation Scientist at the British Museum, for her time and use of their SEM. Thank you to Lucia Burgio and Bhavesh Shah for analysis of the disks. Thanks also to Sandra Smith, Head of Conservation for permission to publish and Marion Kite, Frances Hartog, Louise Egan and Paul Tierney for their comments.

ENDNOTES

(1) Registry documents do not state if it arrived into the collection with detached disks, which suggests that they have become separated in recent years. Unfortunately no original images were found

(2) The Cosmos ensembles were gifted by Pierre Cardin to the V&A for inclusion in the exhibition Fashion: An Anthology by Cecil Beaton, curated by Cecil Beaton in 1971.
In preparation for the exhibition: ‘Cold War Modern: Design 1945-1970’ at the V&A, a significant treatment addressing the sagging upholstery of the museum’s iconic Globe Chair, designed by Eero Aarnio, was undertaken by the Furniture Conservation Department. With the contribution of colleagues both at the V&A and other institutions, it was decided to consolidate the foam and apply a thermo plastic adhesive to the textile to treat the sagging upholstery. This article discusses the treatment process.

INTRODUCTION
The second half of the twentieth century saw extensive development of materials such as plastics, fibreglass and foam for use in furniture. The Globe Chair (Circ. 12-1969), also known as the Ball Chair, was designed by Finnish designer Eero Aarnio and exemplifies the use of these materials. It debuted at the 1966 International Furniture Fair in Cologne. The Victoria and Albert Museum acquired the chair directly from the manufacturer, Asko Furniture Manufacturing Company, in 1969.

Now, several decades later, many of the modern materials used in the manufacture of the Globe Chair have changed in their appearance and material properties. The V&A’s chair required radical treatment to enable it to be included in the V&A exhibition, Cold War Modern: Design 1945-70. It had been on display in a gallery with radically fluctuating environmental conditions that may have exacerbated the degradation pattern of the modern materials. While the glass-fibre reinforced polyester shell had remained stable with the external gel-coat suffering only minor abrasions, the appearance within the shell had changed dramatically. The upholstery had begun to hang limply rather than maintaining the crisp profile intended by Aarnio.

PRE-TREATMENT
The pre-treatment assessment indicated that the reason for the sagging textile was degradation of the adhesive applied between the show cover textile and foam under the upholstery, thus leaving the textile unsupported. This was especially noticeable on the top interior of the shell. After discussions with Gareth Williams, the V&A curator responsible for the Globe Chair, our treatment goal was to improve the appearance of the upholstered interior by addressing the sagging show cover. Within this framework, and limited time and budgetary constraints, we wanted our treatment to retain the original materials and anticipate future re-treatments.

When weighing our treatment options we reviewed current literature on the conservation of modern materials, and conferred with a number of people regarding the treatment including: Dr. Joelle Wickens, then a PhD student (studying the fabric/foam interface on the Globe Chair at the Textile Conservation Centre, University of Southampton); Tim Bechthold, Head of Conservation at Die Neue Sammlung, The International design Museum Munich, experienced in the conservation of 20th century materials; as well as scientists, furniture and textile conservators, and furniture curators at the V&A.

Several ideas were discussed as treatment options including: having an internal mount for the show cover, replacement of the
foam, and the use of adhesives on the current materials. The difficulties of making and securing a mount, attaching it to the textile, as well as the potential consequences from possibly creating a new micro-climate made the first option unappealing. While total replacement of the foam was suggested, finding a foam replacement would not have been an easy task as it would need to be moulded to fit the contour of the shell. Additionally, we did not want to lose original materials. As the foam under-upholstery still maintains some flexibility when compressed, and has not degraded into a powdery dust, it was decided that it should be retained and a treatment that might enhance the longevity of the foam be considered. Whilst being aware that the textile would outlive the foam indefinitely, we aimed to create an option enabling future re-treatment and the possibility of removing degraded foam while retaining the show cover.

**MATERIAL TESTING**

Based on the gathered information, we conducted informal testing using several recommended adhesives and methods on foam and textile samples similar to those found in the *Globe Chair*. We experimented with two types of adhesives for the interface between the fabric and foam: a 2:1 mixture of Lascaux 360 HV & 494 HV, thermoplastic acrylic adhesives, in concentrations of 50%, 25%, and 10% diluted in de-ionized water and Beva 371 film, a thermoplastic elastomeric polymer mixture. Impranil DLV, a polyurethane dispersion, was tested as a consolidant for the foam. Our results provided us with the following information:

- Impranil DLV was a necessary step, otherwise the adhesives either stuck too well or not enough to the foam;
- The Lascaux bond was very weak between the textile and foam;
- Beva 371 film worked well in combination with the Impranil, but was difficult to remove from the textile.

After these findings, we spoke with our colleagues. Elizabeth-Anne Haldane, a V&A senior textile conservator, suggested that, in addition to coating the foam with Impranil, we should try conservation grade nylon net as a carrier for the Beva. The addition of the net would help reduce the residue of BEVA 371 film left on the textile when it needs to be removed in future. This combination proved to be the most successful test we conducted. Additionally, if at any time the textile became detached from the foam, we could re-adhere it with a hot spatula. While heat does accelerate the degradation of the foam, it was decided that this was an acceptable risk for the object.

Prior to treating the upholstery, Clementine Bollard, an intern from the Master for Conservation of Cultural Heritage, Paris 1 Pantheon-Sorbonne University, addressed conservation issues on the fibre-glass shell and the metal pedestal and took pre-treatment photographs. After she completed her treatment, we began working on the upholstery.

The shell is lined with five concave segments or wedges of pre-formed foam with a show covering of an orange, plain weave wool textile. This is stitched to a self piping on the inner rim of the shell with the underside of the textile adhered to the foam. The edges of the fabric covering the five segments overlap onto the underneath of the foam and were glued in place. To initiate the practical treatment, the textile was peeled back from the centre to the outer rim of the shell for each foam segment, exposing the foam and leaving the outer original stitched edge undisturbed. The manufacturer’s adhesive between the textile and foam had degraded, leaving the textile almost adhesive free and easy to separate from the foam.

We then examined the foam and the inside of the fibre-glass shell. The foam sections were easily removed from the inside of the shell. Based on visual and ultra-violet light examination, the foam appears to be merely held in place by compression of the foam segments; no adhesive residue was found. Dr. Brenda Keneghan, conservation scientist at the V&A, conducted Fourier Transform Infrared Spectroscopy (FTIR) on foam samples and on adhesive residue removed from the back of the show cover. Based on the resulting spectra, she identified the foam under-upholstery as a polyurethane (PUR) ether and the adhesive between the show cover and under-upholstery as a neoprene (rubber based) adhesive.
It was decided to apply the adhesives in-situ so that the stitched edge of the textile, around the inner rim of the chair, would not be disturbed. Using this method, we were able to re-insert the foam wedges and work on them one at a time within the shell. We covered the outside of the shell with Tyvek™ to protect it in the cradle during the treatment.

To begin the multi-step process, the foam was brush-coated with Impranil and allowed to dry. We noticed that the top of the foam became harder to the touch and contracted slightly from the addition of the Impranil, but this did not affect the compression fit of the foam wedges, nor was it evident once the show cover was placed on top. A template, based on the size of the foam wedges, was made to prepare a net and Beva™ film, which was first adhered together on a work surface with a heated spatula and barriers of Melinex™ film and then laid onto the foam. Darts had to be cut in the Beva™ net layer to enable it to lay flat on the concave surface of the foam. It was then adhered onto the surface of the foam with a heated spatula and barrier of Melinex™.

After this application, the textile was laid onto the Beva™ net and heated with the spatula, but due to poor adhesive penetration into the textile there was an insufficient bond to hold the textile in place. To increase the adhesive bond, an additional layer of Beva™ film was then applied to the top side of the net. The additional layer of adhesive successfully held the textile in place resulting in a clean, crisp profile on the interior of the shell. Since the completion of the chair’s treatment, it has been included in the Cold War Modern exhibition at the V&A as well as two other venues within Europe. During display and transport no conservation problems have arisen. This treatment has kept the original materials, restored the shell’s interior profile, and anticipates the eventuality of the foam’s degradation and replacement while retaining the original show cover textile. While the treatment method was used on the Globe Chair, it could easily be used on other foam upholstered furniture that may have similar condition issues.

ENDNOTES

1) Eero Aarnio site, Ball Chair by eero Aarnio 1966, http://www.eero-aarnio.com/8/Objects/Ball_Chair.htm as at October 2010.
ABSTRACT
This report describes the conservation of an UP7 also known as Il Piede, a monumental sculpture of a human foot from 1969 by Gaetano Pesce. Il Piede is supposed to be restored for an interior, however it should no longer be used as seating furniture but rather as an exhibit protected from mechanical load. The report starts by describing the fabrication technology of Il Piede, which should provide a better understanding of the object’s materials, their characteristics, aging behaviour and damages. Material analyses (FTIR, SEM) of the work have revealed that the body consists of polyurethane foam1 and the coating is an PUR-elastomer. Subsequently the elaborated conservation concept is introduced. An inappropriately affixed adhesive tape shall be removed. To prevent further loss of material of the original coating due to mechanical influence, the detached coating should be fixed to the foam. Moreover this measure should ensure the protection of the foam against any influence of light and humidity. The losses in the black elastomeric coating shall be closed with inlays in order to restore the original aesthetics of Il Piede. Partial areas of the coating will be reconstructed in order to close the loss. Through the molding of the surface structure and the preparation of models, the inlays are adapted to the original surface and remain recognized as such by the circulating joint. The consolidation of the coating and the inlays will be reconstructed in order to close the loss. Through the molding of the surface structure and the preparation of models, the inlays are adapted to the original surface and remain recognized as such by the circulating joint. The consolidation of the coating and the inlays furthermore protect the foam material against any impact of light and humidity. It should remain evident which parts of the coating are the originals and which ones are the reconstructed inlays. Regarding conservation ethics and the aesthetics of the here introduced Il Piede, the elaborated preservation and conservation measures led to a good result. The methodology of the reconstruction of an elastic inlay is applicable to objects with similar material qualities, however the selection of the material must be adjusted to each individual case. The approach for removing an adhesive tape is also transferable to other cases, depending on the underlying material and the adhesive tape.

KEYWORDS
Reconstruction, adhesive bond, PUR, casting, Gaetano Pesce

UP-SERIES
In 1969 the Italian architect and designer Gaetano Pesce (born 1939) created the Up series for B&B Italia. In the same year it was first presented at the 9th Salone Internazionale del Mobile in Milan. The Up series consists of seven differently sized seating objects made of polyurethane soft foam (information from the manufacturer). Pesce spent several years researching this new material. To Pesce, the individual character of each of his objects was very important. He therefore worked with materials that, to a certain degree, allowed for flaws and distortions even in serial production. The irregularities were used deliberately to emphasize the uniqueness of a product.3

The chairs of the Up series were compressed, vacuum-wrapped and sold in flat boxes. After unwrapping they inflated to their original shape and size. The Up7, also called Il Piede, is a larger than life-sized sculpture of a human foot, consisting of a soft foam body with a homogenous leather-like black surface (see Figure 1). It is used similar to a chaiselongue. B&B Italia started reproducing the Up series in 2000.

PROVENANCE
The age of Il Piede at hand is unknown. Judging from the poor condition it is possible that it was made in the first phase of production in the late sixties. The earliest known location is 2004 in Salzburg, Austria where it was sold into private ownership. After the purchase it was stored near Hannover, Germany for two months and resold again in December into private ownership. The current owner stored Il Piede in Frankfurt, Germany until it was taken to the conservation studio of the Technische Universität München, Germany in October 2008 for examination and treatment. The cracks and losses in the black coating already existed when the object was bought in Salzburg in 2004. The brown tape, used to cover large cracks and losses, had also been applied beforehand.

Characterization
Artist: Gaetano Pesce, New York City, USA; Design: 1969; Identification: Il Piede or UP7; Type: design object; Producer: B&B Italia (Formerly B&V Italia), Novedrate, Italy; Date: unknown; Provenance: private ownership, Frankfurt, Germany; Material: The foam body is an ether-based polyurethane foam that contains aromatic Di-Isocyanate.4 The coating consists of a black coloured polyurethane-elastomer5

Technique: cold cure foam molding, spray coat method6

Colour: black, shiny; Weight: 20 kg7

Measurements: height: 83 cm, width: 67 cm, length: 162 cm8

LICENSE
015 PEDICURES FOR PESCE’S ‘IL PIEDE’
BY REGINA FRÖHLICH
The inner structure was made by using a cold foam process of polyurethane soft foam. Concerning the soft foam, it was more economic to mold the complex shape out of soft foam than to sculpt the object from a block. The liquid raw materials were mixed in a predetermined quantity of polyalcohol (polyol) and polyisocyanate (TDI) and polyurethane foam resulted in its final shape could be demolded.9 The Vitra Design Museum, Weil am Rhein, owns an edition of Il Piede (2002) it is most likely that due to the compacting of the PUR foam in a controlled way. These cavities were closed by the fine “skin” referred to earlier. This has been the weakest link: due to the thin-walled nature of the cell-like structure of the foam, these walls have broken down with time and use (repeated compression) and the coating has separated from the foam core. The black coating has peeled off from the foam body whereas the broken cell walls have remained attached to the reverse of the coating. In some areas fragments of the coating have remained on the foam as well. The analysis and observations indicated that a polyurethane elastomer had been used for the black coating. Other synthetic materials would have shown other properties. The previous owner has used brown, glossy mailing tape - natural rubber on a 5 cm broad PVC film- to close cracks and to secure loose parts of the coating on Il Piede.

Different parameters such as temperature and light has led to rigidification and decay of the tape. By now the adhesive has hardened and the bearing film has turned brittle. The tape has split apart, so that the transparent bearing film has peeled cleanly off towards the edges, leaving the adhesive as brown residue on the black elastic surface. The adhesive and the coating of Il Piede have interacted with each other, causing the surface of the coating to become increasingly dull. In areas where the tape has remained intact, the coating kept its original shine. When first produced, the polyurethane body of Il Piede had been entirely coated with the black elastomer. Where the foam has been directly exposed to the atmosphere, in areas where the coating has failed upon ageing, it has turned from light-grey to yellow. Due to failing mechanical properties, the foam has been sensitive to pressure since the elastic cells have become brittle. In some places this has resulted in irreversible dents. The material that had been used for closing the channels in the foam has been partially lost, whereby causing losses in the black coating as well.

CONDITION AND DAMAGES
Il Piede has a thin, homogeneous, viscoplastic, solid-coloured black layer without a visible cellular structure. The surface of the coating has shown typical signs of thermal and light related decay of elastomers: fine hairline cracks on the surface and also deep cracks protruding into the foam core of the foot. The seating area especially has endured the most damage: here the coating displays large scale’s lifts. The black coating has failed upon ageing, it has turned from light-grey to yellow.

The previous owner has used brown, glossy mailing tape - natural rubber on a 5 cm broad PVC film- to close cracks and to secure loose parts of the coating on Il Piede. Il Piede has a thin, homogeneous, viscoplastic, solid-coloured black layer without a visible cellular structure. The surface of the coating has shown typical signs of thermal and light related decay of elastomers: fine hairline cracks on the surface and also deep cracks protruding into the foam core of the foot. The seating area especially has endured the most damage: here the coating displays large scale’s lifts. The black coating has failed upon ageing, it has turned from light-grey to yellow. Due to failing mechanical properties, the foam has been sensitive to pressure since the elastic cells have become brittle. In some places this has resulted in irreversible dents. The material that had been used for closing the channels in the foam has been partially lost, whereby causing losses in the black coating as well.

CONDITION AND DAMAGES
Il Piede has a thin, homogeneous, viscoplastic, solid-coloured black layer without a visible cellular structure. The surface of the coating has shown typical signs of thermal and light related decay of elastomers: fine hairline cracks on the surface and also deep cracks protruding into the foam core of the foot. The seating area especially has endured the most damage: here the coating displays large scale’s lifts. The black coating has failed upon ageing, it has turned from light-grey to yellow. Due to failing mechanical properties, the foam has been sensitive to pressure since the elastic cells have become brittle. In some places this has resulted in irreversible dents. The material that had been used for closing the channels in the foam has been partially lost, whereby causing losses in the black coating as well.

The previous owner has used brown, glossy mailing tape - natural rubber on a 5 cm broad PVC film- to close cracks and to secure loose parts of the coating on Il Piede. Il Piede has a thin, homogeneous, viscoplastic, solid-coloured black layer without a visible cellular structure. The surface of the coating has shown typical signs of thermal and light related decay of elastomers: fine hairline cracks on the surface and also deep cracks protruding into the foam core of the foot. The seating area especially has endured the most damage: here the coating displays large scale’s lifts. The black coating has failed upon ageing, it has turned from light-grey to yellow. Due to failing mechanical properties, the foam has been sensitive to pressure since the elastic cells have become brittle. In some places this has resulted in irreversible dents. The material that had been used for closing the channels in the foam has been partially lost, whereby causing losses in the black coating as well.

Figure 1
Il Piede side views, before conservation

Figure 2
Bottom side of the Il Piede, showing cavities

Figure 3
Bottom side of the Il Piede, showing cavities

CONDITION AND DAMAGES
Il Piede has a thin, homogeneous, viscoplastic, solid-coloured black layer without a visible cellular structure. The surface of the coating has shown typical signs of thermal and light related decay of elastomers: fine hairline cracks on the surface and also deep cracks protruding into the foam core of the foot. The seating area especially has endured the most damage: here the coating displays large scale’s lifts. The black coating has failed upon ageing, it has turned from light-grey to yellow. Due to failing mechanical properties, the foam has been sensitive to pressure since the elastic cells have become brittle. In some places this has resulted in irreversible dents. The material that had been used for closing the channels in the foam has been partially lost, whereby causing losses in the black coating as well.

Figure 1
Il Piede side views, before conservation

Figure 2
Bottom side of the Il Piede, showing cavities

Figure 3
Bottom side of the Il Piede, showing cavities

CONDITION AND DAMAGES
Il Piede has a thin, homogeneous, viscoplastic, solid-coloured black layer without a visible cellular structure. The surface of the coating has shown typical signs of thermal and light related decay of elastomers: fine hairline cracks on the surface and also deep cracks protruding into the foam core of the foot. The seating area especially has endured the most damage: here the coating displays large scale’s lifts. The black coating has failed upon ageing, it has turned from light-grey to yellow. Due to failing mechanical properties, the foam has been sensitive to pressure since the elastic cells have become brittle. In some places this has resulted in irreversible dents. The material that had been used for closing the channels in the foam has been partially lost, whereby causing losses in the black coating as well.
CONSERVATION
Il Piede will no longer be used as seating furniture. Instead it should serve as an exhibit object and not suffer any mechanical stress. This is why Il Piede was first mounted on a 6 mm thick Alucobond®-composite board produced by Alcan Composites®. This enabled a contact-less transport and simultaneously reduced mechanical stress and torsion to a minimum. The board, consisting of two aluminium sheets (Peralum 100 - 100) and a black polyethylene-core (type LDPE), is suitable for several requirements: Due to its black colour and thin material strength it is barely visible. The hard, scratch-proof board shows good torsion rigidity. The anodized aluminium is durable, stable towards humidity and does not react chemically or physically with the materials used on Il Piede. It was cut according to the footprint of Il Piede with a jigsaw. Il Piede was placed on the board without fixation. It can be moved by means of the board without having to touch its sensitive surface.

REMOVAL OF THE BROWN ADHESIVE TAPE
When detaching the adhesive tape from the coating, the bearing film could only be separated leaving the adhesive stack to the black coating. The hardened adhesive was removed in a second step by soaking it with a solvent, without dissolving it. Afterwards it was scrapped mechanically. Since the coating, consisting of polyurethane elastomer, was considered resistant to petrol spirits, samples of the tape were first soaked with the following aliphatic hydrocarbons: isooctane, petrol spirit boiling range 100-140 °C and Shellol T. Excessive solvent was sniffed with filter paper. The reaction of solvent, bearing film and adhesive could be observed by stereo microscope on mock-ups. As desired neither bearing film nor adhesive dissolved in the solvent. The natural rubber adhesive merely softened and soaked. Shellol T showed the best properties in terms of swelling and evaporation. The aged tape could only be peeled off from Il Piede in small pieces. The soaked adhesive could be removed with a woodchip plug of polyester urethane foam. Areas where the foam lay open were covered with polyethylene film to keep the solvent from moistening the cellular structure and causing further chemically induced reactions (see Figure 3).

REBUILDING THE LOSSES IN THE SOFT FOAM
The texture of the losses in the aged soft foam proved sufficiently stable so that a conservation treatment of the closing of the imperfection with inlays was not necessary. The losses in the soft foam body were closed with a custom-fit plug of polyester polyurethane slab foam at the suitable level. New polyester polyurethane slab foam was used for the fillings because the parameters of the new material seemed to offer the same properties as the foam body, such as cell structure and thickness. Its applicability for fillings was proved. The negative profile of the losses was cast using kneadable silicone, with polyethylene film as interlayer between foam and silicone. The slab foam was trimmed with scissors and scalpel. Because of its elasticity and its strong structure it was impossible to make exact cuts. To avoid the difficulties the pieces of soft foam were soaked with pure water and then frozen. The soft foam solidified because of the frozen water in the cells and could be cut and shaped properly.

After complete dehydration the shaped soft foam was placed in the cavity without any adhesive due to the fact that the cell walls of both foams got stuck. The plugs constitute the base for the reconstruction of the black coating.

TESTING MATERIALS FOR ADHESION
To find an ideal adhesive to reattach the black coating to the soft foam, several materials (dispersions of synthetic resins) were tested by applying the adhesive to the foam in dots. All tested materials must fulfill the following conditions:

- The original soft foam and coating are connected by adhesion, a durable and chemically inert adhesive should be applied sparingly without pressure, the physical parameters of the adhesive such as hardness and flexibility match those of the original materials. The coating should be reattached without pressure, the adhesive should not fill the cellular structure and should therefore not cause a partial solidification of the foam.
- The adhesive should not attract dust.
- The bond made with Lascaux 360 HV (aqueous emulsion of an acrylic copolymer) and PUR-dispersion PU 52 (aqueous emulsion of PUR) showed very good properties. As desired, the laminate of soft foam, adhesive and coating the adhesive failure took place between soft foam and joint after exposing it to stress and strain. In contrast to the Lascaux 360 HV, the PUR-dispersion PU 52 did not remain sticky after setting and therefore did not attract dust.

For consolidating the black coating the PUR-dispersion PU 52 seemed to be the best adhesive, as its parameters matched the parameters of the soft foam and the elastomer coating. The losses of the black coating and the adhesive on the soft foam lay open were covered with polyethylene film to keep the solvent from moistening the cellular structure and causing further chemically induced reactions (see Figure 3).

Table 1

<table>
<thead>
<tr>
<th>Tests for connecting PUR-soft foam and PUR-elastomer</th>
<th>adhesive</th>
<th>No additives</th>
<th>Klucel H (4% solution in water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MonBr. DMC 2 (2% solution in water)</td>
<td>Elasticity of the bond</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Fracture behaviour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyurethane dispersion</td>
<td>Elasticity of the bond</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Fracture behaviour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyurethane dispersion</td>
<td>Influence of shearing forces</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Fracture behaviour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lascaux 360 HV (4% solution in water)</td>
<td>Fracture behaviour</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Fracture behaviour</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tests for connecting PUR-soft foam and PUR-elastomer

- Judgment of the Elasticity of the bond:
  - ++ high elasticity
  - ++ medium elasticity
  - ++ low elasticity
  - ++ insufficient elasticity

- Judgment of the behaviour under the influence of shearing forces:
  - ++ high resistance
  - ++ medium resistance
  - ++ low resistance
  - ++ insufficient resistance

- Judgment of the fracture behaviour:
  - ++ Very low adhesiveness between foam and adhesive
  - ++ Adherence between foam and adhesive
  - ++ Adherence between foam and adhesive

RECONSTRUCTION OF THE BLACK ELASTIC COATING
To replace the missing parts of the coating, an elastic aromatic poly-ether polyurethane, Brush-On by KauPo18, was chosen. The physical and chemical parameters of this material matched those of the original coating. The colour could be modified as necessary. For the inlays the original surface structure of Il Piede was traced and transferred onto the new material. Therefore the inlays could be adjusted to the structure of the surrounding original coating. The new material enhanced the overall impression of Il Piede.

Il Piede was placed in water and then frozen. The soft foam solidified because of the cooled water in the cells and could be cut and shaped properly.

Il Piede was placed in water and then frozen. The soft foam solidified because of the cooled water in the cells and could be cut and shaped properly.

Il Piede was placed in water and then frozen. The soft foam solidified because of the cooled water in the cells and could be cut and shaped properly.
The first step when making an inlay was to record the surface structure with tin foil. The tin foil worked well for tracing the original coating. The tin foil did not interact with the elastomer coating and could be removed without any residue. The surface structure was cast by gently rubbing the foil onto the surface with a soft tool, like a colour shaper or finger. To stabilize the recorded structure with PUR-dispersion PU 52. This turned out to be appropriate, as the characteristics of the adhesive (elasticity and shore hardness) matched both the nature of the soft foam as well as the original and new elastomer coating. The PUR-dispersion penetrated into fissures and formed fibers that bridged cracks. The adhesive did not fill up the pore volume of the foam, preserving the elasticity of the foam body. By tinting the inlay material with opaque and UV-stable Spinel-black, the colour matching and the degree of gloss turned out to be satisfactory. Adjusting the required thickness of the demolded inlays was time-consuming. It could be improved by casting the differing depth of each loss and filling the cast up to that level. With regard to the appearance and conservation, the restorations of Il Piede led to a positive result (see Figure 5). The method of reconstructing an elastic inlay is transferable for similar damages, whereas the materials have to be adapted to every object. Considering sensibilities of the object and the type of tape, the method developed to remove package tape by swelling the adhesive is also transferable to other scenarios, again depending on the materials at hand. Further research could deal with the aging of the new materials compared to the originals. For that reason the test strips were saved to be able to monitor their aging. In a study the new materials could be artificially aged. To follow up the closing of the loss of coating, the cast could be made out of different types of plastic materials such as clay or silicone.

**ENDNOTES**

(1) For the Up-series reproduced by B&B Italia in 2000 Bayflex® from Bayer was used as cellular plastic (www.bayer-materials.com/c德国/internet/global_classification.php). This was visualised by SEM by Luise Lutz.

(2) Formerly B&B Italia, Noordwijk, Italy.


(4) The interpretation of the pictures from the scanning electron microscope (SEM) indicated polyether-polyurethane foam.

(5) Samples were taken and analysed by FTIR by Doerner Institute, Munich.


(7) Measured by the author.

(8) Measured by the author.


(10) Rockfeld 2002.

(11) The polyurethane was produced by the polyaddition reaction of the educts. The isocyanate functional group (-N=CO-) of one molecule reacted with the hydroxyl functional group (-OH) of another molecule to the urethane group (N-H=CO-O-) (Elledge 2007).

There are no by-products in this reaction. To create a cellular structure water is added. The isocyanate reacts with water: carbon dioxide gas (CO2) is released and foams the mixture (www.swiss-verband.de/swasapur5.6ml, as at 23.06.2009)

(12) The colonists were not analysed yet.

(13) Patents registered in the 1960s-70s explain the technological possibilities and their results, that conform to those of Il Piede.

(14) Proceed by consistency to solvent.

(15) ALCAN COMPOSITES, Thyssen Knupp Schulte, Regensburg.

(16) Certain renowned conservation adhesives were chosen for reasons of their specific properties, as mentioned, and chosen from literature as well as the PUR-dispersion form the description of a conservation project (Juling 2001).

(17) This was visualised by SEM by Luise Lutz.


(19) Yellowing appearing in a relatively short amount of time is characteristic of the degradation of all polyurethanes (Waentig 2004, p. 304).

(20) Prefabricated liquid dyes contain a high concentration of pigment, a binder that matches the elastomer and additives. It is not reviewed what effect additives have on the PUR and the pigments.

**ACKNOWLEDGMENTS**

This paper was developed at the Chair of Conservation, Arts Technology and Conservation Science, Technical University Munich, Germany under the direction of Professor Erwin Emmerling. Special thanks go to Mr. Emmerling who provided the opportunity to use the chair’s premises. Thanks also go to the kind and dedicated mentoring by the Chair of Conservation, especially Simone Miller and Luise Lutz.
ABSTRACT
The interpretation of design objects at the Museum of Modern Art, New York (MoMA) has continued to change since the inception of the Design Department in 1932. The museum’s early history begins by exhibiting lamps as functional objects, illuminated, revealing cords and occasionally plugs. More recently, the museum has exhibited lamps with cords and plugs removed. Thus viewed as static sculptures, lighted objects were routinely displayed unplugged or switched off, highlighting the object’s material, manufacture and form but negating its function. Today, the museum has seen a renaissance by curators in the desire to exhibit design objects as they were intended to function — initiating the concept of electrified design objects to once again include essential components such as cords, switches, plugs and bulbs. This paper traces the history of lighted design objects from the Architecture and Design collection at MoMA and presents case studies, illustrating examples of material, the importance of historic components, and examining the consequences of function, which raises questions of the “useful” life of the object.

Many of the lamps in MoMA’s collection have been displayed both lit and unlit. Historic images give us clues as to how these objects were viewed and how their function was important to the display. During certain periods cords and plugs were routinely cut and discarded, highlighting the shift in curatorial presentation, as these elements were not considered part of the object. Additionally, lamp design in MoMA’s collection contains a percentage of elements that are at risk of degradation. Exhibition duration for the museum is considerably longer than that of general use. For example, gallery hours for a 3-month exhibition add up to 672 hours when the object is “on.” During the exhibition, energy from the bulbs can cause plastics, paper and textiles to deform and discolor, resulting in irreparable damage. As a possible solution to retard some of the degradation of materials and to address recent bans on incandescent bulbs, museum design collections are now faced with the issues of stockpiling bulbs or replacing/retro-fitting lamps with LED (Light Emitting Diodes) and Compact Fluorescents. The European Union and the United States have instituted bans on incandescent bulbs, which raise questions of the “useful” life of the object. This paper aims to outline some of the major areas of concern with conservation, historical and curatorial design of display and illumination as well as addressing the practical and technical difficulties caused by obsolescence of components — namely changes as government requires more efficient uses of energy, particularly with the step by step ban of the incandescent bulb.

INTRODUCTION
The curatorial interpretation of design objects at the Museum of Modern Art (MoMA) has seen another shift by curators who now, once again, desire to exhibit functioning design objects — reinvigorating the concept of electrified design objects by including essential components such as cords, switches, plugs and bulbs. This paper traces the history of the display of lighted design objects from the Architecture and Design collection at MoMA and presents case studies, illustrating examples of material, discussing the importance of historic components, and examining the potential harmful effects of heat and light from the bulb, which raise questions of the “useful” life of the object.

HISTORY OF LIGHTED DESIGN AT MOMA
The investigation of MoMA’s lamp history was prompted by preparations for an exhibit by the museum’s Architecture and Design Department. This installation “What Was Good Design? MoMA Message 1944-56” presents the museum’s role as a design transgressor with a selection of more than 100 objects, from the “Good Design” competitions promoted by the museum from 1950-1955. The “Good Design” shows were a series of juried exhibitions organized by Edgar Kaufmann, Jr. and were the result of a partnership between the Museum of Modern Art and the Chicago Merchandise Mart, a wholesale merchandising center. The exhibitions were intended to influence wholesale buyers who determined what furnishings would appear in stores throughout the country, and, in turn, convince manufacturers of the potentially large market for well designed objects (Staniszewski 1998: 167). The “Good Design” exhibits were held bi-annually in conjunction with the Chicago Merchandise Mart; MoMA selected the best items from the summer exhibition
Johnson said, “I think the installation far outweighed the objects. You couldn’t not notice it; obviously the installation was most powerful.” (Staniszewski 1998: 158)

“Machine Art” elevated the status of design and began to blur the boundaries between art and design. Most importantly, during Arthur Drexler’s tenure (curator and director of the Department of Architecture and Design from 1951 through 1985) many of the cords and plugs were hidden and sometimes lamps were even shown unlit with the cord removed. Beginning in the 1970s cords and plugs were routinely cut and discarded, dramatically highlighting the shift in curatorial presentation, as these functional elements were not considered part of the object.

In 1999 the museum received a grant from the Mellon Foundation to catalog digital images of the design collection for the collection’s database system. Objects were chosen by the curatorial staff and scheduled to be photographed digitally. This project resulted in the official “publication” photos for collection objects (when an object is requested for publications, this is the image the museum provides) and also produced a publication for the Architecture & Design Department of some of its best objects: edited by Paola Antonelli, Senior Curator, it is titled “Object of Design.” It was during this period that it was discovered many of the lamp cords had been cut and discarded. The conservator’s role in this project was to clean and/or restore the items prior to photography as well as to place or repair lost cords and plugs so the lamps in the collection could be photographed as lit functional objects. However, the curatorial staff did not want the “unsightly” cords to be a part of the image. Therefore during the photography careful art direction was implemented to hide the cords and illuminate the lamps.

CASE STUDIES

Returning to Wagenfeld’s “Table Lamp” which was installed for the exhibition “Bauhaus 1919–1933: Workshops for Modernity” provides a good example of how an object has been altered during its history in the collection. Looking closely at the curatorially approved publication photo for the Wagenfeld lamp (see Figure 3), the lamp appears to be lit. On closer inspection there is a shadow and opened a modified version of “Good Design” in the winter of the same year (Staniszewski 1998: 173).

To initiate treatment research was necessary to locate missing components. Documentation of museum installations gave conservators an understanding of how lamps have been exhibited historically. One of the earliest instances is a 1933 photograph of the Wilhelm Wagenfeld, Table Lamp, 1923-24 as exhibited at the museum, displayed in a “home-like” setting (see Figure 1). Small domestic vignettes were set up in the museum galleries in the 1950s for the “Good Design” competitions. Mr. Kaufman and his colleagues displayed these newly designed objects as a way to illustrate or demonstrate to the viewers how these objects would look in their own homes, emphasizing the importance that “Function combined with good taste results in Good Design.” (see Figure 2). The installation methods and practices that were instituted during the five years of the “Good Design” exhibitions, both in the department store and in the museum, emphasized the displays as environments that promoted interaction between the objects and the viewers. Such similarities in display practices and the blurring of institutional boundaries were fore-grounded in the “Good Design” exhibitions, most notably with the function of electrified objects such as lamps (Staniszewski 1998: 176).

A conceptual shift took place in the 1960s in exhibition design when design objects began to be displayed as “sculptures” removed from the simulation of a home interior. This practice of placing the lamps on pedestals and removing them from a useful or “domestic” environment can be recorded in photographs of exhibitions from the 1960s and continued in the 80s and 90s. The museum’s practice of object decontextualization can be traced to the 1934 exhibition “Machine Art” organized by Philip Johnson, the Chairman of the Department of Architecture at that time. Johnson installed machine made objects ranging from spring coils, working tools and laboratory appliances, displaying them on white pedestals and platforms, with a focus and drama that at the time was only reserved for sculpture (Antonelli 2003: 11). Philip Johnson was very pleased with his installation as were the critics of the time. When asked about his installation...
cast on the dome and the cord and plug are not visible. It is unclear why this object was photographed in this manner but presumably there was no cord or plug and since it could not be lit the Imaging Services Department felt this was a successful alternative. Interestingly, the same aesthetic can be found in design store catalogs where an object is shown but all evidence of the plug and cord is removed.5 For the conservation treatment of the Wagenfeld lamp, Reinhard Bek, Research Fellow in Sculpture Conservation, researched appropriate cords and plugs for the lamp. Justus A. Binroth, a former student at the Cranbrook Academy of Art, recommended the electrical changes have not been recorded. To track the electrical component record developed by sculpture conservator John Campbell allows the museum to list in detail what materials such as metal and glass, on which heat and light will have little effect. The remaining 46 contain materials that can change with exposure to heat and light, such as plastic, paper and fabric.

Exhibition duration required by museums is considerably longer than that of general use, especially for lamps. For example, MoMA’s gallery hours are 8 hours a day, 7 days a week (a typical 3 month exhibition would add up to 672 hours). But some exhibition cases and galleries are lit for more than the 8 hours a day, 7 days a week, thus making the light exposure considerably longer. Prolonged exposure to light and heat reduce longevity in polymeric materials (Shashoua 2008). With heat, plastics can become flexible and distort, while light can cause dyes and colorants to fade.

By nature then, lamps contain a quality of built-in self-destruction, as a normally functioning lamp is indistinguishable from “aging” tests. Accelerated light aging combined with thermal aging has been used to test suitability of materials in collections (Peller 1994). The basic premise of these tests assumes that the exaggerated conditions mimic natural degradation processes at an accelerated rate. A three-month exhibition of a lamp coincidentally simulates one of these “aging” experiments where the normal use of the lamp contributes to the degradation of materials. Extensive tests on woods, paper and pigments have been performed. Unfortunately the research is difficult to translate into practical application for lamp design. The effects of exhibitions are difficult to predict, as many lamps in the collection contain composite materials.

The museum has seen direct consequences of heat and light from bulbs, shortening the life of lamps in the collection. One example of this can be demonstrated by On and Off Table Lamp, designed by Alberto Meda in 1983.6 Heat from the bulb caused the material to deform and darken, rendering the object unexhibitable. It is unclear if a lower wattage bulb could have prevented this damage. The connection between damage to materials and use hours can be better documented by logging the hours an object is “on,” similar to tracking exhibition light hours for photography or textiles, and by documenting the appearance and structure of the work as well.

RECORD KEEPING

Using the key words “light bulb” to search the museum’s database, five objects in the collection matched. Surprisingly, three of the matched objects were sculptures where light bulbs are a component of the artwork while the fourth was a lamp and the fifth a graphic poster which had an image of a light bulb. One of the matched objects was Robert Rauschenberg’s First Landing Jump from the Painting and Sculpture Collection. The artwork’s listed materials are cloth, metal, leather, electric fixture, cable, and oil paint on composition board, with automobile tire and wood planks. The cord and plug are intricately described in the records, including a sentence that explicitly states that the electric cord and bulbs are part of the art. The blue bulb is specific to the work and the matched objects were sculptures where light bulbs are a component of the artwork while the fourth was a lamp and the fifth a graphic poster which had an image of a light bulb.

FUTURE OF LIGHT BULBS

The design collection contains a number of lamps where the bulb is central to the design. Historic examples in the collection include the 1930 Tube Lamp by Eileen Gray and the 1920 Hanging Lamp by Gerrit Rietveld. Both of these examples emphasize the sleek linearity of the design. The 1930s and 1940s were a time of innovation in lamp design, with many designers experimenting with new materials and technologies. Today, however, the use of light bulbs in lamps is becoming less common as LED lighting becomes more prevalent. LED lighting is more energy efficient and has a longer lifespan than traditional bulbs, making it an attractive option for designers and consumers alike.
Museums will be forced to make important decisions for the future, possible solutions are tracking light hours and stockpiling these components. Lighting design can take clues from painting and sculpture as in the case of the installations of the American artist Dan Flavin, whose artwork is constructed from commercially available fluorescent tubes and ballasts. After research and discussions with the Flavin estate museums have begun stockpiling specialized bulbs. However, there is no research regarding the proper storage for these stockpiles to ensure their function in the future.

**ACKNOWLEDGEMENTS**
Juliet Kinchin, John Campbell, Pamela Popeson, MoMA Conservation Laboratory Staff

**ENDNOTES**
(4) Film on Good Design. Museum of Modern Art Archives.
(9) Illumination study was conducted using a medium format camera with a Phase One™ digital back. The photographs were lit with daylight balanced Lowel®Scandel lights and white balanced using a GretagMacbeth™ color card. Each lamp was photographed with the same aperture and shutter speed for each of the four bulbs tested. (halogen, compact fluorescent, LED and incandescent).
ABSTRACT
The ti3 series of chairs designed by Marcel Breuer in 1923 was painted using a two-colour system. One colour was used for the frame, the other for the seat and back. When the chair arrived at the University of Applied Sciences Cologne it was painted completely in white. A detailed examination of the paint layers showed that the frame was originally painted grey and the seat and back were painted white.1

The conservation concept for the chair envisioned the removal of the overpaint. While the removal showed good results on the frame, the detachment on the seat and the back did not work out well. An optical comparison of the overpaint on the frame and the back showed great similarities between the layers. As there was no additional layer underneath, the idea of a renewed back and seat came up. Thus these two plywood boards were removed and underneath traces of a second and therefore previous nailing were discovered on the frame. Considering the non-originality of the back and the seat, the conservation concept had to be re-evaluated.

KEYWORDS
Bauhaus, Marcel Breuer, exposure of original paint, linseed oil based paint, alkyd resin paint, FTIR spectroscopy

INTRODUCTION
Marcel Breuer designed the chair ti3d together with the children’s chairs ti3a and ti3b as a student at the Bauhaus Weimar in 1923. All chairs of the ti3 series were painted in a combination of two of the three colours: grey, red and white. One colour was used for the wooden frame, the other for the seat and back, which are made of plywood. For the chair discussed in this paper, grey paint was used for the frame and white paint for the seat and the back. Research showed that Lou and Hinnerk Scheper — both students at the Bauhaus Weimar at that time, too — bought the chair in the 1920s. The ti3d stayed in the family until they donated it to the Bauhaus Archiv / Museum of Design Berlin. Upon arrival to the collection the chair was painted completely white which means that the Schepers themselves or their relatives must have repainted it.

In 2001 the ti3d came to the University of Applied Sciences Cologne. Since then several students have examined the object and worked on it.

CONSERVATION CONCEPT
After long discussions, the owner, the tutors and the student presently working on the object decided to remove the overpaint in order to make Breuer’s idea of a two colour system visible again. Breuer’s intention was to emphasize and distinguish the functional parts of a piece of furniture through the use of different colours. In the case of the ti3d he painted the frame, which builds the construction and gives the chair its stability, in a colour different from the one used for the seat and the back, which define its intended use. In order to expose the original paint layer, which consists of linseed oil based paint, a solvent based paste was developed to remove the alkyd resin layers added later. The paste contained China Clay as a binding medium and ethanol and xylene in a ratio of 2:1 as solvents. The solvent paste was tested on the frame of the ti3d and good results were acheived in exposing the original grey paint layer.

OBJECTS OF COMPARISON
As the resulting grey paint layer showed quite a bad condition with large patches of colour completely missing, doubts about the chosen concept arose.

In order to discuss this question, we looked for other specimens of the ti3 series and their conservation treatment. Research which was carried out by the author of this paper, showed that there are very few chairs still existing. Some specimens of the children’s chairs ti3a and ti3b could be found. The two
examples which could be examined more closely still showed their original coat of paint. In contrast to that a t/l/d chair in the Bauhaus Dessau Foundation was also repainted while it was privately owned. Furthermore, the back and the seat of the chair were covered with black linoleum. As a means of conservation treatment in the Bauhaus Dessau Foundation, all later additions were removed. The original paint on the frame was still in good condition so that only those parts in which the wooden frame was visible were retouched. In contrast to that, the paint on the back and the seat was nearly completely lost such that the boards were visible were retouched. In contrast to that, the paint on the back and the seat was nearly completely lost such that the boards were visible were retouched. In contrast to that, the paint on the back and the seat was nearly completely lost such that the boards were visible were retouched. In contrast to that, the paint on the back and the seat was nearly completely lost such that the boards were visible were retouched. In contrast to that, the paint on the back and the seat was nearly completely lost such that the boards were visible were retouched.

Figure 1
T1/d repainted all-white

Figure 2
Condition of the original paint layer on the frame after the exposure

Figure 3
Traces of a former fixation (see colour plates, p. 170)

Even though research was broadened to wooden furniture from the Bauhaus era in general, only few examples of conservation treatment could be found. Some treatments consisted of repainting the objects in an attempt at imitating the original colouring while from another object all remains of the original paint had been removed completely before repainting. A common trait in all studied conservation concepts for objects from the Bauhaus era was the intention to present the objects in their original colouring again and to represent their original appearance as accurately as possible. But most of them differed from the concept developed at the University of Applied Sciences Cologne in that they did not consider exposing the original paint with its damages and traces of use. The most common goal was to present the furniture the way it probably looked when it was new, thus either sacrificing part of the original substance or covering it up.

DISCOVERIES DURING THE EXPOSURE

While the exposure of the grey paint layer on the frame of the t/l/d with the solvent based paste described above showed good results, the same treatment did not work well on the plywood boards of the seat and the back. The paint layer, which had been identified as the original surface by way of examinations with embeddings and FTIR spectroscopy, could not be exposed. A parallel step by step removal of the white paint layers on the frame and the back showed a great similarity in their characteristics. As there were no more layers underneath, there was justifiable doubt about the validity of the results based on embeddings and FTIR spectroscopy. Even though x-ray pictures did not show traces of previous mounts, the idea of seat and back being renewed arose. Because of that, the two plywood boards were removed and underneath traces of a second set of nail holes were discovered.

With the high probability of seat and back renewal in mind, additional samples from the white paint layers on the plywood boards and on the frame were examined with FTIR spectroscopy. The results show that the first white paint layer on both the frame and the boards is based upon linseed oil while the later ones are based on alkyd resin. This probably means that two new untreated plywood boards had been added before the whole chair was painted with white linseed oil colour for the first renovation.

RE-EVALUATION OF THE CONSERVATION CONCEPT

Due to the fact that new plywood boards were added, the original paint chosen by Marcel Breuer could not be exposed on the back and the seat. Therefore the conservation concept based upon the idea of merely making visible the original paint, had to be re-evaluated. Keeping in mind the target of showing Breuer’s original design, the new concept envisioned the exposure of the first paint layer applied to the seat and the back. Thus the first goal of presenting the two-colour paint scheme of the chair could be maintained. Furthermore, the first white paint layer on the replaced boards is based upon linseed oil like the original grey colour on the frame, so it can be assumed that the characteristics and the optical appearance are quite similar to the colour chosen by Marcel Breuer. A final reason for the new extended concept was that the first white paint layer to be found on the boards of the seat and the back was applied to the chair close to the time the frame was painted grey.

CONCLUSION

The experience and discoveries made during the restoration practice on the t/l/d show how important detailed examinations and observations are. Even though scientific methods like x-ray and FTIR spectroscopy were used, only a deeper look into the object by opening up concealed parts could reveal the truth about its history.

Furthermore, research revealed that the question of how to treat objects from the Bauhaus era has neither been discussed thoroughly nor have standards for their restoration been developed yet. Due to the lack of comparable conservation examples, it has been difficult to come to decisions and to evaluate them. However, exposing the original coat of paint of the t/l/d – even though it is in a bad condition – could serve as an example for conservation treatments of furniture from this period of time. It could be a feasible alternative to the practice of creating a flawless surface by repainting the object completely anew to reach an impression as close as possible to the original appearance. Restoring an object to its appearance close to the time of its production, by keeping as much of the original substance as possible, offers the chance to present the object as part of a historical process bearing traces of use.

ENDNOTES

(1) The complete documentation of the object is to be found at the University of Applied Sciences Cologne and at the Bauhaus Archiv / Museum of Design Berlin.
Isa Genzken is a German contemporary sculptor (born 1948). In preparation for an extensive retrospective of the artist at Museum Ludwig, curators and conservators were confronted with the fragile and complex art work of Isa Genzken, especially in her installation *Kinder filmen* ("Children filming") 2005, which has belonged to the museum’s collection since right after its creation in 2006.

*Kinder filmen* was created with toys, puppets, furniture, design objects and home decoration accessories. The choice of materials and objects, and their application in the installation, are very important to the artist and the intention of her artwork. The artist chose these individual elements spontaneously as she found them, regardless of their age, material, technical suitability, general quality and condition, manufacturing or application, and brought them together to create her installation. This artistic independence is crucial for the artist; it defines her artistic practice and therefore was crucial for the curators and conservators at Museum Ludwig.

From the very beginning, and continuing to the present day, the installation needs conservation care and treatment: foam inside a toy crumbles, a light chain and other technical equipment fail, and plastic elements degrade and result in losses.

This article introduces briefly the range of objects in the collection of Museum Ludwig and the variety of the artwork created by Isa Genzken in general. Then the article reports examples from the processes, changes and challenges within the installation *Kinder filmen* from its creation and first performance in an art gallery in Cologne to its way into the museum’s gallery. This includes finding presentation options and conservation approaches in order to follow a mutually acceptable way for the artist, the curator and the conservator to preserve and present this installation in the long-term.

In the end the article raises several general questions regarding the procedure when acquiring new art and whether the conservator can be the assistant of the artist.

---

**KEYWORDS**

Isa Genzken; contemporary art; installation; documentation

---

**INTRODUCTION**

Museum Ludwig is a museum of modern and contemporary art in Cologne, Germany, that was founded on the collection of Mr. and Mrs. Ludwig. The main focus of their collection is on paintings of the Russian avant-garde, an exclusive collection of works by Pablo Picasso and American Pop Art. Additionally, an Expressionist collection and works by other representatives of Classical Modernism are presented at the museum. Since the museum’s establishment, the collection has been extended by works of contemporary artists, such as Isa Genzken.

Isa Genzken (born 1948) is one of the most known German contemporary artists. Her œuvre employs a diversity of materials, and therefore comprises a variety of artworks, such as installations, paintings, photographs, films and works on paper. On one hand her work is constantly reflecting her confrontation with architecture in general; on the other hand, it reflects her approach to exceptional social life situations and structures such as the one she shows in the installation *Kinder filmen* ("Children filming") (see Figure 1).

Her artwork is distinguished by the use of different materials, simple and cheap ones, like tapes or sheets, combined with exclusive and expensive ones like acrylic mirrors or boxes (by the company Kartell for example) that are available as ready made articles. In the end her objects appear incomplete and imperfect, although they can be comprised of products by exclusive designers; her artwork stands out for its imperfection and openness, wanting to provoke the viewer as she attempts to do in *Kinder filmen*. Here she criticizes the social phenomenon of children filming the ill treatment of other children with their mobile phones, in order to then upload those films on the Internet without any adult oversight.1

**HISTORY AND CONSERVATION CHALLENGES IN THE INSTALLATION KINDER FILMEN AT MUSEUM LUDWIG IN CHRONOLOGICAL ORDER**

Isa Genzken created *Kinder filmen* for a presentation at a Cologne art gallery, where the installation had its first performance; the artwork was presented there for six weeks. The installation consists of several elements, the main elements are installed on the floor, forming the core of the installation. When those main elements were installed in the museum the artist added more elements to the installation, in order to complete her artistic intention for the presentation at Museum Ludwig. In the end, two hanging elements under the ceiling and two wall objects were added. All elements of...
the installation are independent objects and can be presented by themselves.

In August 2006, the installation Kinder filmen was delivered to the museum as a new acquisition in two shipments. An image of the installation setup at the art gallery in Cologne from which it came was included as technical installation instruction. The first shipment of the new acquisition arrived in many small packages containing: three umbrellas, one tall and two small movable shelves, puppets and comic figures (e.g. one duck toy installed on all of the movable shelves), four books, a pistol, a blinking light in the shape of a pineapple, a plastic bag, a lighted aquarium, a ventilator, a pen, two mirrors, one piece of paper and two chairs that lay on their sides. Upon its arrival to Museum Ludwig, challenges to conservation history and to the installation began immediately with the discovery that the duck toy - installed on one of the movable shelves - was no longer working (see Figure 2). The duck’s head and its arm were not moving properly, but for its presentation in the museum’s gallery it was necessary that they function as will be described.

The next step was to install all pieces of the installation in the museum gallery. The installation is presented in its own gallery niche, and visitors are invited to walk through the installation. Upon agreement between curator and conservator it was decided to install a motion detector so that the electrical elements start working when someone enters the niche, thus minimizing the hours of operation as much as possible. The pistol was adhered to the top of the bookshelf, and the books and bags were secured with strips of a clear polyester foil. Also a set of installation instructions for future installation and de-installation purposes was prepared.

The installation was opened to the public and two days later the second breakdown of an element, the malfunctioning blinking light in the shape of a pineapple (see Figure 3), was reported to the conservation lab. Therefore the light was taken out of the installation. The conservation work on the light continues until today. On June 25 2008, the next message was sent to the conservation lab: one of the hanging elements had fallen down from the ceiling and broke entirely (see Figure 4). All broken plastic pieces were collected off the floor and have since been kept in an acid-free paper box.

When the damage was discovered the exact reason for the failing of the plastic was not known or further examined scientifically due to time constraints. Beside this first hanging element, there was a second hanging element just below the ceiling. Its construction, and with that the materials used, were obviously identical to the destroyed element. It was thus decided to take down the still intact element as soon as possible. The materials will be examined and a solution will have to be found to prevent the hanging elements from falling.

This estimate of the impending failure of the plastic material proved to be true. After taking the second element from the ceiling, it was kept in the dark photo studio and photographically documented immediately. After another three months in the dark photo studio this element also fell to the ground, due to degradation of the plastic.

At the Museum Ludwig, it was agreed that the artist would create two new hanging elements. When the artist had finished them, however they did not integrate into the original installation. This motivated finding a solution to preserve the two original hanging elements of the installation Kinder filmen, even more.

In the meantime, the two hanging elements were the third and fourth objects of the installation that had broken and could not be shown in the installation any longer. The fifth followed right away: the lighted aquarium had ceased to function (see Figure 5). The aquarium consists of a plastic container shaped like an aquarium; in its center there is a round light tube around which plastic sheets move. The plastic sheets show fishes which appear to swim in this aquarium. The light tube was broken and the plastic sheet was not moving anymore.

That was the moment in the installation history at the museum when the curator asked the question: do we have to de-install the artwork Kinder filmen because the installation is no longer complete due to failing elements? It was a conscious decision to keep the artwork installed in order to gain more experience in the preservation of the materials of the single elements,
CONSERVATION OPTIONS AND APPROACHES

In the following chapter the solutions found thus far for each damaged element mentioned before will be described and discussed. Each treatment measure on the installation passed a consultation with the electrician we began an Internet search to find the company that had produced them or to find a new blinking light in the shape of a pineapple, but with no luck. We also contacted Isa Genzken to ask her where she had taken out of the installation and shown to the museum electrician. He also explained that it is not clear whether or not the timer on the light was still working. The blinking sequence of the different light bulbs was not documented before the pineapple light was installed in the artwork.

Parallel to the consultation with the electrician we began an Internet search to find the company that had produced them or to find a new blinking light in the shape of a pineapple, but with no luck. We also contacted Isa Genzken to ask her where she had taken out of the installation and shown to the museum electrician. He also explained that it is not clear whether or not the timer on the light was still working. The blinking sequence of the different light bulbs was not documented before the pineapple light was installed in the artwork.

THE DUCK TOY

With the first message of the damaged duck toy (see Figure 2), the owner of the gallery also passed on the name of one of Isa Genzken’s assistants who fortunately lives in Cologne. To prepare the assistant’s work on the duck, it first had to be removed from its pedestal. The pedestal consists of two boards that are attached on top of each other – the lower one is wider than the top one. The duck’s removal from the pedestal turned out to be more difficult than expected. This intervention would definitely change the duck’s condition, and since these changes should be as small as possible, the curator decided that a conservator would remove the duck from its pedestal. Isa Genzken was informed and agreed to this procedure.

First the screws from underneath the pedestal were removed. Only then was it realized that those screws and plain paint attached the two boards of the pedestal to each other. The plain paint had emerged from the outside in-between the two boards while creating the pedestal. The duck itself was still attached to the second top panel of the pedestal by a second pair of screws, which was only discovered when it was taken off the lower board of the pedestal.

This paint in between the two pedestal boards was still liquid. To reach the screws of screws, the excess paint was carefully removed with tissues and the paint was allowed to dry. When the paint was dry, the second pair of screws could be removed and the duck could be taken off for repair. To reach the inside of the duck’s arm and head, its clothes were carefully removed and the seams of the textile skin layers were opened. Inside the duck toy it was discovered that clumsily polyurethane soft foam forms the inside of the arm and that there is a blinking light. Isa Genzken liked the replacement very much. Her answer to the question regarding the “disco light ball” Isa Genzken liked the replacement very much. Her answer to the question regarding the “disco light ball” was “it is just important that there is a small light blinking, independently of the shape of the lamp and independent of the blinking and color sequence”.

To find a replacement a new small lamp was found to fit perfectly inside the plastic bag in the installation. It blinks in different colors and is a small so-called “disco light ball” Isa Genzken liked the replacement very much. Her answer to the question regarding the “disco light ball” was “it is just important that there is a small light blinking, independently of the shape of the lamp and independent of the blinking and color sequence”.

The hanging elements, part of the installation “Kinder filmen” (see Figure 4). The second hanging element is made of white plastic material and has a round flower-shaped construction hanging by itself. The reason for the falling of the elements is the break of the chains joining the hooks with the rectangular or flower-shaped ring. Due to its much shorter distance to the floor, the green carriage with the pineapple lamp is not important; rather, it is essential for her presentation that the exact sequence of the blinking of the light bulbs in the pineapple lamp is not important, the fact that it is made of green plastic material and has a round flower-shaped plastic construction ring in its center. Here two small umbrellas are attached to the ring with clothespins. These were intact. Only the nitrile gloves of the first element showed some tears due to the accelerated aging of the plastic underneath the ceiling and to the sun. As with the chains, some of the clothespins were broken too.

The central carrying constructions of both hanging elements are entirely made of an unstable plastic, probably polystyrene. The original and now degraded plastic material will not hold any weight again by itself. These hanging constructions are called “clothes drying wheels” and are available in camping stores.
Due to the different conditions of the two hanging elements, after their damage we decided to proceed with two different treatments:

For the first hanging element, the rectangular one, only the plastic shreds and the image from the gallery remained. As described above, there was no luck in finding a new “drying wheel” of the type that Isa Genzken had used before. However, for the artist it was important that we find such a “drying wheel” as a finished product instead of reconstructing something that was thought could fit. Upon incidentally visiting a Japanese store in Cologne, a small rectangular “drying wheel” made of plastic was used instead of the original hanging construction. The two original polyurethane plastic parts were re-hung because their condition was good. A pair of new orange nitrile household gloves were used instead of the original hanging construction. A pair of new orange nitrile household gloves were re-hung because their condition was good. A pair of new orange nitrile household gloves were used instead of the original hanging construction.

Figure 5 The lighted aquarium, part of the installation “Kinder filmen” (see colour plates, p. 170)

Due to the much shorter distance to the floor, the flower shaped construction of the second hanging element was not destroyed by the fall. All pieces attached to the second element were also intact. After several discussions in the lab, we decided to support the second hanging element in the following way: a metal conservator at the Museum for Applied Arts in Cologne was consulted and asked to shape a metal support that exactly fits the shape of the flower-shaped ring on which the original plastic part should rest. The hanging parts, such as the umbrella and the orange plastic sheet, should be joined to the metal support frame and not to the plastic ring. In this way, all preserved parts of the original drying wheel would still be part of the installation, supplemented with new, more stable parts. Thus the hook, the chains and the clothespins that have to hold the weight of the other elements were replaced by metal. The whole metal construction was lacquered in a green color to integrate it into the original green flower-shaped plastic ring. With this new metal construction supporting and holding the original plastic ring, the hanging element is shown in the installation since then.

THE LIGHTED AQUARIUM

As a solution for the broken lighted aquarium, it was decided to use a replacement. A new aquarium was found on the Internet. Its size is bigger than the original one but aside from the size it has the same appearance.

The lighted aquarium consists of a plastic container shaped like an aquarium; its center there is a round light tube around which plastic sheets move. The plastic sheets show fishes which appear to swim in this aquarium (see Figure 5). As with the pineapple light, these electrical elements were not designed to run for long periods. Regarding the lighted aquarium, there was also the problem that the artist had changed the position of its application. Instead of presenting it in the upright position, as the aquarium was designed for, the artist laid the aquarium flat on its back. Since the interior equipment of the aquarium is not intended for this position, it does not support this stress, and thus no longer works.

CONCLUSIONS

The three most important experiences during the conservation history of the installation are summarized in the following aspects:

1. The choice of the materials and their application in the installation are very important to the artist and the intended effect of the artwork. The artistic independence is crucial not only to the artist but also to the curators and conservators at Museum Ludwig. Therefore the preservation of the original plastic parts is the primary goal in conservation. However due in particular to past experience treating Genzken’s installation Kinder filmen, conservators also have to be prepared for the moment when the original plastic material will fail. Then it rests with the responsible conservator to find methods of conservation, restoration or reconstruction, depending on the artist’s intentions. Therefore, the artist interview, including answers to conservation questions is crucial when acquiring a new contemporary artwork.

2. The presentation of Kinder filmen at Museum Ludwig including how to handle the fragile installation is therefore it was necessary to have the ensemble installed for at least for one to three years. In this way it was possible to collect experiences regarding the life-span of the single objects applied and to develop solutions for its long-term presentation.

3. Currently, Isa Genzken is working together with a conservator before she releases new artworks. The question remains, to what extent should a conservator act as an artist’s assistant? It was a great experience to join Isa Genzken when she was visiting the installation Kinder filmen again in the context of her retrospective exhibition at Museum Ludwig and to see that her eyes were shining.

ENDNOTES

(2)Ellen Kostthaus, student at the University of Applied Sciences in Bern, will be researching her master’s thesis in 2010 and will try to find a conservation treatment for the light in the shape of a pineapple. She is looking into options for preserving the original electrical elements, so that in the future the light chain in the pineapple light can be consolidated or easily replaced.
The formulations of fluorescent paints have improved since the second half of the XXth century. These new colours have been introduced in artistic practices and have changed the perception of both colours and the consumer related symbols. Little is known about fluorescent pigments. Information given by manufacturers is sometimes non-existent and is secret knowledge. Therefore, it is important to characterize and to assess the degradation aspects of fluorescent paints found in works of art.

This study focuses on the photochemical degradation of fluorescent colours, using accelerated ageing tests under UV-A & B light and weathering accelerated ageing conditions, applied on experimental laboratory samples. The characterization and the assessment of the chemical change of materials during the ageing process are performed with the help of Fourier Transform Infrared (FTIR) spectroscopy and colour measurement by photometric devices. Severe ageing conditions were purposely used, as this relates to the stressful environment surrounding works of art, in particular graffiti artworks exhibited in public places.

A case study of late XXth century screen-printing artworks is also included in this project.

KEYWORDS
Fluorescent paint, graffiti, ink marker, screen-printing, FTIR spectroscopy, artificial ageing

INTRODUCTION
Today, fluorescent pigments are used in several fields. It is estimated that approximately half of the daylight fluorescent pigments produced is found in paints. The remaining half is used in plastics, printing inks, paper coatings and textiles. Although the Japanese made use of the luminescence of lakes based on oyster shells in the tenth century, it is with the emergence of new trends in contemporary art that fluorescence and phosphorescence made its appearance in the arts (Elias et al. 2006). Even though fluorescent colours appeared on the market around the 1940s, it is only since the 60s that they have been used by artists.

Little is known about the formulations of these paints, in particular the pigment/dye and the binding/resin. The latter can vary based on the use, the support background and the packaging, while the former remains identical. Moreover, manufacturers are quite reluctant to provide information data reports, which makes the identification of such materials difficult using conventional analytical techniques. Therefore, it is equally important to characterize these materials and to study their behaviour with regard to their degradation. The knowledge of alteration mechanisms of such materials, found in cultural heritage, is significant from a preservation point of view and yet, they have not been extensively investigated up until now. The purpose of this work is first, to identify the fluorescent pigment/dye and complement some existing databases on Raman and FTIR spectra (Colombini et al. 2008) and, second, to look more specifically into the degradation aspects (Valageas 2009). A short list of standard paints has been made according to their use in artworks and commercial materials. Tests have been carried out on various paints, sampled from regular paint cans, spray cans and ink markers, along with investigation into fluorescent paint artworks, including fluorescent colours and screen-printing. A case study of recent screen-printed artworks is also included in this project.

FLUORESCENT COLOURS IN WORKS OF ART
Fluorescent colours have been used by artists since the 1960s and are becoming a major concern from a purely aesthetic, as well as from a preservation and conservation point of view. This is a non-exhaustive overview of fluorescent paints in artworks. Fluorescent colours were rapidly associated with the Hippie culture, notably the summer of love in 1967, which took place in Central Park, New York City, where body and face of the “Flower Children” were covered with fluorescent paints. Fluorescent paints were also used during the psychedelic years to imitate the effect of drugs, such as LSD or mescaline, on the perception of colour (Elias et al. 2002).
As part of the New Realism artistic movement of the 60s, Martial Raynaye’s paintings reflected artificial and sensual traits of the consumer society, in particular models depicted with fluorescent colours.

Pop Art was also a precursor with regard to the use of fluorescent colours in paintings as a means of showing the spectac-ular nature of the consumer society. This topic was largely exploited by New York artists such as Roy Lichtenstein, Tom Wesselmann or even James Rosenquist.

Op Art movement artists like Frank Stella worked on the effects produced on spectators by fluorescent paints.

In the 80s Keith Haring, a graffiti artist became famous as he started to use fluorescent paint on canvas working in his attic. Spectators are generally regarded as a target move-ment, witnessed by “Né dans la rue”, an exhibition dedicated to graffiti which was shown at the Grand Palais in Paris in 2009.

THEORY

BRIEF HISTORY

Luminescence has been a well-known phenomenon since antiquity. Before the introduction of “luminescenza” by the German physicist Eilhardt Wiedemann in 1888, only the term “phos-phorescence” was used (Valeur 2004). The “Bologna stone”, also called “sponge-light”, appeared in the early seventeenth cen-tury. This first synthetic luminescent material was discovered by Vincenzo Cascariolo, who obtained it by heating stones containing barium sulphate (Carlini et al 1982 ; Christie 1993). In 1866, Theodore Sidot prepared the first luminescent zinc sulphate (Etunite) that, for the origin of the term luminescence comes from fluorine (calcium fluoride), which emits blue light when exposed to UV light (Valeur 2003). The first synthetic fluorescent dyes with a molecular structure & phosphorescence, both part of the main types ofphotoluminescence, was introduced by Francis Perrins in 1929. In the case of fluores-cence, light is emitted as a result of radiation; with phosphorescence, the latter is often mixed in fluo-rescent dyes during the manufacturing process of the resin in order to improve the colourfastness, the resistance to heat and the stronger fluorescence behaviour. The light fastness of daylight flu-orescent pigments is inferior to that of high performance organic pigments, and to some extent, limits their use for outdoor applica-tions. Their light-fastness is also mediocre due to poor stability of the fluorescent dyes and/or brightness agent, while the resin matrix has a good light fastness (Lewis 1988). Today, the polymer most commonly used in spray paint is tolueneultra-grade melamines, while the resin matrix, although polyurethane, polyamide and polyester are also on the market as binding media.

FLUORESCENT PIGMENTS

Detailed theoretical aspects of fluorescence are largely covered by literature. Basically, these pigments absorb both short-wave-length visible light and convert this radiant energy into visible light. The emitted light then combines with the nor-mal reflected light to give rise to brilliant colours. In most cases, fluorescences occur with the molecular aspect of the pigment (Christie, 1991). Rhodamines have no fluorescence emission rules. The red fluorescent dyes are the best known derivatives, such as rhodamine B (Tetracyclic Rhodamine Izo Thio Cyanate) and rhodamine 6G and B. With fluorescent compounds, they are the families of highly fluorescent dyes. The latter are derivatives of xanthene. These are known to be sensi-tive to the structure of the dye molecule. For instance, the tetracyclic series have groups with strong fluorescence; the most well-known derivative is the 4-amino-naphthalimide with a yellow fluorescence. Another type of molecules that do not lose their fluorescence properties are organic molecules with high fluorescent properties, notably from red to yellow. Derivative benzanthrone, benzoxanthone and benz-pyrrole are also found. They provide fluorescence from yellow to orange.

EXPERIMENTAL METHOD AND ANALYTICAL TECHNIQUES

Various commercial and artistic paint samples were studied si-multaneously. The choice of commercial products was dictated on the basis of their use in the art world, and of high standard quality in the case of fluorescent acrylic paint. There is little doc-umentation available about formulations by manufacturers, often reduced to safety data sheets.

REFERENCE SAMPLES

SPRAY PAINTS

Spray paints are commonly used for signage and are commonly used for graffiti. They are all trademarked. The Montana Gold series was chosen for this project since it was found that fluorescent spray paints may be used by artists and supposedly very resistant to light and rain. The fluorescent colours were available in the Gold range. A protective varnish from weathering, heat and humidity, trade name Duplo-Colo, was also tested, as proposed by manufacturers.

Fluorescent spray paints tested were:

Flower 1000 – Desert Sand;
Flower 2000 – Power Orange;
Flower 3000 – Red Fire;
Flower 4000 – Glamour Pink;
Flower 5000 – Flame Blue;
Flower 6000 – Acid Green

INK MARKER

The ink markers studied here are the Posca brand; they are also used in the graffiti world. They are described as markers of water-based pigments. Their colours are resistant to light and water. The fluorescent colours are available in the Uni-range Posca beveled edge, with a width of 8 mm.

Fluorescent colours tested were:

pink, green and red.

Spray paint was given by the manufacturer as: water is contained in all the colours between 61 and 67%, a resin be-tween 20 and 26%, and between 3 and 9% of ethylene glycol, according to colour.

INK MARKER

The ink markers studied here are the Posca brand; they are also used in the graffiti world. They are described as markers of water-based pigments. Their colours are resistant to light and water. The fluorescent colours are available in the Uni-range Posca beveled edge, with a width of 8 mm.

Fluorescent colours tested were:

pink, green and red.

Spray paint was given by the manufacturer as: water is contained in all the colours between 61 and 67%, a resin between 20 and 26%, and between 3 and 9% of ethylene glycol, according to colour.

EXPERIMENTAL METHOD AND ANALYTICAL TECHNIQUES

Various commercial and artistic paint samples were studied simultane-ously. The choice of commercial products was dictated on the basis of their use in the art world, and of high standard quality in the case of fluorescent acrylic paint. There is little documentation available about formulations by manufacturers, often reduced to safety data sheets.

REFERENCE SAMPLES

SPRAY PAINTS

Spray paints are commonly used for signage and are commonly used for graffiti. They are all trademarked. The Montana Gold series was chosen for this project since it was found that fluorescent spray paints may be used by artists and supposedly very resistant to light and rain. The fluorescent colours were available in the Gold range. A protective varnish from weathering, heat and humidity, trade name Duplo-Colo, was also tested, as proposed by manufacturers.

Fluorescent spray paints tested were:

Flower 1000 – Desert Sand;
Flower 2000 – Power Orange;
Flower 3000 – Red Fire;
Flower 4000 – Glamour Pink;
Flower 5000 – Flame Blue;
Flower 6000 – Acid Green

INK MARKER

The ink markers studied here are the Posca brand; they are also used in the graffiti world. They are described as markers of water-based pigments. Their colours are resistant to light and water. The fluorescent colours are available in the Uni-range Posca beveled edge, with a width of 8 mm.

Fluorescent colours tested were:

pink, green and red.

Spray paint was given by the manufacturer as: water is contained in all the colours between 61 and 67%, a resin between 20 and 26%, and between 3 and 9% of ethylene glycol, according to colour.

INK MARKER

The ink markers studied here are the Posca brand; they are also used in the graffiti world. They are described as markers of water-based pigments. Their colours are resistant to light and water. The fluorescent colours are available in the Uni-range Posca beveled edge, with a width of 8 mm.

Fluorescent colours tested were:

pink, green and red.

Spray paint was given by the manufacturer as: water is contained in all the colours between 61 and 67%, a resin between 20 and 26%, and between 3 and 9% of ethylene glycol, according to colour.
behaved as those without varnish. The varnish did not prevent this discolouration, and the samples marked difference. UV-A artificial aging had similar consequences. Overall thin white opaque film. Only the blue sample shows a less and green have lost their fluorescence, leaving the surface with an crease for green, blue and yellow, and some increase for pink, red crease for green, blue and yellow, and some increase for pink, red

FTIR SPECTROSCOPY

Each sample was analysed by FTIR spectroscopy. The relevant spectra did not show any major differences, as they are more or less identical (see Figure 2). The distinction of colours with different composition was not possible. Some complementary Raman investigations have brought more information on the nature of pigments and extender while FTIR allowed the medium to be identified (see Figure 3).

The assignments of the various IR absorbance bands confirm the presence of an acrylic melamine resin. The characteristic peaks of acrylic and melamine are represented in the following table (see Table 2). Acrylic resins are thermoplastic synthetic resins produced by polymerizing esters of acrylic acid and methacrylic acid. The trimethylmelamine is used as a cross-linking agent. These resins may contain up to five different acrylic monomers (methylenecrylate and acrylonitrile as a hardening agent, ethylacrylate to achieve a more flexible film, and hydroxyethylacrylate sites providing reagents necessary for polymerization). They are often modified with melamine and styrene.

INK MARKER

For this type of paint, the colour change is clearly visible for all samples aged under both UV-A and UV-B. No difference is perceived between the parts maintained by the sample holder and the TO samples. However, observations under microscope show some crack networks on both hidden and UV radiated parts. The photograph taken under an optical microscope shows the in-depth degradation of approximately 90 µm due to UV-B irradiation (see Figure 4).

COLOUR MEASUREMENTS

These samples have generally shown some brightening, resulting from a great loss of fluorescence, and this irrespective of colour. The green and orange samples have tended to shift towards red, while the pink and red towards green. The yellow and orange samples have been yellowing. For others, their colours have a

Figure 1
Yellow fluorescent Montana sample after UV-B ageing, shown protected and unprocted by the sample holder; surface "scraped" from the sample revealing the underlying layer

Figure 2
FTIR spectra of Montana unaged samples from top to bottom: Yellow, Orange, Red, Pink, and Phosphorescent

Figure 3
FTIR spectrum of Montana fluorescent yellow; A = acrylic; M = Melamine absorbance band assignments

Figure 4
FTIR spectra of the Montana unaged samples from top to bottom: Yellow, Orange, Red, Pink, and Phosphorescent

SPECTROSCOPY

Each sample was analysed by FTIR spectroscopy. The relevant spectra did not show any major differences, as they are more or less identical (see Figure 2). The distinction of colours with different composition was not possible. Some complementary Raman investigations have brought more information on the nature of pigments and extender while FTIR allowed the medium to be identified (see Figure 3).

The assignments of the various IR absorbance bands confirm the presence of an acrylic melamine resin. The characteristic peaks of acrylic and melamine are represented in the following table (see Table 2). Acrylic resins are thermoplastic synthetic resins produced by polymerizing esters of acrylic acid and methacrylic acid. The trimethylmelamine is used as a cross-linking agent. These resins may contain up to five different acrylic monomers (methylenecrylate and acrylonitrile as a hardening agent, ethylacrylate to achieve a more flexible film, and hydroxyethylacrylate sites providing reagents necessary for polymerization). They are often modified with melamine and styrene.

INK MARKER

For this type of paint, the colour change is clearly visible for all samples aged under both UV-A and UV-B. No difference is perceived between the parts maintained by the sample holder and the TO samples. However, observations under microscope show some crack networks on both hidden and UV radiated parts. The photograph taken under an optical microscope shows the in-depth degradation of approximately 90 µm due to UV-B irradiation (see Figure 4).

COLOUR MEASUREMENTS

These samples have generally shown some brightening, resulting from a great loss of fluorescence, and this irrespective of colour. The green and orange samples have tended to shift towards red, while the pink and red towards green. The yellow and orange samples have been yellowing. For others, their colours have a

Spray Paints

Some significant colour changes between the non-irradiated area (the one covered by the sample holder in the UV chamber) and the irradiated one, are visually noticeable for all samples (see colour plates p. 171). It seems that the yellow, orange, red, pink and green have lost their fluorescence, leaving the surface with an overall thin white opaque film. Only the blue sample shows a less noticeable difference. UV-A artificial ageing had similar consequences. The varnish did not prevent this discolouration, and the samples behaved as those without varnish.

a Perkin Elmer Spectrum 2000 FTIR combined with ATR single reflection diamond cell was used. IR spectra were recorded from 4000 to 580 cm⁻¹. Colour measurements were performed with a Spectrocolorimeter HunterLab MiniScan XE, diffuse mode under Standard illuminant D65 (Daylight 65) viewing area of 4 mm diameter, using *E* colour change.

RESULTS

Spray Paints

Some significant colour changes between the non-irradiated area (the one covered by the sample holder in the UV chamber) and the irradiated one, are visually noticeable for all samples (see colour plates p. 171). It seems that the yellow, orange, red, pink and green have lost their fluorescence, leaving the surface with an overall thin white opaque film. Only the blue sample shows a less marked difference. UV-A artificial ageing had similar consequences.

The varnish did not prevent this discolouration, and the samples behaved as those without varnish.

On the other hand, no significant alterations were displayed under artificial weathering ageing. A confirmation of the chromatic alterations resulting in a thin opaque film was done by observation under microscope. No alterations of surface such as scaling and cracks are noted. It seems like the radiation had only affected the surface of the paint layer. Indeed, a scratch made by a scalpel on the surface, allows for locating of the original yellow colour (see Figure 1). Cross-sections viewed under microscope do not allow the depth of surface alteration to be measured.

Colour Measurements

Colour measurements carried out on aged samples have correlated the visual observations. All L* a* b* values vary after UV (A & B) ageing tests. The brightness L* value has shown some decrease for green, blue and yellow, and some increase for pink, red and orange colours (see Table 1). The varnish applied has not prevented discolouration. Results have shown that no significant changes are noticed for the weathering tests, confirming the visual interpretations.

### Table 1: Montana red fluorescent spray paint; examples of colour measurements results occurring after different aging tests

<table>
<thead>
<tr>
<th>Type of artificial ageing tests</th>
<th>∆L</th>
<th>∆a</th>
<th>∆b</th>
<th>∆E</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-A (unvarnished sample)</td>
<td>24.98</td>
<td>3.14</td>
<td>39.59</td>
<td>18.52</td>
</tr>
<tr>
<td>UV-A (varnished sample)</td>
<td>29.55</td>
<td>4.95</td>
<td>24.42</td>
<td>17.28</td>
</tr>
<tr>
<td>UV-B</td>
<td>25.13</td>
<td>2.23</td>
<td>23.47</td>
<td>9.86</td>
</tr>
<tr>
<td>Weathering</td>
<td>2.05</td>
<td>5.91</td>
<td>1.54</td>
<td>0.46</td>
</tr>
</tbody>
</table>

### Table 2: Main characteristic FTIR band of the Montana fluorescent yellow

<table>
<thead>
<tr>
<th>Wavenumber (cm⁻¹)</th>
<th>Assignment</th>
<th>A</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>4850</td>
<td>C-O, carboxylic compound</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>7120</td>
<td>(O-C=O)</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>1485</td>
<td>C=O, COOH</td>
<td>A,M</td>
<td></td>
</tr>
<tr>
<td>1570</td>
<td>Triazine ring</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>1640</td>
<td>-CH=CH</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>2874</td>
<td>C-H2, saturated hydrocarbon</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>3070</td>
<td>Triazine ring</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>3400</td>
<td>Hydroxyl group</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Colour measurements of Montana paints after UV-B ageing

<table>
<thead>
<tr>
<th>Sample</th>
<th>∆L</th>
<th>∆a</th>
<th>∆b</th>
<th>∆E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>16.39</td>
<td>4.44</td>
<td>14.71</td>
<td>10.91</td>
</tr>
<tr>
<td>Orange</td>
<td>11.28</td>
<td>2.76</td>
<td>7.68</td>
<td>5.72</td>
</tr>
<tr>
<td>Yellow</td>
<td>7.97</td>
<td>2.13</td>
<td>2.71</td>
<td>6.21</td>
</tr>
</tbody>
</table>

#### FTIR spectra of Montana unaged samples from top to bottom: Yellow, Orange, Red, Pink, and Phosphorescent

#### FTIR spectrum of Montana fluorescent yellow; A = acrylic; M = Melamine absorbance band assignments

#### FTIR SPECTROSCOPY

Each sample was analysed by FTIR spectroscopy. The relevant spectra did not show any major differences, as they are more or less identical (see Figure 2). The distinction of colours with different composition was not possible. Some complementary Raman investigations have brought more information on the nature of pigments and extender while FTIR allowed the medium to be identified (see Figure 3).

The assignments of the various IR absorbance bands confirm the presence of an acrylic melamine resin. The characteristic peaks of acrylic and melamine are represented in the following table (see Table 2). Acrylic resins are thermoplastic synthetic resins produced by polymerizing esters of acrylic acid and methacrylic acid. The trimethylmelamine is used as a cross-linking agent. These resins may contain up to five different acrylic monomers (methylenecrylate and acrylonitrile as a hardening agent, ethylacrylate to achieve a more flexible film, and hydroxyethylacrylate sites providing reagents necessary for polymerization). They are often modified with melamine and styrene.

#### Ink Marker

For this type of paint, the colour change is clearly visible for all samples aged under both UV-A and UV-B. No difference is perceived between the parts maintained by the sample holder and the TO samples. However, observations under microscope show some crack networks on both hidden and UV radiated parts. The photograph taken under an optical microscope shows the in-depth degradation of approximately 90 µm due to UV-B irradiation (see Figure 4).

#### Colour Measurements

These samples have generally shown some brightening, resulting from a great loss of fluorescence, and this irrespective of colour. The green and orange samples have tended to shift towards red, while the pink and red towards green. The yellow and orange samples have been yellowing. For others, their colours have a
tendency to turn blue. The varnish did not prevent the discoloration of samples. However, this alteration is less marked than previously. All samples were greenish and bluish except for the pink sample. This consistent trend is probably due to the ageing of the varnish covering the samples. Artificial weathering ageing caused a slight brightening. However, the colours do not appear to have undergone great change. As with the spray paints, the distinction between UV-B and UV-A artificial aged samples has shown an overall decrease of the absorption bands. This includes the expected changes for the chemical class such as carbonyl C=O, linear and aliphatic hydrocarbon chain and alkyl nitro chain. This information underlines the difficulty experienced with FTIR spectroscopy in its ability to characterize with precision the chemical transformation that may have occurred. The hypothesis of the loss of fluorescence induced by photo-degradation should be considered. Once again, the weathering artificial ageing tests did not show any significant difference that could correlate with visual interpretation and colour change measurements.

**CASE STUDY**

Some screen-printing paints used by artists of "Le Dernier Cri" have been tested in this project. Based in Marseille, "Le Dernier Cri" is an independent publishing house run by Pakito Bolino. Following the French graphic movement of the 1980s, it represents Post-Punk screen-printing artists such as Moominx, Fredox, Keiti Ota or Ichiba Daisuke. This publisher specializes in graphic design and comic books. Most of the production of this workshop comes in the form of screen-printed books.

In order to inhibit the photo-oxidation, UV "filters" are sometimes found in pigment formulations. In this project some preliminary tests have been carried out on some UV stabilizers such as Irganox and Tinuvin B75. So far, the latter has shown promising results. It will be the subject of future research.

**Acknowledgements**

We would like to thank Pakito Bolino for his cooperation in this research, not forgetting the physico-chemistry team of the Forensic Laboratory of Marseille for their knowledgeable advice and interest in this research.
Lecture 004 / Figure 1
Photograph of the plasma pen by displaying the plasma jet under magnification.

Lecture 002 / Figure 6
Housing and Manual of Marcel Wanders’ Airborne Snotty Vase: Pollinosis, 2001

Lecture 001 / Figure 5
Werner Aisslinger, Soft Chaise Longue (1999), showing discolouration of Technogel, with detail view of Technogel.

Lecture 005 / Figure 1
Andreas Slominski’s Untitled (1992): Bicycle with plastic bags and suitcases.

Lecture 003 / Figure 6
Housing and Manual of Marcel Wanders’ Airborne Snotty Vase: Pollinosis, 2001
Optical microscopy was used to examine PMMA for scratches after cleaning. Polar filters revealed the presence of parallel scratches after a new piece of PMMA had been cleaned with microfiber cloth.

Dummies shaped true to the original, according to the glue joint geometry of the damaged sculpture.

Restoration of the coating using a shellac-filling.
Stereo microscopy images of the morphology of the polymer in Fantasma and Taraxacum.

Plastic objects dating from the 1960's to the 1980's. From left to right:
- Lemonade glass (polystyrene)
- Bottle with cap (polyethylene)
- Measuring cup (polyethylene)
- Small decorative stand for cacti (polystyrene)

Shows a replaced disk after treatment.

Stratigraphy of laminate.
Mount made to support chair during treatment.

Il Piede before and after applying the inlays.

Wilhelm Wagenfeld Table Lamp 1922-23: chromed metal, glass, electrical components.
Lecture 017 / Figure 3
Traces of a former fixation

Lecture 018 / Figure 5
The lighted aquarium part of the installation “Kinder filmen”

Lecture 019
Posca colours before and after aging under exposure to UV-B light
FORS portable instrumentation spectrophotometric modules equipped with fiber optics.

The vitreous retouch. Scratch on front side.

Rescue Apparatus
Dräger-model 1984/85
Bergbau-Museum Bochum
Postersession 004 / Figure 1
The front (left) and rear (right) views of Figure n. 37 by Antonio Bueno, 1966

Postersession 008 / Figure 3
The electric violin of Max Mathews

Postersession 007 / Figure 1
Art Books
Deutsche Werte (aufblasbar)
ABSTRACT

The present work is aimed at investigating the applicability of two non-invasive spectroscopic techniques, namely the Fibre Optic Reflectance Spectroscopy (FORS) and the Dielectric Spectroscopy, for the characterisation of plastics in artworks. Both these techniques can be implemented by means of portable instrumentation, and are already routinely employed for non-invasive diagnostics in situ on traditional artworks and antiques. Nevertheless, these analytical methodologies have not ever been tested on plastics and polymeric materials, and their applications to diagnostics of contemporary collections are still unexplored. In the framework of a broader experimentation conducted within the EC Research Project “POPART” (Preservation Of Plastic ARTefacts in museum collections), tests have been carried out on a set of materials selected among the plastics more commonly occurring in contemporary art collections, and the preliminary results obtained are discussed here.

KEYWORDS

Fibre Optic Reflectance Spectroscopy, Dielectric Spectroscopy, non-invasive diagnostics, UV-VIS-NIR spectroscopy, identification, degradation

INTRODUCTION

Contemporary art collections include a huge variety of polymeric materials - briefly identified as “plastics” - that react differently to the same environmental conditions and, once exposed, can undergo dramatically diverse degradation processes. A fundamental starting point to establish suitable preservation strategies is the identification of polymers constituting the objects, as well as the assessment of their degradation stage. At present, the available analytical techniques used for the identification of plastics are borrowed from the polymer industry, where non-destructivity is not an essential requirement. The majority of well-established methodologies for plastics analysis are indeed destructive or, at least, micro-destructive (spot tests, heating tests, etc.) and require samples (FTIR, ATR-FTIR, Pyrolysis GC-MS, etc.). Conversely, in the museum context, preserving the integrity of the artworks under analysis is of fundamental importance and, hence, the recourse to non-invasive methodologies would be highly preferred (Blank, S. 1995; Shashoua 2008a). Unfortunately, nowadays the most common alternatives to destructive techniques for classifying plastics in collections remain the simple non-analytical methods, like the evaluation of appearance, odour and consistency. In the last decade, with a progressive awareness of the complexity of the problem of deterioration of plastic materials in contemporary art-collections, the conservation community has fully recognized the need of dedicated studies and scientific protocols aimed at providing specific tools for preservation of modern artefacts. Within this context strong efforts have been made to develop non-invasive methodologies, based on portable equipments that allow analysis in-situ and do not require any displacement of the object.

The present work is devoted to investigating the potentialities of two non-invasive spectroscopic methodologies, namely Fibre Optic Reflectance Spectroscopy (FORS) and Dielectric Spectroscopy, for a quick identification of the plastics and characterization of their most frequent degradation phenomena. Both these techniques are considered to be of particular interest since they can be implemented by means of compact, user-friendly, and portable equipment. Moreover they are already well-established in applications on traditional artworks and antiques, on which they turned out to be powerful tools for a non-invasive investigation and analysis. Nevertheless, so far these methodologies have not been tested on contemporary artworks, which require dedicated studies. In particular it is necessary to establish whether the techniques can be used for discriminating the different plastics, or if they can be effective for promptly recognizing the initial stages of degradation on polymeric materials. Tests have been carried out on a set of certified
standards and reference samples of different plastics occurring in collections, and the preliminary results obtained are discussed here. These results lead to a wider research performed in the framework of the on-going research project POPART. (Preservation Of Plastic ARTefacts in museum collections), aimed at developing common strategies for preservation of plastic objects in collections.

**Fibre Optic Reflectance Spectroscopy**

**The Technique**

Fibre Optic Reflectance Spectroscopy (FORS) is a non-invasive technique specifically developed for diagnosis of artworks, based on the measurement of the reflectance spectrum in the Ultraviolet (UV), Visible (VIS) and Near-Infrared (NIR) region of the electromagnetic spectrum. An impinging beam (Io) of radiation is conveyed to the object through a bundle of optical fibres connected to a probe-head, so as to illuminate a small area on the object (about 0.5 cm²). The retro-diffused radiation (I) is thus collected by another set of optical fibres in the same bundle, and sent back to the spectrometer. The corresponding reflectance spectrum R=Io/I is expressed as percentage of the reflected radiation I with respect to the impinging radiation Io, versus the wavelength. The incident radiation Io is measured using a white reference, a highly reflecting standard, (usually a 99% diffusing certified Spectralon®).

Thanks to the versatility of optical fibres, any part of the object can be measured without constraints due to size or shape of the object and the reflectance spectrum can be recorded in situ, without any displacement of the artwork. In general the UV-VIS-NIR reflectance spectra are exploitable for different purposes: the NIR spectrum can provide indications about the occurrence of selected chemical species, characteristics of a given polymeric class. The spectral reflectance in the UV-VIS spectral range is usable for colorimetric analysis and is in principle a powerful tool for monitoring changes in appearance as symptoms of several degradation phenomena.

FORS was originally designed for non-sampling investigations on unmovable artworks (e.g. frescoes), and, thanks to the development of increasingly sophisticated portable instrumentation, it is currently employed for diagnostic purposes on several types of traditional artworks (Bacci, M.; Baldini, F.; Carla, R. et al. 1991; Bacci, M.; Baldini, F. and Casini, A.; Bacci, M. et al. 2002; Cucca, C. et al. 2005). Nevertheless, to the best of our knowledge no applications of FORS to the study of polymers are reported in literature, and therefore the use of FORS for the analysis of plastic artefacts still needs deeper investigations. Actually, the effectiveness of the technique for identification purposes strongly depends on the availability of spectral databases of reference materials, which are necessary for a correct interpretation of data acquired on real objects. Whereas for traditional artistic materials typically occurring in contemporary art collections, and the preliminary results obtained are discussed here. These results lead to a wider research performed in the framework of the on-going research project POPART. (Preservation Of Plastic ARTefacts in museum collections), aimed at developing common strategies for preservation of plastic objects in collections.

The probe head was optimised for measurements on irregular (non flat) surfaces with variable levels of gloss, opacity and transparency, as may occur in plastics artefacts (see Figure 2).

**RESULTS AND DISCUSSION**

As anticipated, the characterization of materials in the UV-VIS spectral region is usable for colorimetric analysis, and it is therefore the reflectance to provide a powerful tool if a degradation process involving chromatic changes has to be monitored over time. Thanks to their non-invasivity, FORS measurements can be repeated at different times on the same object of the polymer family, but with different chemical additives (e.g. different types of plasticizers), which can be distinguished. Nevertheless, in some cases it can be difficult to distinguish differences in material composition from original objects by visual inspection. Indeed, a recurring question when dealing with plastic objects in collections is to ascertain if the object is manufactured with natural or semi-synthetic material. A preliminary study, measuring the UV-VIS portion of the spectrum for a set of polymeric materials typically occurring in contemporary art collections. A preliminary data analysis was carried out, aimed at establishing whether FORS could be successfully employed to differentiate the various polymeric materials included in the set. It turned out that samples belonging to the same polymer family but with different kind of additives or plasticizer, could not be distinguished on the basis of their spectral features, since their slight chemical differences were not detected by their NIR spectra. Nevertheless, considering sub-sets of samples belonging to the same polymer family, it was possible to single out spectral markers which allowed the exclusion of the specular component of the reflected signal, according to the CIE (Commission Internationale de L’Eclairage) recommendations for color measurements.

The probe head was optimised for measurements on irregular (non flat) surfaces with variable levels of gloss, opacity and transparency, as may occur in plastics artefacts (see Figure 2).

**Figure 1** FORS portable instrumentation spectrophotometric modules equipped with fiber optics (see colour plate, p. 172)
Dielectric spectroscopy has proved to be partially successful in discriminating among the different polymers. Further studies are needed to complete the dielectric characterization of polymers considered in the example. Nevertheless, the results of the analysis suggest that the dielectric characterization can be profitably used to complement other analytical techniques.

### RESULTS AND DISCUSSION

Dielectric spectroscopy has proved to be partially successful in discriminating the polymer species included in the set of samples considered. The technique appears to be useful for distinguishing plastics, but probably is not self-sufficient.

### CONCLUSIONS

FORS and Dielectric spectroscopy are two well-established spectroscopic techniques commonly used for non-invasive diagnostics on traditional artworks such as ancient paintings, frescoes, poly-chrome surfaces. FORS can be used for identification purposes, since it provides qualitative information on the presence of selected chemical species. Moreover FORS allows a colorimetric characterization of the surface analyzed, which is extremely useful to monitor colour changes due to degradation processes. Dielectric spectroscopy thus far has been applied in the conservation field to control the moisture content on wall paintings and hence their degradation stage. Both techniques are implemented by means of portable equipments and offer the possibility of making analysis in-situ, in a rapid and non-invasive way. So far they have not ever been tested on modern materials, in particular on polymers. In the present study, carried out in the framework of the EC research Project POPART, preliminary investigations have been carried out on the possibility of using these techniques for diagnostics on plastics artworks. Hence a series of tests on a large set of plastics of interest for museum collections have been carried out, and preliminary results have been presented. The preliminary results obtained are encouraging, and suggest that, provided that a suitable spectral archive of reference materials is available, the techniques are good candidates for developing new tools for diagnostics on plastics.

### ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Community’s Seventh Framework Programme FP7/2007-2013 under grant agreement n° 232218. The study presented is framed within EC Research Project “POPART” (Preservation Of Plastic ARTefacts in museum collections; http://popart.mnhn.fr).

### ENDNOTES

(1)http://popart.mnhn.fr/, as at October 2009.

### Table 1

<table>
<thead>
<tr>
<th>ResinKit® No.</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Cellulose Acetate</td>
</tr>
<tr>
<td>12</td>
<td>Cellulose Acetate Butyrate</td>
</tr>
<tr>
<td>13</td>
<td>Cellulose Acetate propionate</td>
</tr>
<tr>
<td>15</td>
<td>Nylon 6.6</td>
</tr>
<tr>
<td>16</td>
<td>Nylon 6</td>
</tr>
<tr>
<td>17</td>
<td>PVC</td>
</tr>
<tr>
<td>18</td>
<td>Polyurethane</td>
</tr>
<tr>
<td>23</td>
<td>Polyethylene  LD</td>
</tr>
<tr>
<td>25</td>
<td>Polyethylene  HD</td>
</tr>
<tr>
<td>26</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>30</td>
<td>PVC Rigid</td>
</tr>
<tr>
<td>31</td>
<td>Polystyrene High Impact</td>
</tr>
<tr>
<td>32</td>
<td>Polystyrene Medium Impact</td>
</tr>
<tr>
<td>33</td>
<td>Polystyrene High Impact 2</td>
</tr>
<tr>
<td>41</td>
<td>Polyethylene</td>
</tr>
<tr>
<td>44</td>
<td>Polybutylene</td>
</tr>
<tr>
<td>47</td>
<td>Nylon 6</td>
</tr>
<tr>
<td>49</td>
<td>Polyethylene MD</td>
</tr>
<tr>
<td>54</td>
<td>Cellulose Acetate</td>
</tr>
<tr>
<td>58</td>
<td>Cellulose Nitrate</td>
</tr>
<tr>
<td>60</td>
<td>Baltic Amber</td>
</tr>
<tr>
<td>61</td>
<td>Ivory</td>
</tr>
<tr>
<td>62</td>
<td>Tortoiseshell</td>
</tr>
</tbody>
</table>

Map on the plane for the samples of Resinkit® measured by dielectric spectroscopy and listed in Table 1.
ABSTRACT
Materials, very particularly plastics, emit what is known as volatile organic compounds (VOCs). These VOCs can be found in the air in rooms containing plastic products and items, with emission starting from the very moment these materials are produced. Plasticisers, stabilisers, solvent rests and products from the degradation of the polymer itself can usually be encountered as forming part of these emissions.

The complexity of modern materials formulation, along with the preference for non-invasive techniques, make objects made of modern materials in museums ideal subjects for state-of-the-art VOC measurements. Since these emissions are also due to the ageing of the material, monitoring these compounds is potentially able to provide information on decay processes.

Given the importance of air pollutants in human welfare and the increasing interest for environmental policies, an ever-growing body of methodologies and literature dealing with VOC analysis exists. Information contained in the literature will be reviewed, and a comparison made between the most important techniques coupled to GC/MS (SPME, thermodesorption) available in the market for VOC analysis which are applicable within Conservation Science.

KEYWORDS
VOC analysis, marker for degradation, SPME, TD-GCMS, polymer degradation

INTRODUCTION
The Music Archive of the Ethnological Museum (National Museums of Berlin, Germany) houses, among other collections, a large number of recordings on magnetic tapes. Since the archive was revived after World War II in 1952, a large and diverse collection on magnetic storage media has been assembled. Around 10,000 items form now part of this section of the Archive. At the end of 2008 the project ILKAR, Integrated Solutions for Preservation, Archiving and Conservation of Endangered Magnetic Tapes and Cylinders (www.ilkar.de), was launched, aiming at:

- developing methodologies for the identification of especially endangered cylinders and tapes, in order to prioritise their digitisation;
- integration of these developments into the workflows of audiovisual research collections.

Thus far the only definite proof of the real conservation state of a magnetic tape is through playback. In the study, further supporting techniques are being introduced to provide the necessary information about the conservation state of the magnetic tapes without playback.

The recordings were taken during a long span of time, during which polymer formulation was subject to constant changes in the search for the optimal material properties. The degradation processes are material related, but the wide range of possible influences (among them life history and the interaction of the different materials forming part of the tape) prevent an easy identification of the most endangered holdings of an archive.

In the frame of this project, a preliminary study of the VOCs emitted by magnetic tapes in different conservation states will be carried out. The present review, while not intending to be exhaustive, forms part of the bibliographical search to identify the most suitable technique to carry out the study. It presents some of the techniques found in the literature that have been either applied to museum objects or have a strong potential to be applied to them. The article concentrates thus on Solid Phase Microextraction (SPME) and thermal desorption techniques, since they allow non-destructive analysis of material degradation.

FUNDAMENTALS
Volatile organic compounds (VOCs) are defined as those organic compounds having a boiling point less than or equal to 250 °C measured at atmospheric pressure. Regarding this parameter they are further classed into very volatile organic compounds...
(VOCs) and semi volatile organic compounds (SVOCs) (EU, 2004). A range of different products, from food packaging to materials used for car interiors (the characteristic ‘new car’ smell), emit VOCs. Plasticisers, stabilisers, solvent rests and products from the degradation of the polymer itself can usually be encountered as forming part of these emissions. Given the importance of air pollutants in human welfare and the increasing interest for environmental policies, a number of norms describe the different means of measuring VOCs according to international standards. In Germany, the VDI Norms 4300 and 4301, and ISO Norm 16000 describe the measurement of indoor-air pollution, and include a comprehensive list of the sources of indoor-air pollutants and the substances they emit. Gas chromatography is the usual analytical method of choice in these norms, where thermodesorption is used for the sample preparation.

Gas chromatography – Mass Spectrometry (GC/MS) is the technique of choice for the analysis of VOCs in the industry, typical applications being indoor air analysis and testing of emissions. For analysis of gas materials, GC/MS is a chromatographic technique that allows for the analysis of complex mixtures of organic materials. In the gas chromatograph (GC) the components are separated as they travel through a capillary column. As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

The study was performed on a limited set of magnetic tapes with different formulations. Some difficulties arose when trying to correlate the data from an optimised (destructive) extraction procedure of the VOCs with the obtained results, because of the small size of the coating, low detection limits are often difficult to correlate with the macroscopical changes in the material to be analysed (polymer, wood, etc.) in a stainless steel or plastics desorption tube, which can contain either the sample itself (direct TD) or an adsorbent where the VOCs can be gathered and concentrated; and (b) a thermal desorption system, where the VOCs are extracted from the thermal desorption tube by heating and then further transferred to the GC column for analysis. TD requires a stronger initial financial investment, but in return offers a higher sensitivity and allows more general analyses, given the possibility to combine different adsorbents (with different affinities for the different VOCs) in the same tube (Hübbschmann 2004).

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

The study was performed on a limited set of magnetic tapes with different formulations. Some difficulties arose when trying to correlate the data from an optimised (destructive) extraction procedure of the VOCs with the obtained results, because of the small size of the coating, low detection limits are often difficult to correlate with the macroscopical changes in the material to be analysed (polymer, wood, etc.) in a stainless steel or plastics desorption tube, which can contain either the sample itself (direct TD) or an adsorbent where the VOCs can be gathered and concentrated; and (b) a thermal desorption system, where the VOCs are extracted from the thermal desorption tube by heating and then further transferred to the GC column for analysis. TD requires a stronger initial financial investment, but in return offers a higher sensitivity and allows more general analyses, given the possibility to combine different adsorbents (with different affinities for the different VOCs) in the same tube (Hübbschmann 2004).

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

The study was performed on a limited set of magnetic tapes with different formulations. Some difficulties arose when trying to correlate the data from an optimised (destructive) extraction procedure of the VOCs with the obtained results, because of the small size of the coating, low detection limits are often difficult to correlate with the macroscopical changes in the material to be analysed (polymer, wood, etc.) in a stainless steel or plastics desorption tube, which can contain either the sample itself (direct TD) or an adsorbent where the VOCs can be gathered and concentrated; and (b) a thermal desorption system, where the VOCs are extracted from the thermal desorption tube by heating and then further transferred to the GC column for analysis. TD requires a stronger initial financial investment, but in return offers a higher sensitivity and allows more general analyses, given the possibility to combine different adsorbents (with different affinities for the different VOCs) in the same tube (Hübbschmann 2004).

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.

As they emerge at the end of the column they are detected by the mass spectrometer (MS), which provides certain information about their structure, thus assisting in the identification of the compounds of the original sample. However, in order to gather the volatiles, different sample preparation techniques have been devised (Hübbschmann 2004). Of all them, solid phase microextraction (SPME) and thermodesorption (TD) have the highest potential for the study of the degradation of museum objects in Conservation Science. The complexity of materials, the highest potential for the study of the degradation of museum objects is achieved by means of temperature by bringing the fibre directly into contact with the hot injection port of the GC. The VOCs are then transferred to the GC in a similar way as potential indicators for their conservation state. Ultimately, a tool for the lifetime prediction of these materials was sought which could help in the prioritisation of the items in the digitisation procedure.
physical properties. However, the early diagnosis of degrading paper can help implement timely, and economically convenient deacidification protocols.

Preliminary analyses suggested furfural and acetic acid as indicator compounds, given their increasing concentrations with respect to a set of compounds (terpenoids and alkanes) assumed not to be affected by the decay process, thus having in the study a similar function to an internal standard.

Artificial ageing studies further confirmed the hypothesis for the proposed degradation markers. The methodology was used for the assessment of typically used de-acidification procedures and their long-term efficacy with the help of a newly developed, so-called dynamic ageing.

This approach takes full advantage of SPME as a non-destructive technique. Although applied to a different kind of material, particularly a well-characterised and thoroughly studied chemistry, the described methodology is still relevant for the study of other systems.

A statistical approach to the study of historical paper

Volatile ‘degradic’ fingerprinting has recently been shown to be useful to advance the understanding of paper degradation mechanisms, as well as for the recognition of further relevant degradation markers in historical paper (Strlic 2009). This study used SPME-GC/MS to produce a relatively large body of data, which allowed for the generation of multivariate models by using statistical tools such as partial least-squares and principal component analyses. These models in turn allowed to relate the VOC concentration measured in the aged material with certain chemical parameters as quantifiable paper properties (e.g. pH).

Well characterised samples have been used at the present stage of the analysis, taking advantage of the database generated by the SurveNIR project. Although in principle possible, the study has not yet been applied non-destructively.

The authors conclude that information yielded by VOC analysis is not only limited to hints about the composition and degradation mechanism of aged paper. Ultimately it is proposed that SPME in-situ sampling of VOCs in the library may eventually serve as a tool to evaluate the conservation state and the life expectancy of historical documents.

The use of emission chambers for the sampling of VOCs

As exposed above, this kind of analysis is used in the industry for the assessment of the safety of emissions from final products such as furniture, fridges or even cars. Also newspaper and journals, electronic devices and a wide range of household products have been systematically tested in emission chambers for safety reasons (Advhammer, 1999).

A number of emission chambers has been designed to account for the different sizes of objects of study. From small-scale to large scale chambers, the inner volume can vary between a few litres to room-sized compartments. In an emission chamber a strict control of the air quality, as well as of humidity and temperature, but also the surface of exposed sample with respect to the total volume of the chamber, among many others are essential. The chamber is thus isolated hermetically from the exterior. At the exit of the chamber the sampling takes place, once the atmosphere is homogeneous, which is achieved after an equilibration time. The sample thus obtained is then submitted to analysis in a TD-GC/MS. This approach has been used to evaluate emissions coming from materials used in museums showcases (Schieweck 2011).

Conclusions

In this article two of the possible methodologies for sampling of VOCs previous to a GC analysis have been shortly presented, along with a discussion on their main advantages and limitations. They have been chosen since they both offer a potential application in the field of Conservation Science by allowing the design of non-invasive studies.

Solid Phase Microextraction (SPME) has been thus far the most widely applied, due to its ease of use and the relatively small investment in equipment needed. It has been successfully used in the field of historical paper degradation by several authors, while in other areas such as polymer degradation most of the studies lie outside the application area of museum objects.

Thermal desorption offers more controlled environmental conditions when an emission chamber is available for the sampling of VOCs from the object – but at a much higher cost. Current applications in the field of material testing may prove very useful in the assessment of the degradation state of objects made of new materials.

Finally, the use of an emission chamber allows a fine control of the sampling conditions. Although originally designed for TD techniques, also SPME could potentially benefit from its use.
ABSTRACT
The goal of this poster is to initiate a discussion on the possibilities of a transparent or translucent retouch, which lets through light from behind and has to imitate the character of a slide (Cibachrome).

KEYWORDS
Paloma Navares, vitreous retouching, Cibachrome, Cibatrans, PMMA, Primal AC 33/35, Paraloid B 72, PRIMAcryl / Schmincke

INTRODUCTION
From the 1990s until 2003 Paloma Navares (*1947, Bourgos) made a couple of lighting-steles with not only the theme Adam and Eve, but also with copies of other female nudes, where originals represent highlights of the history of European art in 15th – 16th century. These women are both images of immateriality and fragility, aside from being the strong female personalities. The steles were motivated by Adam and Eve of Albrecht Dürer, painted in 1507 on wood (209 × 80/81 cm) belonging to the Prado, Madrid. At the collection of the Landesmuseum Mainz, there are two paintings on wood of a 16th century Dürer pupil who exactly copied these Madrid paintings.

ARTIST
Paloma Navares belongs to the established visual artists. In her oeuvre she assembled in an autobiographical tone common topics of illness, loneliness and isolation. She plays with reality and fiction when she showed large Cibatrans photos of intense color inside of illuminated boxes or tubes. So she sets up a reciprocal relationship between her pieces and the viewer and between the spaces where the pieces are situated and where the viewer is situated. Navares is interested in showing enigmatic objects that allude both to a generic situation of anguish and to that of her own confinement, because she suffers from an incurable eye complaint, which leads to blindness.

THE ARTWORK
The steles are life-size copies of the original paintings consisting of mixed media: ‘photography, silicone, duraclear, methacrylate, cibatrans, fluorescent tube, cibachrome’.1 The Cibatrans shows in full-scale a reproduction of Dürer’s “Eve”, rolled and positioned into a PMMA-tube. It is lit from behind by a fluorescent tube. With one screw the tube is fixed in a plug, which is glued at the top lid of the acrylic tube, from where it fell down as a consequence of incorrect handling.

CIBACHROME PROCESS
The Cibachrome process was developed by the Ciba-Geigy Corporation of Switzerland in the 1960s. The quality of Cibachrome was different from other photographic processes because no dyes are formed during the development process. The extremely durable azo dyes in Cibachrome are already in the manufacture of the material provided and account for the frankly spectacular colors. In the development process, the unnecessary colors just bleach away. This process is exactly the opposite of normal
photographic development processes where dyes are formed during development. Cibatrans is the opaque Cibachrome version. It is coated on the back side with a grey layer so as not to see the fluorescent tube behind. Cibatrans-foils are available on the market in length up to 5 m and are used as ‘transparencies’ in public displays, prints for outdoor use, etc. In most cases they are illuminated with fluorescent tubes. Due to the special development process Cibatrans is stable against UV-light.

CONDITION OF THE ARTWORK AND CONSERVATION TREATMENT

Because of the good UV-stability the Cibatrans of Paloma’s “Eve”, the works show no sign of fading. Moreover in our case the Cibachrome wasn’t scratched (see Figures 3-4) so the vitreous retouching has to close the coating of the Cibatrans (see Figure 1). To find the suitable color and binding material we tested acrylic-based binders and a polyvinylacetate-based binder. Because of its dull surface Mowilith DM 25/1 was eliminated from the beginning of the test period. PVAc is famous for fading and the binding capacities decrease while aging.

As a next option we chose three acrylic dispersions: Primal AC 33, Primal AC 35 and Plexol D 360. Initially it seemed as if Primal AC 35 would have the best characteristics. It is a solvent-free acrylic polymer, an extremely resistant binding media for colors with high gloss.

It has a low viscosity, so it is useful for retouchings in the area of 1 mm. In contrast Primal AC 33 has a much higher viscosity, which leads to a visible heterogeneous structure of the retouching. Due to its higher viscosity Plexol D 360 was also eliminated: its characteristics switched to a pasty and glossy, however totally transparent retouching. The difficulty with Paraloid B 72 was the accelerated drying of the acrylic resin.

For this type of damage we needed a translucent retouching medium, enabling a low viscosity, retouching a small area. Moreover a sufficient UV stability to avoid yellowing is necessary. Therefore we chose PRIMAcryl from Schmincke3, where the pigments are dispersed homogenously within the acrylic binder. It has good drying properties and creates a dull but homogenous surface. It isn’t saturated enough to also work as a filler compound (see Figure 2).

CONCLUSION

At the end it became obvious that the problem to solve was less the binding media than the different light refraction of the coating, the scratch and the retouching which led to a pale shadow in the retouching (see Figure 5). So there is still one problem to solve, namely the correct filler compound for vitreous retouching in small areas.

ENDNOTES

(2) For short information: www.kremer-pigmente.de, as at 30.9.2009
(3) www.schmincke.de, as at 30.9.2009
ABSTRACT
This work is part of a research project on the conservation and restoration of works of art made exclusively with, or containing, polymer based materials in the collection of the GAM (Galleria d’Arte Moderna e Contemporanea) of Turin, Italy. We would like to present an interesting piece, Figura n. 37 (1966) by Antonio Bueno (1918-1984), which is from a series of female portraits created with the children’s game Coloredo, manufactured by Quercetti (Turin, Italy). This piece was chosen because it shows many different problems, both with respect to its chemical and physical states of conservation and to the ethics surrounding a potential restoration treatment. To understand Figura n. 37 in full, research into its traceable history and the artist was done along with the characterization of the materials. This work is the basis of the research required for an eventual conservation treatment.

KEYWORDS
Antonio Bueno, polyvinyl chloride, polyethylene, conservation of plastics

INTRODUCTION
Antonio Bueno was an active artist in the Florentine art scene in the 1960s. In 1963 he was considered among the principle creators of the new artistic movement, ‘Gruppo 70’, which was devoted completely to multimedia and interdisciplinary artistic research. Bueno’s group aimed for the largest inter-artistic collaboration, without disciplinary limits, many times exceeding and neglecting traditional painting methods. Since the beginning, the communal intent of the group was the definition of a technological art form, obtained from commercial originals, such as consumable, advertisement and journalistic materials and objects transformed from their original function into anti-intellectual applications for the people. In this field, his works most noted and dispersed were his faces and the female figures which he painted with a newer stylized fashion (using essential lines) since the end of the 1950s. These face paintings in the beginning appeared sporadically, and from around 1958 they became his most prevalent subject. From here, Bueno started a long and auspicious series of variations on the theme.

Figura n. 37 (see Figure 1), from the collection of the Galleria d’Arte Moderna e Contemporanea (GAM) of Turin, Italy, is an artistic representation of a familiar childhood game, which plays with the memory of the viewer. The Coloredo was introduced to the Italian market in the late 1950s, and is still produced and sold today, from the toymaker Quercetti based in Turin, Italy. The game consists of an ordered perforated plastic platform with multi-coloured plastic pegs that are placed in the holes, allowing the realization of infinite compositions. Through direct contact with the company, information was collected on the constituent materials of the game in the mid-1960s, including the packaging, pegs and plastic platform. The packaging used was a plasticized polyvinyl chloride (PVC), the platform was explained to have always been low density polyethylene (LDPE), since its ‘waxy’ feel helps the pegs stay inside the holes, and the pegs were also made with a coloured LDPE, except for the first 3 or 4 years (late 1950s to early 1960s), where polystyrene (PS) was used; the polystyrene pegs were discontinued since they tended to break much easier. In this study a ‘Coloredo’ game produced in the late 1960s or early 1970s was purchased as a reference model for the understanding and identification of the materials, since access to the game inside the box in Figura n. 37 was not possible.

Figura n. 37, 1966, (29.5 × 29.5 × 4 cm) is part of Bueno’s ‘make it yourself’ series and is one of the female figures. The original game was removed from the plastic film and cardboard box packaging and the pegs were organized in the form of a face
of a woman. The suggestion that the game was removed from the box comes from the fact that coloured surfaces were glued below the white platform to fill in the face (white) and hair (yellow), so the darkness of the holes was less distracting, and also that the game was invented from its original position (with the bottom at the top). Once back in the box it was possibly rewrapped in the PVC plastic film. On the back of the box, a paper sheet was attached using adhesive tape, and it was signed and dated; however, the signature does not correspond with Bueno’s (see Figure 1). Bueno signed the front of the game along the bottom edge of the perforated plastic platform. It is believed that he used pegs from another Coloredo to compose the image and to re­fill the box, made of polystyrene, of coloured pegs (on the left side of the pegs) Pyrolysis-gas chromatography/ mass spectrometry (py-GC/MS) was performed on this period, the mixture may be made of polyethylene and poly­styrene pegs. Also, the box may be a newer one that does not corresponding with the actual game. She also explained that there were multiple versions of his Coloredo art, which he called ‘make it yourself’, and that she never remembered her father sealing them in the plastic film packaging. The film was already present at the time of the 1985 conservation, so it is suspected that the film was added by Bueno himself or by gallery staff in the late 1960s when the piece was donated to the GAM. It was also noted that the adhesive tape was reinforced and re­placed over time.

Figure n. 37 shows a number of substantial problems associated with its plastic components, but before a conservation project can be initiated the materials used in the piece must be identified and the specific one was identified with py-GC/MS. Finally, the plastic box for the pegs was identified as polystyrene with a C< sub>3</sup>H< sub>7</sub> chain peak at 1251 cm<sup>-1</sup>, C–C stretching at 958 cm<sup>-1</sup> and C–Cl stretching at 1600 and 1580 cm<sup>-1</sup> (doublet), in plane deformation at 2999–2900 cm<sup>-1</sup>, CH< sub>2</sub> and CH in-plane deformation at 1426 and 1380 cm<sup>-1</sup> (doublet), in plane deformation at 1074 cm<sup>-1</sup> and out of plane deformation at 743 and 704 cm<sup>-1</sup> (shoulder) from the plasticizer. From the spectrum, a plasticizer containing aromatic rings, likely a phthalate plasticizer was identified and the specific one was identified with py-GC/MS.

Present in the py-GC/MS pyrogram (see Figure 2) were peaks coming from molecules formed by the thermal decom­position of the plasticized PVC polymer: hydrochloric acid from the leaching of plasticizer (see Figure 4a) and 2-ethylhexanol, another side group fragment. There was also a small amount of dibutyl phthalate noted. Traces of film stabilizers, such as UV absorbers, were not detected in the smaller peaks. The plastic perforated platform and coloured pegs from the reference game were identified as polystyrene by FTR-ATR. Present were the C<sub>9</sub>H<sub>12</sub>O<sub>4</sub> stretching peaks at 2915 and 2840 cm<sup>-1</sup>, the in-plane C<sub>H</sub> stretching deformation peak at 1472 cm<sup>-1</sup> and C<sub>H</sub> rocking vibration peak at 715 cm<sup>-1</sup>. The plastic film packaging was iden­tified as PVC containing a (2-ethyl hexyl) ester and/or di­isooctyl phthalate as the main plasticizer, with a smaller concentra­tion of dibutyl phthalate, using FTR-ATR and py-GCMS. Finally, the plastic film was identified as polystyrene with a CH<sub>3</sub>C=C stretching between 3150 and 3000 cm<sup>-1</sup>, CH<sub>2</sub> asymmetric and symmetric stretching between 3080 and 2850 cm<sup>-1</sup>, benzene ring stretching peaks between 1600-1372 cm<sup>-1</sup>, C–H in-plane deformation at 1028 cm<sup>-1</sup> and out-of-plane deformation of C<sub>H</sub> at 753 cm<sup>-1</sup>. The identifica­tion of these materials confirm the descriptions given by Querceti about the plastics they use for the Coloredo games and it is assumed that similar materials are in present in Figure n. 37.

**EXPERIMENTAL**

Small samples of the plastic film from Figure n. 37 and the ref­erence Coloredo game were collected and analysed with Fourier transform infrared spectroscopy – attenuated total reflectance (FTIR-ATR) and pyrolysis – gas chromatography/mass spec­ trometry (py-GCMS). FTR-ATR was performed with a Thermo Nicolet FTIR NEXUS instrument and Smart Endurance ATR accessory, from 4000 to 500 cm<sup>-1</sup> and for 32 scans with a resolu­tion of 4 cm<sup>-1</sup>. Data was collected and analysed with OMNIC 6.1a software.

For the Py-GCMS studies, an Agilent Technologies 6890N Network GC system GC with an Agilent 5973 Network Mass Selective Detector quadruple mass spectrometer was used along with the CDS Analytical 9000 thermal desorption unit and a CDS Analytical helium flow microdosing syringe. Samples were prepared in CDS Analytical quartz tubes with quartz wool. The program used was: 4°C for 2 min, ideal solution to stop and prevent further degradation and dam­age to the piece.

**RESULTS**

**Analytical Results**

The plastic film was identified as a heavily plasticized polyvinyl chloride (PVC) film using FTR-ATR and py-GCMS. The plasticizer was identified as di-(2-ethylhexyl) phthalate (also known as DEHP), a common phthalate plasticizer used in PVC. To support this conclusion, there are small peaks between 3.4 and 4.6 min, which are characteristic fragments of the 2-ethylhexyl side group, and at 12.8 min there is evidence of 2-ethyl hexanol, another side group fragment. There was also a small amount of dibutyl phthalate noted. Traces of film stabilizers, such as UV absorbers, were not detected in the smaller peaks.

The plastic perforated platform and coloured pegs from the reference game were identified as polystyrene by FTR-ATR. Present were the C<sub>9</sub>H<sub>12</sub>O<sub>4</sub> stretching peaks at 2915 and 2840 cm<sup>-1</sup>, the in-plane C<sub>H</sub> stretching deformation peak at 1472 cm<sup>-1</sup> and C<sub>H</sub> rocking vibration peak at 715 cm<sup>-1</sup>. The plastic film packaging was iden­tified as PVC containing a (2-ethyl hexyl) ester and/or di­isooctyl phthalate as the main plasticizer, with a smaller concentra­tion of dibutyl phthalate, using FTR-ATR and py-GCMS. Finally, the plastic film was identified as polystyrene with a CH<sub>3</sub>C=C stretching between 3150 and 3000 cm<sup>-1</sup>, CH<sub>2</sub> asymmetric and symmetric stretching between 3080 and 2850 cm<sup>-1</sup>, benzene ring stretching peaks between 1600-1372 cm<sup>-1</sup>, C–H in-plane deformation at 1028 cm<sup>-1</sup> and out-of-plane deformation of C<sub>H</sub> at 753 cm<sup>-1</sup>. The identifica­tion of these materials confirm the descriptions given by Querceti about the plastics they use for the Coloredo games and it is assumed that similar materials are in present in Figure n. 37.
Present in some points of the plastic PVC film were small perforations (likely a form of physical damage). Corresponding to these holes, directly below the film on the white LDPE platform there are black marks where dust and dirt have accumulated by passing through the holes (see Figure 4b). Some peeling or brittleness of the outer layer of the larger blue pegs was noted. This is likely the result of the ageing and degradation of the outer part of the peg.

6. An overall slight yellowing of the white polyethylene perforated platform is visible. This is from the plastic-oxidation of the material and the formation of chromophore species. Yellowing of the adhesives in the various types of adhesive tapes is also present. The top, right and bottom edges and possibly also the left edge of the platform are painted white. It is unknown if this was done by Bueno or as part of the conservation treatment to cover up the yellowing polyethylene. In some areas, the painted areas are starting to peel away from the plastic surface (see Figure 4c). Polyethylene has a low surface polarity and therefore weak interactions with coatings.

7. Some of the pegs that were glued together (see Figure 5a) have become loose, revealing the glue layer, the painted area below and paint on the pegs themselves (see Figure 5b). These loose pegs are also shifting down into the other containers. Finally, largely because of accidental mishandling and, to a lesser extent, shrinkage of the plastic film, there are several deformations in the paper box. Also along the top edge there is a hole.

CONSERVATION AND RESTORATION CONCERNS

The overall conservation of the artwork is advisable. The main conservation issues concern the PVC film and can compromise the piece in the future, both chemically and visually. A logical solution would be to remove and replace the PVC film; however, it raises many different ethical concerns. By removing and replacing the original film, an original part of the artwork is lost, and it can be argued that also the artist’s intent is lost. On the other hand, this aged PVC film is causing damage to and compromising the main part of the artwork, and is itself very distracting to the eye because of the problems with the plasticizer. Major concerns are also raised by the possible formation of highly corrosive hydrochloric acid via dechlorination of the PVC polymer.

The current opinion is that the PVC film should be removed and replaced, and the original film should be stored in the archives of the museum. The fact that the plastic film has degraded substantially makes it dangerous for the overall conservation of the object and also it was perhaps not original to the piece. Antonio Bueno’s daughter confirmed the existence of similar pieces with similar components but without the plastic protective film and she supposed that it was added later during a pre-1985 conservation treatment or when it arrived at the GAM. The PVC film shows many signs of degradation, which already starts to damage the paper box, in particular because of the leaching of plasticizer. Based on this, the PVC film should be removed and replaced by a new film that is compatible with the rest of the materials and object. At this point in the project, the best replacement material must still be determined and will be researched in the next phase of our work. The decision to replace an integral component of a work of art creates a large ethical dilemma and the consequences must still be thoroughly investigated and discussed.

ACKNOWLEDGEMENTS

The authors would like to thank the Fondazione C.R.T., Fondazione I.S.I. and the Fondazione Torino Musei for financing this project. Also we would like to thank the director, Prof. Eucher and vice director, Dr. Pasos of the Galleria Arte Moderna e Contemporanea (GAM) of Turin, Italy, for access to the gallery’s collection. Thank you also to Quercetti & C. S.p.A. for information and access to historic games and materials. We would also like to thank Ms. Isabella Bueno, the daughter of Antonio Bueno, for information about her father and Coloredo “make it yourself” series.
The article introduces preliminary results of the project “Anti-aging for cultural heritage objects containing elastomers” which is supported by the Federal Cultural Foundation as part of the Program “KUR – Program for the Conservation and Restoration of Mobile Cultural Heritage Objects.”

Since the 19th century elastomers fulfill various functions in apparatus and objects of everyday use due to their highly variable properties. The rapid decay of the elastomer parts of objects of cultural heritage causes severe conservation problems. The KUR project of the German Mining Museum in Bochum is developing and putting into practice conservation concepts for numerous elastomer objects from different museums in cooperation with the Film Museum Potsdam, the Modern Materials and Industrial Heritage course of the University of Applied Sciences (HTW) Berlin and the conservation studio Linke, Berlin. The aim is to develop scientifically sound methods of treatment for the conservation of specific forms of degradation of elastomers and to evaluate the possibilities of preventive conservation of objects containing elastomers and, where necessary, to develop such methods. Test series and preliminary results of the practical conservation and restoration work are brought up for discussion.

**KEYWORDS**
elastomer, rubber, antiaging, binding materials, coatings, preventive conservation

**INTRODUCTION**
The project “Antiaging for cultural heritage objects containing elastomers” which is supported by the Federal Cultural Foundation together with the Cultural Foundation of the German Federal States as part of the Program “KUR – Programm zur Konservierung und Restaurierung von mobildem Kulturgut” (KUR – Program for the Conservation and Restoration of Mobile Cultural Heritage Objects) was initiated by the Deutsche Bergbau-Museum (German Mining Museum) in Bochum (see Figure 1).

In cooperation with three partners the development and putting into practice of conservation and restoration methods for the preservation of cultural heritage objects consisting of elastomers and composite objects with a high proportion of elastomers (natural and synthetic rubber) will be performed on a selection of objects.

In cooperation with several museums’ 53 objects were chosen. These objects represent a wide spectrum of the use of rubber in the fields of everyday culture (clothing, leisure and household goods), industry and technology (life-saving apparatus, movie cameras, diving cap, insulating materials), transport (tires), medicine (various examination apparatus) and art (modern works of art and scenographic models) (see Figure 2, 3).

The different conditions of exhibition and storage in which the rubber objects of the participating museums are kept represent typical situations that can be characterized in a manner relevant to practice. They range from an outdoor presentation – partly under the extreme conditions of their former use during occasional practical demonstrations – to storage in a climate-controlled depot (see Figure 4).

**PROCEDURES**
The elastomer parts of the objects are subjected to climatic, mechanical and other influences that can speed up deterioration. On the basis of these stress factors the possibilities of preventing further decay by removing oxygen, rinsing or filling with an inert gas and underwater storage will be examined. The implementation will be tested within the given limits of the objects such as their size and material composition, as well as their presentation during practical demonstrations and other conditions of the collection and its storage. At the same time these factors unique to each collection, form the precondition for developing object-compatible presentation and storage aids such as props, and for testing the suitability of conservation grade exhibition and wrapping materials, in order to give recommendations for their further use.
The main causes for rapid ageing, deterioration and complete destruction of rubber are environmental influences such as light, oxygen, ozone, heat and humidity, as well as mechanical strain and decomposition by "rubber poisons" such as copper, manganese, iron(II), cobalt and nickel ions. This subject matter has been sufficiently discussed in theory in specialist (Kleemann 1963) and conservation (Leadman 1993: 66) literature.

The changes in the materials become visible on the aged rubber surfaces through characteristic crack formations such as fatigue or ozone cracks (Nagdi 2003), crazing effect and fronting, discoloration (Bayer AG 1991: 436) like the pinking effect caused by bifunctional phenols acting as antioxidants, and structural change of the polymer chains and their matrix (Doležel 1978: 264), manifested in the hardening of the material due to cross-linking and/or softening caused by the scission of the polymer chains and interconnections.

The approach of the project towards this wide spectrum of different rubber materials, their mixtures and application formulas can only be rudimentary. The most important aspect is the age-induced condition of the rubber materials that are part of the objects. These materials are diversified according to their historical and technological use. They consist mainly of types of rubber and mixtures on the base of natural and styrene-butadiene rubber, which due to their prolific use and variety form the main basis for conservation and restoration within the context of the project.

Further objects consist of latex and silicone rubber and other materials not yet identified. Most of the objects were selected for the reason of serious changes in the material manifested by the softening and/or hardening of the rubber. Mechanical impact on hardened rubber often leads to the formation of cracks and the loss of substance. Object-specific methods for cleaning, methods of stabilization by constructions that give mechanical support, lamination, the use of gluing and infilling, will all be presented and tested. Ageing-inhibiting substances and surface coatings that actively conserve the object will be evaluated and put into practice. Various materials will be tested under different conditions of usage and exposure. Examples of some of the methodical approaches of the current project work will be given below. Brittle and hardened rubber materials take up a large proportion of the selected objects. This is the most common problem in collections and often makes the presentation of such objects impossible, in so far as they might already be on the verge of disintegration due to mechanical strain.

By evaluating different methods of reformation, the effects on the aged material are to be examined, the best conservation method found and then applied during a single reformation with subsequent stabilization.

This will happen on the basis of the results of various tests of reformation on hardened rubber samples that have been directly exposed to solvents, a solvent-saturated atmosphere or the effects of heat in different media (Link 2001).

The solvents used were benzine (free of aromatic compounds), ethanol, acetone and toluene, whereby only acetone proved to be sufficiently effective in the tests thus far. The fact that an initially nonpolar natural rubber can be accessed by a highly polar solvent can only be explained by an increase in polarity of the material due to radical reactions during the process of aging. The direct application of acetone caused serious formation of fissures, this method, which also bears the danger of washing out or causing migration of components such as ageing inhibitors, was not examined any further.

There was no increased formation of fissures during reformation in an acetone-saturated atmosphere, but a migration of parts of the rubber mixture also cannot be excluded. There was no further investigation into the migration of materials, as the very small differences in concentration lie within the error rate of instrumental analysis (Pfenninger 2004). Further tests are scheduled, as it has not yet been resolved why this method did not work on all of the samples, even after a day of exposure. The question whether this is due to the type of rubber, the mixture, the degree of ageing or just the thickness of the material is to be examined.

A more gentle method, and applicable to all rubber samples, even those 5 mm in strength, was the thermoplastic reformation at about 70°C. As rubber is a weak heat conductor,
infrared rays which penetrate more deeply into the material were used. Thus a relatively short time of exposure (30 sec up to sever-

everal minutes, according to the thickness of the material) avoided an overheating of the rubber surface and limited the effect of thermal degradation. The intended examinations with analytical instruments (FT-IR spectroscopy, thermoanalysis DSC/TG) will provide information about the influence of short-term heat ex-

posure. Rubber samples reformed eight years ago show no changes compared to untreated material.

It must be clearly stated that the method of reformation should not be employed light-heartedly for the manipulation of deformed rubber parts, but can only be considered as a last re-

sort with regard to the conservator’s ethical responsibility to-

wards the object.

A further aspect is the evaluation of binding materials, which could be appropriate for stabilisation, bonding and for filling ma-

terials for rubber. The examination exclusively considered elastic binding materials that had a medium strength adhesion to the rubber material. Binding materials on the base of protein, starch, cellulose ether etc., were not considered, as they only have little adhesion strength and are not very flexible. This does not consti-

tute a rejection of these materials, which has happened in some cases documented in restoration literature (Allington 1988). The reduced adhesive power can be of use for the stabilisation of un-

stressed rubber surfaces, which are hard and brittle. They are of little use for flexible stabilisations under tension.

Binding materials with an aqueous base (Acronal 500 D, Plextol B 500, Lascaux Acrylic Adhesive 498 HV and Acrylic Emulsion D 498M, PU-Dispersion PU 52) were preferred, as old rubber surfaces are seldom affected by aqueous systems. For the special cases of highly degraded, water sensitive rubber materi-

als, Lascaux–Hot-Sealing Adhesive 375 in toluene/special boil-

ing point benzine and Kraton G1650 M dissolved in toluene and

als, Lascaux D498M, from left to right: Acrona soft resin powder; PE-LD granule; Faber – Castell 7041-20 eraser; powder; Milan Gigante eraser, powder; Acrona BC 305, Cellulose fibre 0,2 mm; the criteria for the evaluation of the surface properties are:

surface structure; transparency/colour; flexibility; adhesion/compaction to rubber; adhesion/touch and transparency/colour

As an insight into the selection of the elastic binders and fillers used in the ongoing test series, as well as the relevant assessment
criteria, is given in Figure 5 and 6. In order to evaluate the fill-

ing materials, thin films and blocks from 1 mm to 10 mm in thickness were prepared in cut-out spaces in a new rubber plate

355

Figure 3 Testing bending film with elastic in-filling materials in Lascaux D498M, from left to right: Acrona soft resin powder; PE-LD granule; Faber – Castell 7041-20 eraser; powder; Milan Gigante eraser, powder; Acrona BC 305, Cellulose fibre 0,2 mm

Figure 4 Blocks with elastic in-filling materials in bound in Lascaux D498M, from left to right: Acrona soft resin powder; PE-LD granule; Faber – Castell 7041-20 eraser; powder; Milan Gigante eraser, powder; Acrona BC 2050 Cellulose fibre 0,2 mm

compacted wax coating creates a shiny, almost new surface im-

pression, which aesthetically counterbalances the surface impression of an aged material or composite object.

A further limitation of the protection of rubber by wax
coatings applies for materials that are under physical strain and temporarily deformed, as any mechanical stress can lead to fis-

ures in the wax layer and thus to an increased local oxidation (Jentzsch 1994: 319; Loadman 1993: 71). Therefore only rub-

ber materials that are not under tension can be waxed. The application of microcrystalline waxes was carried out on some objects at the HTW Berlin in 2002 and expanded by the addition of antioxidants and antiozonants (Lunke 2000). The disadvantage of the employed waxes not being emulsifiable in water was countered by the use of rapidly evaporating solvents. Damage to the surface through fissures caused by swelling could thus be avoided.

Wax coatings offer a long-term method of conservation for the large scale objects exposed to the elements in the port of
Hamburg, which are a category of their own in the project. However, they can only offer protection against aggressive envi-
ronmental influences if they are maintained and replenished on a regular basis.

The evaluation of this method in the project is carried out with a wax emulsion in an aqueous base. This treatment avoids the repeated interaction with organic solvents.

It is not yet clear how and in which form of application ageing inhibitors can be useful if they are applied later onto rub-
ber surfaces. Their application will be determined by the out-
come of the tests. The project will pursue the question whether diffusion that only takes place on the surface has a sufficient ef-
f

Along with the active conservation and restoration meas-
ures, preventive conservation is of importance. It needs to be stressed at this point that a large variety of different objects was deliberately included in the project. There are more possibilities of storing small objects than large ones. Most objects consist of many different materials. Examples are the Van Carrier (Figure 4) and the suction device (Sauger IV), which are open to the elements and partly under operational strain during practical demonstrations.

Oxygen is an important degradation factor. Oxygen-free storage thus appears to be promising. In conservation litera-
ture oxygen absorbers such as the Ageless® or RP-K® systems have been presented, with which objects can be stored in gas-
tight films (Grieve 2008; Elert 2000; Shashoua 1999). Both systems are feasible solutions for small objects under museum conditions and would offer good protection in exhibition and storage environments. Indicators are used for monitoring the absence of oxygen in the bag. This is a concept for which no model tests have been carried out (Loadman 1993: 72). As this means of storage has a potential for rubber objects, it will be included in the test series. Naturally such a form of storage is not suitable for composite objects. There is also the risk of mi-
croorganisms developing. Handling of the objects for routine controls, surveys etc. will also be hampered. Security questions, such as the storage of water in a depot would have to be checked before use.

Despite these problems there are interesting questions for further investigation. What happens to rubber objects; for instance the exclusion of light and the relatively stable water temperature possibly of crucial importance, along with the reduction of oxy-
gen? Which components are drawn out of the rubber in the course of time? Is this manner of storage suitable for already de-
graded material, i.e. are degradation processes that have already begun, slowed down or stopped? What is the best drying method? How does rubber react to a change of surrounding medium when taken out for an exhibition and then placed back in water? Does the ageing process proceed at the same rate as be-
fore or is it accelerated?

Packaging is an important element of preventive conserva-
tion, either for transport or long-term storage. The migration of ageing inhibitors from the rubber into plastics like polyethylene and polyvinylchloride has often been reported (Jentsch 1994: 319; Shashoua 2008: 153, 156). Based on these observations it is possible to derive some recommendations for suitable pack-
aging materials. Direct contact of the rubber with plastics, such as air bubble film, should be avoided. The degradation processes of use of sulphurous iron in oxygen ab-
sorbers constitutes a danger for composite objects that contain silver and copper metals (Waller 2010). It must be kept in mind that these preventive concepts are only suitable for smaller elastomer objects, such as balloons and bathing caps and that absorbers can only reduce, but not completely remove oxygen. Nonetheless, the oxidation processes of rubber can be slowed down by using gasproof films.

Storage in an atmosphere of almost pure nitrogen could be a possibility. A slight excess pressure protects from the penetration of dust and outside air. Representing a reaction-free system it could also be useful for larger rooms and showcases and is al-
ready used successfully for pest control in the food industry (Elert 1997). The problems here are also uncertainties about the effects of dust and outside air. Representing a reaction-free system it could also be useful for larger rooms and showcases and is already used successfully for pest control in the food industry (Elert 1997). The problems here are also uncertainties about the effects of dust and outside air.

At the moment the project will pursue the question whether the absorption of oxygen in an absence of oxygen.

There are occasional reports of surprisingly well-preserved rubber objects found in water (Grieve 2008). In 2008 Grieve recorded over 50 rubber objects, amongst them rubber from pre-
serves, pipe flanges, hard rubber combs and buttons from a ship that sank in 1562 and was lying in a depth of 250 ft. Even after 150 years, the rubber gaskets were still in a well-preserved state. On the whole though, there is little experience with rubber stored in water, even less with rubber stored in fresh water.

The storage of rubber in water is a concept for which no model tests have been carried out (Loadman 1993: 72). As this means of storage has a potential for rubber objects, it will be included in the test series. Naturally such a form of storage is not suitable for composite objects. There is also the risk of mi-
croorganisms developing. Handling of the objects for routine controls, surveys etc. will also be hampered. Security questions, such as the storage of water in a depot would have to be checked before use.

Despite these problems there are interesting questions for further investigation. What happens to rubber objects; for instance the exclusion of light and the relatively stable water temperature possibly of crucial importance, along with the reduction of oxy-
gen? Which components are drawn out of the rubber in the course of time? Is this manner of storage suitable for already de-
graded material, i.e. are degradation processes that have already begun, slowed down or stopped? What is the best drying method? How does rubber react to a change of surrounding medium when taken out for an exhibition and then placed back in water? Does the ageing process proceed at the same rate as be-
fore or is it accelerated?

Packaging is an important element of preventive conserva-
tion, either for transport or long-term storage. The migration of ageing inhibitors from the rubber into plastics like polyethylene and polyvinylchloride has often been reported (Jentsch 1994: 319; Shashoua 2008: 153, 156). Based on these observations it is possible to derive some recommendations for suitable pack-
aging materials. Direct contact of the rubber with plastics, such as air bubble film, should be avoided. The degradation processes of use of sulphurous iron in oxygen ab-
sorbers constitutes a danger for composite objects that contain silver and copper metals (Waller 2010). It must be kept in mind that these preventive concepts are only suitable for smaller elastomer objects, such as balloons and bathing caps and that absorbers can only reduce, but not completely remove oxygen. Nonetheless, the oxidation processes of rubber can be slowed down by using gasproof films.

Storage in an atmosphere of almost pure nitrogen could be a possibility. A slight excess pressure protects from the penetration of dust and outside air. Representing a reaction-free system it could also be useful for larger rooms and showcases and is already used successfully for pest control in the food industry (Elert 1997). The problems here are also uncertainties about the effects of dust and outside air. Representing a reaction-free system it could also be useful for larger rooms and showcases and is already used successfully for pest control in the food industry (Elert 1997). The problems here are also uncertainties about the effects of dust and outside air.
ABSTRACT

Conservation and preservation of cultural heritage has started in China with high scientific support since 1950s. For Chinese wall paintings, different consolidation materials and techniques were applied. Unfortunately in many cases no documentation about conservation intervention materials is available. In the cooperation project ‘Rescue and Conserve the Endangered Wall Paintings in the Museums of China’ between the Academy of Fine Arts in Vienna and the Chinese Academy of Cultural Heritage, systematic study about the materials used in Chinese wall paintings was carried out. Consolidants including polyvinyl acetate (PVA), acrylic resin, gelatine, alkyd were identified in different paintings respectively, which is very important information in making proper conservation strategies for the paintings. This paper demonstrates that Py-GC/MS is an effective method for the characterization of conservation intervention materials, even when confronted with a mixture of different substances.

KEYWORDS
Py-GC/MS, PVA, acrylic resin, gelatine, alkyd, Chinese wall paintings.

INTRODUCTION

China has a rich history to illustrate social and religious life wall inscription, dating from XianQin (221BC) to Qing Dynasty (1840AD). Wall paintings are found widely in China and are normally divided into three groups according to the location. One group contains the wall paintings on tomb chambers, another group comprises wall paintings from ancient temples or palaces and a third group are the wall paintings from grotto sites such as the Mogao caves on the Silk Road. They are like an inexhaustible encyclopedia, which provides first-hand material for the study of the history, social life, religion and painting techniques in that time. Many recent advanced research in the conservation of wall paintings have allowed for in situ preservation. However, there were still many fragments excavated and removed in the last century and housed in the museums of China, for example the wall paintings from Tang tomb stored in the Shaan xi History Museum and the wall paintings from Dazhao temple stored in the Interior Mongolia Museum. The paintings were consolidated and mounted on wooden frames. Problems such as flaking and deformation occurred after long-term storage. In the cooperation project ‘Rescue and Conserve the Endangered Wall Paintings in the Museums of China’, the systematic analytical investigation about the materials (both original and latter conservation intervention) used in the wall paintings has been carried out. The knowledge of the materials used for conservation is as important as the knowledge of the original materials to ensure appropriate conservation and maintenance procedures for the future. In this paper, only the study about the conservation materials is discussed; the investigation results about the original material in the paintings will be discussed in a different publication.

In the 1950s, conservation and preservation of cultural heritage started in China with high scientific support. For the wall paintings, different consolidation materials and techniques were applied. Apart from the natural material (peach gum), polyvinyl acetate (PVA) and polyvinyl butyral (PVB) were mentioned to be used when detaching the wall paintings from their support (Yang 2006). From the 1970s on, epoxy was the main product used for consolidation (Shen 2006). Recently, materials including polyvinyl alcohol, polyamide (Yang W. 2006) and gelatine (Su 2009) were reported to be applied as well. Unfortunately in many cases no documentation about conservation intervention materials is available.

Apart from spectroscopy techniques (Painter 1997, Learner 1995) a wide range of pyrolysis-gas chromatography-mass
spectrum methods have been developed for the characteriza-
recently, thermally assisted hydrolysis and methylation per-
formed with tetrathylammonium hydroxide (TMAH)
(Capitelli 2002) and hexamethyldisilazane (HMDs) has
been proposed for the analysis of synthetic resins and natural prod-
ucts (Osete-Cortina 2006, Doménech-Carbó 2008), with better
chromatogram for the polar components in the analyzed sam-
ple. However, when confronted with unknown samples (mix-
ture of different materials), the appearance of derivatization reagents in the chromatogram may hinder some important py-
rolysis product peaks. The aim of this work is to study the con-
servation materials used in Chinese wall painting by direct Py-GCMS technology, since it is feasible for the identification of most polymers used in artworks (Learner 2003).

EXPERIMENTAL SECTION

REFERENCE MATERIALS

The following natural materials, synthetic resins and emulsions supplied by Kremmer (Kremmer Pigmente GmbH & Co. KG, Ger-
many) were used as reference materials: animal glue, casein, Pri-
mal 35 (p EA/MMMA), Plexol D 498 (p in EA/MMMA) and Rohaglas SD15 (p/EA/MMMA)

THE SAMPLES AND PREPARATION FOR THE ANALYSIS

Three samples from Chinese wall paintings (on the area of for-
mer conservation treatments) were analyzed respectively. One sample was taken from the wall painting of Dazhao temple of In
er Mongolia (labelled as DZS). In this painting epoxy was sus-
ppected as the consolidant by the conservators, another one sam-
ple was taken from the Tang murals from Shanxi Museum from the consolidated areas labelled as B112 and B302 respec-
tively. For Py-GCMS analysis small amounts of samples (about
0.2 mg) were put into the sample cups and were introduced by the
auto sampler directly into the Frontier Lab pyrolyzer. The
volatility pyrolysis products were analyzed by GC/MS.

INSTRUMENTS AND PARAMETERS

Pyrolysis gas chromatography-mass spectrometry (Py-GCMS) analy-
sis was carried out. A double shot pyrolyzer Py-2010AD (Frontier Lab, Japan) and a gas chromatograph-mass spec-
trometer GC-MS-QP2010 Plus (Shimadzu, Japan) were
employed. The Shimadzu GC-MS-QP2010 Plus was used for GC-MS control, peak integration and mass spec-
tra evaluation. Pyrolysis was performed at 600 °C for 10 s.
The pyrolysis interface was set at 320 °C and the injector at 250 °C, respectively.

A capillary column SLB-SMS (5% diphenyl/95% dimethyl siloxane) with 0.25 mm internal diameter, 0.25 μm film thick-
ness, and 25 m length (Supelco) was used in order to provide an ade-
quate separation of components. The chromatographic con-
ditions were as follows: the oven initial temperature was 40
°C for five minutes, with a gradient of 6 °C per minute up to
292 °C, a temperature which was hold for three minutes. The
carrier gas was Helium (He, purity 99.999%). The electronic
pressure control was set to a constant flow of 0.6 ml/min,
in split mode at 1:40 ratio. The mass spectrometer operated in the
EI positive mode (70 eV) and MS spectra were recorded in TIC
mode. The Shimadzu TOF and NIST 05s from the Libraries of Mass Spectra
were used for identifying compounds. According to Learner (2003) the pyrolysis program was slightly changed and
validated for analysis of reference materials.

RESULTS AND DISCUSSION

The three samples were subjected to Py-GCMS analysis, with
independent results. The chromatogram of sample DZS is depicted
in Figure 1. The dominant peak in the chromatograms is ph-
thalic anhydride, which indicates that alkyd resin is present in
the sample. For all alkyd paints, phthalic anhydride was
the principal peak detected by pyrolysis analysis and was there-
fore used as the diagnostic peak for all alkyd based on ortho-
phthalic acid (Learner 2003). The detection of styrene
represents that the alkyd was modified with styrene to improve
its properties. Dibutyl phthalate(DBP) and diisobutyl phthalate
(DBIP) were the plasticiser used in the alkyd. In addition, the
detection of phenol and identification of the maker compounds for
epoxy - bisphenol A by comparing the mass spectrum with litera-
ture [Learner 2003: 50], indicate the presence of epoxy. The
mass spectrum of bisphenol A is shown in Figure 1a. Most epoxy
resins are condensation products of bisphenol A and
4,4’-isopropylidene (chloromethyl-oxirane) [Wincorpyk 1996].
Since the curing agent for epoxy is often a polyamine [Store
1993], the detection of phthalimide and N-amino phthalimide
approved the presence of epoxy in the sample. In summary,
alkyd and epoxy with phthalimide groups could be the con-
servation materials used for this painting in the previous con-
servation treatments.

CONCLUSION

Py-GCMS analysis was shown to be an effective analytical method
for the identification of the conservation materials used in Chi-
inese wall paintings. Through this study, PVA, acrylic resin, gela-
tine, alkyd and epoxy were identified as consolidates in some
Tang dynasty mural paintings of the Shann xi History museum
and in a Ming dynasty wall painting of Dazhao Temple from
Inner Mongolia respectively. The information obtained is defi-
nitely very important to develop proper conservation strategies
for the Chinese wall paintings.
ABSTRACT
This paper describes the conservation and restoration of the object Deutsche Werte (aufblasbar) from 1967 by KP Brehmer. As an artist of the Capitalist Realism movement, working in Hamburg and Berlin during the 1960s and 70s, he is mainly known for socio-critical themes and for illustrating communication processes. He used various media (e.g. plastic material) and Pop-Art methods such as the reproduction of common images in bright colours. The object in focus is an inflatable multiple with two air chambers made of PVC film. The film has a linocut print (alkyd paint) on two sides and is suffering from leakage, losses, flaking, and surface dirt, all endangering its stability. Research was therefore undertaken to determine an appropriate adhesive for consolidation and retouching. During conservation treatment new methods were developed to apply the consolidant to areas of minute pieces of flaking paint from the inside and outside of the chambers. Inside, where access was only possible through a very narrow valve, consolidation was achieved by means of a flexible hose steered with magnets from the outside. On the exterior, a Rotring®-pen helped to implement treatment. Retouching was conducted with a coating system using layers of primer and paint. By use of the mentioned application techniques and materials, new options for conserving inflatable objects with layers of paint were established.

KEYWORDS
PVC film, inflatable art, consolidation, magnet, Degalan® N742, Aquazol® 200, alkyd paint

INTRODUCTION
In preparation for an exhibition about the German artist KP Brehmer at the Hamburger Kunsthalle, the object Deutsche Werte (aufblasbar) from 1967 (see Figure 1) was conserved and restored in cooperation with the Academy of Fine Arts Dresden in 2009.

In Deutsche Werte (aufblasbar) [German Values (inflatable); 87 × 55 cm] the artist uses the image of stamps magnified 100x and printed on PVC film. It becomes a discernible picture which incites critical considerations from the spectator. The motive of collecting plays a prominent role in the work of KP Brehmer who dealt critically with social studies in the 60s and 70s. The “democratisation of art consumption” was one of his themes. Being a press operator he used modern materials from reproduction techniques and constantly improved his own technical knowledge while producing his artwork.

The inflatable multiple Deutsche Werte (aufblasbar) consists of two air chambers made of PVC film with a linocut print (alkyd paint) on two sides. It is supposed to be exhibited inflated (see Figure 2).

Because of the different ageing properties of the original materials as well as incorrect handling of the object, flaking paint and losses have occurred. Furthermore, small holes in the PVC film have rendered the object incapable of retaining air.

RESEARCH
For the consolidation it was necessary to find an appropriate adhesive that is able to adhere brittle alkyd paint to flexible PVC film (see Figure 3).

Various binding media and industrial priming methods were reviewed and evaluated according to different requirements for aged materials and the small dimensions of areas to be treated. Furthermore, the conservation treatment was to remain reversible. Resins, for example, bonded by chemical reaction were not suitable for this purpose. Binding media that retain their solubility for future treatments were evaluated as the best choice. Appropriate solvents had to be found, knowing that any solvent may be harmful to the original materials.

Before applying an adhesive solution to the PVC film, it was necessary to learn more about its surface wettability. Properties like adhesion of the dried film, stickiness, flexibility and solubility provided information about an adhesive’s long-term behaviour. Furthermore, it was necessary to determine possible changes in the original material after the application of a consolidant with long-term contact.
In order to find answers to these questions, the following tests were carried out with each consolidant:

- Application on PVC film (surface wettability) and subsequent cross cut tests of the dried films to learn more about adhesion and flexibility. Stickiness and removability were examined as well as changes to the plastic material (see Figure 4).
- Application on alkyd paint, which was aged at 150°C for 8 hours, to learn more about adhesion, optical changes, removability and changes to the paint film.
- Consolidation of flaking paint on PVC film to compare application and handling properties of the tested solutions.

The following solutions were selected for the tests:

- Aquazol® 200 (poly (2-ethyl-2-oxazoline)) in isopropyl alcohol
- Degalan® N742 (poly (ethylmethacrylate)) in isopropyl alcohol
- Degalan® PQ611 (poly (isobuthylmethacrylate)) in isooctane
- Laropal® A81 (aldehyde resin) in isopropyl alcohol
- Mowilith® 20 (polymethylacetae) in ethanol
- Lascaux Medium for Consolidation® in a water-based dispersion

Concentrations of 2.5, 5 and 10 percent were used. The dispersion was used as provided by the manufacturer. These adhesives are established in conservation practice and have known ageing properties (Down 1996).

RESULTS OF CONSOLIDATION TESTS

Due to low viscosity and appropriate wettability, all selected adhesive agents were applicable to plasticised PVC and alkyd paint. During consolidation, capillary forces were sufficient to transport the adhesives underneath the flaking paint. In general, the optical properties of the tested adhesives were adequate for a consolidant, although all the adhesive films were glossier than the aged alkyd paint (esp. Mowilith® 20 and Lascaux Medium for Consolidation®). Glossiness could be reduced after consolidation by removing the surplus of the consolidant from the paint layer. Aquazol® 200 could be removed easily with water and a cotton swab or a brush. All other tested adhesives were removable with the solvents used for their application, except Lascaux Medium for Consolidation®. Here swelling with isopropyl alcohol and additional mechanical friction was necessary.

The consolidation of PVC film to each tested binding medium was remarkably different. The layers of Aquazol® 200 and Mowilith® 20 showed poor adhesive strength while Lascaux Medium for Consolidation® had moderate adhesion properties to the test film. Hence, these adhesives are not adequate for consolidation of alkyd paint on plasticised PVC. The acrylic media Degalan® N742 and Degalan® PQ611 as well as the aldehyde resin Laropal® A81 demonstrated good adhesion strength.

A highly flexible adhesive was necessary to allow bonding between the plasticised PVC and the brittle alkyd paint. Unfortunately, the flexibility was almost proportional to the stickiness. The latter had to be avoided as the adhesive also had to be bonded to the inside of the chambers – without the PVC films adhering to each other by mistake. Therefore, a compromise had to be found.

As a result of these experimental tests Degalan® N742 (PEMA = polyethylmethacrylate) diluted in isopropyl alcohol was chosen to consolidate the flaking alkyd paint to the artwork's PVC film. It adheres very well to PVC and alkyd paint with its low stickiness does not pose a problem in the near future. PEMA is transparent and has so far proven to be stable during ageing (Down 1996). This acrylic adhesive conformed generally best with the required properties.

RESULTS OF RETOUCHING TESTS

As an appropriate retouching material, additional properties were important. The bonding between binding medium and pigment, for instance, can affect the resulting characteristics of the retouching paint. Tests with black pigments (ivory black, iron oxide black, spinel black) and the adhesives mentioned above were carried out on PVC film. In general, all self-prepared retouching paints (30 percent binding medium in isopropyl alcohol) were removabled with the solvents used for their application. All other tested adhesives were removable with the solvents used for their application, except Lascaux Medium for Consolidation®. Here swelling with isopropyl alcohol and additional mechanical friction was necessary.

The adhesion of PVC film to each tested binding medium was remarkably different. The layers of Aquazol® 200 and Mowilith® 20 showed poor adhesive strength while Lascaux Medium for Consolidation® had moderate adhesion properties to the test film. Hence, these adhesives are not adequate for consolidation of alkyd paint on plasticised PVC. The acrylic media Degalan® N742 and Degalan® PQ611 as well as the aldehyde resin Laropal® A81 demonstrated good adhesion strength.

A highly flexible adhesive was necessary to allow bonding between the plasticised PVC and the brittle alkyd paint. Unfortunately, the flexibility was almost proportional to the stickiness. The latter had to be avoided as the adhesive also had to be bonded to the inside of the chambers – without the PVC films adhering to each other by mistake. Therefore, a compromise had to be found.

As a result of these experimental tests Degalan® N742 (PEMA = polyethylmethacrylate) diluted in isopropyl alcohol was chosen to consolidate the flaking alkyd paint to the artwork's PVC film. It adheres very well to PVC and alkyd paint with its low stickiness does not pose a problem in the near future. PEMA is transparent and has so far proven to be stable during ageing (Down 1996).
alcohol, ethanol or isooctane; volume proportion: 1+1) were easy to apply. It was also possible to take off the paint films with the same solvents used for their application.

Aquazol® 200 gave the best results as a binding medium for the retouching paint and was preferred due to its solubility in water and its ease of application. It is most compatible to the original materials, highly flexible and a good pigment binder. Its solubility in isopropyl alcohol was also important for adequate wettability, but compared to the other it did not provide best adhesion to plasticised PVC. Hence, an interface layer of Degalan® N742 was applied before retouching. Spinel black was selected because of its intense shade of black and its long-term stability.

CONSERVATION TREATMENT

During conservation treatment, the object rested on a small and light construction covered with a transparent polyethylene terephthalate (PET) film, which allowed the object to be visible from all sides. A metal grid was positioned above the object allowing magnets to hold the object in an inflated position while the valves of the transparent chamber were open and gave access to treatment tools if necessary.

The flaking paint was consolidated with a solution of 5 percent Degalan® N742 in isopropyl alcohol. On the outside, the consolidant was applied with a Rotring® pen with a 0.1 mm needle – commonly used for technical drawings in architecture. The only access to the inside of the chamber was a small valve (see Figure 5). Hence, the treatment was carried out with a thin silicone hose, with a syringe at one end and a very small cannula at the other end (see Figure 6-7). After consolidation, the surface was cleaned with a microfiber cloth. To work on the inside, the microfiber cloth was wrapped around small magnets that would fit through the valve and were steered from the outside with padded metal or magnets (see Figure 8). In some areas water was used to swell the dirt.

Retouching was carried out with a brush in a two-layer-system: A preparatory layer of 5 percent Degalan® N742 in isopropyl alcohol was applied to the PVC film, followed by the actual retouching paint consisting of 30 percent Aquazol® 200 diluted in distilled water/isopropyl alcohol (2+1 respectively 3+1) and spinel black pigment (solution of binding media/pigment volume proportion: 1+1), (see Figure 3).

The holes in the PVC film were closed with new PVC patches using the acrylic dispersion Plextol® B500 (Dirks 2004). Afterwards the object was inflated by hand using a balloon pump. The artist intended the object to be inflated while on display. Moreover, it should remain inflated when being stored to avoid any further damage. To reduce migration of plasticiser in storage, it should be covered with siliconated PET film. An oxygen-free encapsulation is recommended for long term storage (Shashoua 2008).

CONCLUSIONS

The development of appropriate techniques provided the conservation treatment of the inflatable object Deutsche Werte (aufblasbar).

Materials were tested and selected to match the optical and functional requirements of the art object. As a result of this research and accomplished conservation treatment, the object is once again ready for display and can be handled and stored safely for years. Further research should go into professional ageing tests of the selected adhesives in order to support the observations and evaluations made in this research project. Further investigation of the influence of the PVC’s plasticisers on the applied adhesive (e.g. through migration process) would also be interesting. Research regarding the influence of compression and atmospheric composition inside the chambers of inflated PVC art objects would be very useful to set standards for storage and display.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. Dr. Christoph Herm, Academy of Fine Arts Dresden for analytical research. Special thanks to Dipl. Rest. Simone Mager and Dipl. Rest. Heidi Weinbek for editing the diploma thesis, Dipl. Rest. Silvia Castro and Heike Schreiber for discussing the conservation treatment. Thanks to Sandra Hons and Louise Cone for revising the English version of this manuscript.
ABSTRACT
The Musée de la musique, Paris offers a great collection of musical instruments. It recently reopened a department devoted to the music of the 20th century. Until then, percussion instruments, electronic oscillators, magnetic tape and sound objects were unusual in the musical field. All of these instruments brought great creativity, and a particular technical richness emerged thanks to an intensive cooperation between musicians and scientists.

Unfortunately, many of the resources that would allow for the documentation of these instruments, or have disappeared. Restoring materials or sound generators raises specific problems, mainly because of the lack of theoretical knowledge of these technologies. Most of the instruments are made with industrial materials and techniques, or are “ready mades”, which is often a characteristic of contemporary art objects. Many materials show unknown alterations because they were built for a precise functional purpose and for a limited performance time. The nature of the materials is defined by their functionality.

This article describes the general methodologies for the conservation/restoration, the condition and the recurrent alterations of this type of instrument that were observed. A type of guideline for these works is proposed and illustrated through the example of an electronic violin.

KEYWORDS
methodology, electronic, musical instrument, conservation, restoration

PRESENTATION IN THE MUSEUM
Inaugurated in 1997, the Musée de la musique, within the Cité de la musique, is a unique site that harbours a collection of musical instruments, works of art and scale models covering four centuries of the history of Western music and presenting an overview of the main musical cultures throughout the world. The current display of the museum’s 20th century collection shows the development of “serious” musical traditions, which are directly related to the musical forms described for the 18th and 19th centuries. This section is illustrated by about 80 instruments, including percussion instruments, electronic oscillators, magnetic tape and sound objects. Exposed in a chronological way, they show different aspects and developments of the creation of 20th century music and musical research. Technology has also facilitated the proliferation of exchange between Western and non-European forms of music and between “serious” and popular traditions. These aspects are illustrated in the museum by many audiovisual displays, with large-screen projection of a selection of major 20th century works.

PERFORMANCE VERSUS PRESERVATION
In the 20th century, with the fascination with machines, and thus the possible commercial exploitation of the mechanization of music-making increased. The technological developments led to radical changes in language: electronic music, concrete music, and real-time interactions between instruments and computers were possible. These technologies allowed for new expression in musical thinking. The major revolution remained the production of sound with an electronic circuit (Battier 1995a). The first example was the Theremin, developed later with the Ondes Martenot in 1928.

In the first period, models imitated pre-existing instruments. The production was meant for all kinds of audiences. Specific materials and components were launched as well: lamps, valves, dynamos and transformers. Then, in the 1950s, electronic instruments appeared, created for sound synthesis. At first, the synthesis was possible through analog systems. Digital synthesis appeared afterwards. Creations were far more orientated towards a specialized audience and for specific instruments (for example electric guitars), offering production in series. But soon, the gap between compositions and their audiences started to deepen (Battier 1995b).

Concrete music appeared in 1948, bringing a new paradox: the music was no longer created for a specific instrument. In the studio, sound had become like musical objects to be mixed.
through combinatory programs. Later, sound synthesizers served as substitutes for studios. In 1957 the numeric, or computing era emerged. The first modular or analog synthesizer appeared in 1958. During the 1960s, the first modern musical synthesisers emerged. The first modular or analog synthesizer appeared in 1958. During the 1960s, the first modern musical synthesisers emerged. The ephemeral nature of sounds increases problems with regard to material (Hummelen 2005). Thus, in addition to the natural change of the materials, the tools and materials often become obsolete (Dardos 2008). Some components, such as electrolytic capacitors and soldering and insulating materials, deteriorate on their own, even when not in use. The wood, used in traditional strung instrument industry, and considered as essential to the quality of the sound of the instruments, became of minor importance. Its role decreased as the instruments evolved.

The role of synthetic and plastic materials increased during the 20th century. Designers and musicians were concerned with the good working state of the machines and their components, but had little care for their external aspects as long as they had no direct influence on the play, and the production of sounds (see Figure 2). Many instruments are conserved far from their original or functional context, and are fragmentary. Three kinds of materials can be observed with regard to these instruments:

- Specific: The model initially used by the designer is the only one to be used.
- Interchangeable: The model can be changed after the identification of its technical properties.
- Modified: The original material, as used by the designer, is modified, and the present material is now unique.

The identification of materials cannot take place without documenting the designer’s and musician’s intentions, as well as elements such as the conditions in which the instruments were played and the effects they produce.

A METHODOLOGY FOR ESTABLISHING THE QUALITY OF CONSERVATION AND THE PURPOSE OF A POSSIBLE INTERVENTION

There are no specific conventions concerning the conservation and restoration of these kinds of instruments. In the laboratory of the Musée de la musique, a certain approach was developed, mainly based upon works of contemporary art and more traditional objects (Van Wegen 2003). The research led by Barbara Appelbaum on the concept of an ideal state is very interesting and can be a basis for this approach (Appelbaum 2007). She defines the ideal state as “the physical state of an object that is considered most desirable by its custodian. It is not intrinsic to the object but depends on the present ownership, the use, the meaning and its future”. The knowledge of this state is not obtained by a physical description of the instrument only, but also with the age of the instrument, which can be discovered in biographical information. Information about the object can be found thanks to various specialists: curators, scientists, instrument makers, musicians and conservators. The information can be classified into four groups (Barclay 2004):

1. Technical documents about the nature of the sound produced, the reception and realization modes
2. An iconographic approach
3. An inventory of the associated musical production and the sound or visual recordings
4. documentation about the sponsor, the context of the work, and the instrument maker

After the process of collecting data, the instrument can be analyzed according to a list of values crossed with the different periods and biographical events that transformed the material condition. For each value, a level can be given: high (4); some (3), negligible (2) or none (1). Taking into account each time period of the object, we can visualize the gain or loss of values over time. These variations help to define its ideal state, corresponding to the ideal level of values.

The list of different values proposed by Barbara Appelbaum can be summarized as below (see Table 1):

- Value of art: The object was created intentionally as art or has to be appreciated as such.
- Aesthetic value: An object has aesthetic value when it is prized for how it looks. Aesthetic refers to beauty in the broad sense of visual appeal.
- Historical value: Historical value recognizes objects as bearers of information about history. The object has an authentic link with a particular historical event.

• Use value: It refers to things that are valued for their usability.
• Research use: When the object can yield information to research from its history, technology.
• Educational value: When the object conveys information or ideas to viewers.
• Value of age: Looks old and is desirable that way. It is a value when the viewer feels that it enhances the appeal of the object rather than detracts from it.
• Value of newness: The object looks new and is desirable that way. The desirability depends on its being in a virtually pristine condition.
• Sensitival value: It engenders personal sentimental feelings. It springs from individuals’ direct personal experience with the object.
• Monetary value: The object is worth money on the open market.
• Association value: Objects with associative value have connections to a person with a considerable amount of fame, either as the object’s owner, user or creator.
• Commemorative value: The object commemorates a person or event. It derives from the intent of the commissioning group or institution at the time the object was created and applies primarily to monuments.
• Value of rarity: There are rather few examples of this type. It is also a non-material aspect of the object because it is based on a human judgement, not on numbers only.

For the specific corpus of contemporary music instruments, some values are more relevant than others. We can propose a first classification around major or minor values.

Very often, the artistic and aesthetic values are not considered of such importance for this type of instrument. Although they exist, they are not subordinated to technical imperatives. Musical instruments are objects which by definition are bound to their use: any transformation caused by their users becomes intrinsically part of them (Jaquot 1996). The direct consequence of this fact is that the notion of authenticity becomes synonymous as long as authenticity refers to the presence of original material rather than to the concept of truth (how an instrument looked like at some point in its past). The designer and musician rarely consider the external aspect of the instruments. Therefore, very often, values such as age and newness do not seem relevant, except for a few instruments like electric guitars, for example. Only a few instruments have great historical or commemorative value. Nevertheless, this value cannot be considered minor because it is linked to the activity of research characterizing these instruments. The educational value is of high importance, especially for research from its history, technology.

In the mode of operation or construction still determines the capacity of the instrument. In the same way, the research aspect is a major
value. One of the characteristics of the instruments of the 20th century is the relative rise of the new trio musician/instrument conceptor/scientist which can also sometimes be concentrated on two or even one person. The use value is relevant because the musical instrument is intrinsically bound by the way it is used. The value of rarity is pertinent too, since these research tools are made in series, but often each of them is a unique piece, like the example developed below. As far as instruments made for industrial production are concerned, such as some electric guitars and synthesizers, the number of models can have an influence on the way they will be collected. In this case two types of collections can be organized: a patrimonial collection, storing the instrument in its actual condition, and a museum for a presentation to the public including possible use.

### POSSIBLE INTERVENTION

As for contemporary art objects, the traditional approach of conservation and restoration does not necessarily relate to the alterations, ageing and obsolescence of the materials. An alternative strategy for preservation strategies must therefore be undertaken. Some of them are developed and adapted as explained below.

**Storage:** The most “conservative” collecting strategy is to store the work physically. The major disadvantage for obsolete materials is that the artwork will disappear once the ephemeral materials cease to function (Dazord 2008).

**Maintenance:** A kind of active conservation process, essential if the use or educational values are important. It can consist of simple acts which, however, might have to be repeated regularly:

- Switch on the electrical components
- Handle the switches (selector, potentiometer…) just to avoid oxidation on the contact points
- Isolate the power cable of the synthesizer
- Check the ext tension
- For value instruments, according to the voltage required (either 110 or 220V), put progressively under voltage with an adapted voltage regulator.

**Emulation:** To emulate a work is to find a solution to imitate the original through completely different means. It can be generally applied to any refabrication or substitution of an artwork component (Dazord 2008).

**Migration:** To migrate an artwork involves upgrading it, either for use or for exhibition. It represents a detailed research and the creation of contemporary musical instruments.

**Table 1**

<table>
<thead>
<tr>
<th>Major values</th>
<th>Minor values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td>The instrument is the intersection between a musical creation and a scientific, economic, and market phenomenon.</td>
</tr>
<tr>
<td>Use</td>
<td>Art</td>
</tr>
<tr>
<td>Reuse</td>
<td>Monetary</td>
</tr>
<tr>
<td>Research</td>
<td>Necessity</td>
</tr>
<tr>
<td>Educational</td>
<td>Importance</td>
</tr>
<tr>
<td>Conservational</td>
<td>Creation of these instruments is often related to important milestones of musical composition.</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>Sentimental</td>
</tr>
</tbody>
</table>

**MAX MATHEWS’ ELECTRONIC VIOLON**

In our study, the electronic violin designed by Max Mathews serves as an example (see Figure 3). This violin was created in 1983 and was given to the museum in 1992 by Max Mathews himself. Mr. Mathews is an American scientist who played a major role in the research and the creation of contemporary musical instruments. The violin remained in the storage room of the museum until the reopening of the 20th century section in 2008. Previously a conservation treatment was undertaken. The violin is made of aluminium and is reduced to a sleeve, four strings and a traditional chin, without any resonance chamber. The bridge has been modified and has four piezoelectro microphones. The amplifier appears as a grey “ready made” suitcase for easy carrying. A transformer is also part of the instrument.

Apparenty, a first electronic violin similar to this instrument was made by Mathews in 1973, in collaboration with a music teacher and a violin player. The study of the different kinds of vibrations of the resonance chamber led to the choice of a curved form. In 1982, a similar violin exermined in the laboratory, a tone sounding like that of a Stradivarius violin was made possible. The first process was technological: the characteristics of the violin were reproduced by electric circuits. Under each string a piezoelectro microphone caught the sound and transformed it into an electric signal. The vibrations kept were dispached through four electronic resonators, which reproduced the exact curvature of the violin. As the designer said, it became easier to play this instrument than a traditional one. The electronic violin can be adapted to various acoustic conditions and therefore can produce a large range of sounds. Mathews created twelve electronic violins, all slightly different from one another. He described them as research tools (Mathews 2007). The components used were industrial, for example car loudspeakers, but the finish of the aluminium parts was imperfect. Nevertheless, this instrument was rather marginal among the production of musical instruments and only a few compositions were created specifically for it. Most of these violins, however, are still played today, for example by Laurie Anderson. The electronic violin seems to be an anomaly rather than a fundamental element in the evolution of the stringed instruments of the 20th century.
Unfortunately, it is impossible, without an irreversible dismantling, to discover whether the electronic components, such as capacitors and loudspeakers, recovered the technical characteristics they once had. But the poor technical quality and the known instability of some of them lead us to believe that they would never have the same sound or feedback as when the violin was played. The violin itself has no specific problems. The tension on the strings cannot damage the rest of the structure, which is made of aluminium instead of wood. Thanks to the plans brought by Max Mathews and the help of an electrician, it was possible to establish a total list of the electrical components of the amplifier. In the future, if the violin has to be played, a new amplifier could be assembled. Regarding the few musical compositions for this violin, this option is not a priority. We can compare our intervention with the first levels of values described earlier.

This methodology helps us to define the aims and the limits of our intervention. Actually, the instrument has recovered most of its major values and the documentation has been completed for other future presentation options.

CONCLUSION

The new approach of using priority value assessment of objects in the collection can help to establish clear objectives for their comprehension and conservation. This methodology will be applied to all instruments of the 20th century in our collection, in order to validate the process of research and documentation. At the same time, contacts will be launched with other institutions, were similar instruments are conserved. A dynamic exchange should be established with all individuals who are actively engaged in preservation issues and who retain a high standard for the appropriate presentation of contemporary musical culture. For their help in this work.

ACKNOWLEDGEMENTS

I would like to thank Stéphane Vaiedelich and Sandie Leconte, scientists of the laboratory of research and conservation, and Thierry Maniguet, curator of the 20th century section of the Musée de la musique.
REFERENCES
A-D Strips: A CONDITION SURVEY METHODOLOGY AND SUPPLIERS AND REFERENCES
Word 2002: Reemay polyester fabric: GallerySystems, New York, NY USA
Buffalo, NY USA
GretagMacbeth ColorCheckers: X-Rite
The Museum System (TMS): GallerySystems, New York, NY USA
Reemay polyester fabric: Fibeweb through Talas, New York, NY USA
Word 2002: Microsoft
REFERENCES
Aslinger, W. 2009. Correspondence with author.
London: ICOM-CC; James & James.
Shabousa, Y. 2009. Correspondence with author.
Lecture 002: MEETING THE NEEDS OF CONTEMPORARY DESIGN: A NEW SURVEY METHODOLOGY REFERENCES
‘‘Europe’s Ban on Old-Style Bulbs Begins’’. London: V&A Publication.
Shawbury: Rapra Technology Ltd.

Lecture 003: ADHESIVES OF PLASTICS - WHAT CAN WE DO ABOUT IT? REFERENCES

Lecture 004: FINE-TUNING CONTEMPORARY ART AND PLASTIC TO IMPROVE THE BONDABILITY AND COATABILITY OF PLASTICS IN MODERN AND CONTEMPORARY ART SUPPLIERS
Infrared emission sticker: Cosmo Data AG, CH-8306 Zurich, Switzerland.
Polymer samples for tensile shear and pull-off testing: Sumina AG, 5660 Kern, Germany (PE-LD); Cellpack AG, 5612 Wüllmern, Switzerland (PP); Kundert AG Kunststofftechnik, 8645 Jona, Switzerland (PE-HD); Acryplex GmbH, 8931 Schlieren, Switzerland (PS).
Paradise B-72: Lascaux Colours & Restauro, 8306 Brittishuilen, Switzerland.
REFERENCES
Shawbury: Rapra Technology Ltd.

Lecture 005: PLASTIC BAGS - RESEARCH INTO POLYETHYLENE BAGS OF THE SERIES ‘‘BICYCLES’’ BY ANDREAS SLOMINSKI SUPPLIERS
Acrylic adhesives 360 HV and 489 HV Lascaux: Barbara Diehrhelm AG, Züriehstrasse 42, CH-8306 Brienz, Switzerland.
Dispensers of thermoplastic acrylic polyethylen on the basis of methyl methacrylate and butyl acrylate. The two types 360 HV and 489 HV are thickened with acryl bulkester, have a pH 8 - 9 and are biocide stabilized. Water-thinnable, insoluble in water after drying. Permanently soluble in polar solvents, e.g. acetone. For lightweight and non-ageing non-cross-linking linings, laminations, collages etc. For wet application or reactivation of dry film, on absorbent and nonabsorbent supports.
360 HV: extremely elastic, dry film remains permanently tacky. Can be used as a contact adhesive when doing hot-sealing linings.
Röhm, O. and Bauer, W. 1937.
Russel, E. W . 1949a.
National Advisory Committee for Aeronautics 1938.
Lorne, A. 1999.
Imperial Chemical Industries sine anno.
Berlin: Springer-Verlag.
Lecture 008
NATIONING BROKEN PIECES
RESEARCH INTO METHODS AND MATERIALS FOR ADHERING BROKEN UNSATURATED POLYESTER ARTWORKS
SUPPLIERS
Polyc-Pol P5 230, cast polyester resin UP:
Peroxan ME-50L, Methyl Ethyl Ketone peroxide
poly-service BV, Wennekebachweg 49a,
1096 AK Amsterdam, The Netherlands
http://www.polymeric.nl, as at: October 2009.
Fynebond: Fyne Conservation Services
St Catherine’s, Argyll PA25 8BA, UK
Hegart Y-A: Adlington Studio, The Old Bakery,
Marwood, nr Bridport, Dorset DT6 2QJ, UK
http://www.addingtonstudio.co.uk, as at: October 2009.
Paraloid B72: Labshop Twello, Oude Rijksstraatweg 44,
7391 ME Twello, The Netherlands
http://www.labshop.nl, as at: October 2009.
REFERENCES
‘Controlling the refractive index of epoxy adhesives with acceptable yellowing after ageing’
Student project art conservation department of the State University College at Buffalo (SUCB).
Kaczmarek, H., 1996, 

Imperial Chemical Industries sine anno.
**REFERENCES**


Inside Installations, Preservation and Presentation of Installation Art, www.inside-installations.org/index/index.php


---

**REFERENCES**


echnical Supplement No. 3. Washington, DC.

American Association of Museums.


---

**POSTSESSION 001**

**NON INVASIVE TECHNIQUES FOR IDENTIFICATION AND CHARACTERIZATION OF POLYMERS IN CONTEMPORARY ARTWORKS**

**SUPPLIERS**

The Reascon Company 1112 River Street, Woonsocket, RI 02895 PH (401) 767-2700 IR (800) 944-ATPG (4874)


---

**POSTSESSION 001**

**NON INVASIVE TECHNIQUES FOR IDENTIFICATION AND CHARACTERIZATION OF POLYMERS IN CONTEMPORARY ARTWORKS**

**SUPPLIERS**

The Reascon Company 1112 River Street, Woonsocket, RI 02895 PH (401) 767-2700 IR (800) 944-ATPG (4874)

FX (401) 767-2823 www.plasticsgroup.com

Part of the objects analysed were provided within the framework of the POPSART Project, by the Project Partners: Institut Collectif Nederland (ICN), National Museum of Denmark (Natmus), Denmark and Victoria and Albert Museum (V&A), UK.


Postersession 004: "A Case Study: Consolidation and Retouching of Alkyd Paint on an Inflatable PVC-Bag from 1967"

References:


Max Matthews. 2007. 'Portraits polychromes'. Institut National de l'Audiovisuel.


BIographies

Nigel Bamforth is a Senior Conservator at the Victoria & Albert Museum in London. Nigel Bamforth is an associate professor for modern materials conservation at the Bern University of the Arts since 2005. He holds a PhD in Physics from the Politecnico di Milano where he is now a Researcher and lecturer. His research focuses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. He has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Anna Comiotto is an associate professor for modern materials conservation at the Bern University of the Arts since 2010. She holds a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. Her research focuses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Daniela Comelli graduated from the Politecnico di Milano with a degree in Electrical Engineering. She went on to obtain a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. She is the co-author of over 20 publications. Her research focusses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art.

Daniela Comelli is associate professor for modern materials conservation at the Bern University of the Arts since 2010. She holds a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. Her research focuses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Eva Brachert is working as a conservator of paintings and sculptures at the Landesmuseum Mainz. eva.brachert@landesmuseum-mainz.de

Oscar Chiantore is currently a research fellow at the University of Torino, Italy. He gives courses on Polymer Materials, Chemistry of Conservation and Degradation of Materials, and is the Chair of the University Curriculum on Conservation and Restoration of Cultural Heritage. His scientific activity is focussed on the stability and degradation mechanisms of natural and synthetic polymers, with particular attention to the analysis and characterisation of organic materials in works of art. The topics currently investigated in his research group are degradation and conservation of modern and contemporary art objects, along with the ageing behaviour of modern artists paints, (acrylics and alkyds) and of plastic materials in art works. oscar.chiantore@unito.it

Alain Colombini is a conservation scientist at the Textile Conservation Studios, Hampton Court Palaces, London, on the composition and properties of modern artists paints, (acrylics and alkyds) and of plastic materials in art works. Alain.colombini@cicrp.fr

Anna Comiotto is associate professor for modern materials conservation at the Bern University of the Arts since 2005. She holds a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. Her research focuses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Daniela Comelli graduated from the Politecnico di Milano with a degree in Electrical Engineering. She went on to obtain a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. She is the co-author of over 20 publications. Her research focusses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Anna Comiotto is associate professor for modern materials conservation at the Bern University of the Arts since 2005. She holds a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. Her research focuses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Daniela Comelli graduated from the Politecnico di Milano with a degree in Electrical Engineering. She went on to obtain a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. She is the co-author of over 20 publications. Her research focusses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.

Anna Comiotto is associate professor for modern materials conservation at the Bern University of the Arts since 2005. She holds a PhD in Physics from the Politecnico di Milano where she is now a Researcher and lecturer. Her research focuses on imaging and time-resolved fluorescence spectroscopy of a wide range of materials including works of art. She has worked on the analysis of important masterpieces including works by Masolino, Michelangelo and Mantegna.
Costanza Cucci

Costanza Cucci graduated in Physics and got her PhD in Conservation Science from University of Florence (Italy). Since 2000 she has carried out her research activity at the Institute of Applied Physics “Nello Carrara” of the National Research Council (IFAC-CNR), Italy. Her research interests concern the application of spectroscopic techniques to characterization of materials with a special focus on non-destructive methodologies, development and testing of optical sensors and monitoring systems for different application fields, such as conservation of cultural heritage, environmental monitoring, safety/quality controls in food products. Presently she is involved in the on-going EC research Project “POPART” (Preservation Of Plastic ARTefacts in museum collections, FP7-2007-2013).

Elda Cwiertnia

Elka Cwiertnia worked for two years in different conservation studios with various freelance and museums conservators in Hamburg and Cardiff. In 2004 she began her studies in conservation and restoration of easel paintings, modern and contemporary art at the Academy of Fine Arts Dresden. During this period she worked project-based for the Museum Ludwig Cologne, Kunsthistorisches Museum Vienna, Kunsthastus Zürich and for freelance conservators in Zürich and New York City. For her final degree she wrote a thesis about pearlescent pigments and restored the object Deutscher Werte (an/blasbar). Since 2009 she is employed as a conservator for paintings and modern sculptures at the Kunsthastus Zürich. elke.cwiertnia@northumbria.ac.uk

Margo Delidow

Margo Delidow is currently a Research Fellow at The Museum of Modern Art in New York, New York. Margo received a MACAS in sculpture conservation at Buffalo State College and her B.F.A. in sculpture from the Center for Creative Studies in Detroit, Michigan. Prior to life in conserva-

Marc Egger

Marc Egger is since 2004 associate professor at the Department for Conservation and Restoration, Specialisation Modern Materials and Media at the Berne University of the Arts, Switzerland. Besides holding workshops and lectures, he is involved in research projects concerning the conservation and restoration of contemporary art. He obtained in 2002 his diploma in Conservation and Restoration at the Berne University of the Arts. Since then he works also part time in his own conservation studio and is specialized in the conservation and restoration of contemporary art.

Regina Fröhlich

Dipl. Rest. Univ. Regina Fröhlich studied industrial design at the Federal University for Design, Media and Arts / HfG Karlsruhe, Germany (2001-2003) and Conservation, Arts Technological and Conservation Science at the Technische Universität München, Germany (2005-2010). Regina is interested in documentation, conservation and trans-

Regina Graner

Susanne Graner trained as a cabinetmaker in Munich from 1992 to 1995. After two years of internship she studied Conservation, Art Technology and Conservation Science at the Technical University in Munich (1997-2002). The topic of her diploma thesis was the conservation of “The Lemon Room by Bruno Paul in Faber-Castell Castle in Stein near Nuremberg”. Upon completing her de-

giorgio.galleani@triennale.it

Elena Gómez-Sánchez

While finishing her PhD in Organic Chem-

Stephanie Grossman

Stephanie Grossman is currently at the University of Ap-

Margarita del Dolce

Margarita del Dolce has been the Director of the California Academy of Sciences’ Center for Scientific Illustration since 2005. Prior to this she worked as an artist and writer in Paris, New York, and Berkeley, California. She holds a B.S. in Biochemistry from the University of California, Berkeley and has been an active artist for more than 25 years.

giorgio.galleani@triennale.it

Lena Sjöholm

Lena Sjöholm is a member of the design team at the Center for Creative Studies in Detroit, Michigan. Prior to life in conserva-

giorgio.galleani@triennale.it

Elena Gómez-Sánchez

Margo Delidow received a MACAS in sculpture conservation at Buffalo State College and her B.F.A. in sculpture from the Center for Creative Studies in Detroit, Michigan. Prior to life in conserva-

Marc Egger

Marc Egger is since 2004 associate professor at the Department for Conservation and Restoration, Specialisation Modern Materials and Media at the Berne University of the Arts, Switzerland. Besides holding workshops and lectures, he is involved in research projects concerning the conservation and restoration of contemporary art. He obtained in 2002 his diploma in Conservation and Restoration at the Berne University of the Arts. Since then he works also part time in his own conservation studio and is specialized in the conservation and restoration of contemporary art.

Marc Egger

Marc Egger is since 2004 associate professor at the Department for Conservation and Restoration, Specialisation Modern Materials and Media at the Berne University of the Arts, Switzerland. Besides holding workshops and lectures, he is involved in research projects concerning the conservation and restoration of contemporary art. He obtained in 2002 his diploma in Conservation and Restoration at the Berne University of the Arts. Since then he works also part time in his own conservation studio and is specialized in the conservation and restoration of contemporary art. marc.egger@kkk.fhfb.ch

Regina Fröhlich

Dipl. Rest. Univ. Regina Fröhlich studied industrial design at the Federal University for Design, Media and Arts / HfG Karlsruhe, Germany (2001-2003) and Conservation, Arts Technological and Conservation Science at the Technische Universität München, Germany (2005-2010). Regina is interested in documentation, conservation and trans-

Regina Graner

Susanne Graner trained as a cabinetmaker in Munich from 1992 to 1995. After two years of internship she studied Conservation, Art Technology and Conservation Science at the Technical University in Munich (1997-2002). The topic of her diploma thesis was the conservation of “The Lemon Room by Bruno Paul in Faber-Castell Castle in Stein near Nuremberg”. Upon completing her de-

giorgio.galleani@triennale.it

Elena Gómez-Sánchez

While finishing her PhD in Organic Chem-

Stephanie Grossman

Stephanie Grossman is currently at the University of Ap-

Margarita del Dolce

Margarita del Dolce has been the Director of the California Academy of Sciences’ Center for Scientific Illustration since 2005. Prior to this she worked as an artist and writer in Paris, New York, and Berkeley, California. She holds a B.S. in Biochemistry from the University of California, Berkeley and has been an active artist for more than 25 years.

Margo Delidow

Margo Delidow is currently a Research Fellow at The Museum of Modern Art in New York, New York. Margo received a MACAS in sculpture conservation at Buffalo State College and her B.F.A. in sculpture from the Center for Creative Studies in Detroit, Michigan. Prior to life in conserva-

Marc Egger

Marc Egger is since 2004 associate professor at the Department for Conservation and Restoration, Specialisation Modern Materials and Media at the Berne University of the Arts, Switzerland. Besides holding workshops and lectures, he is involved in research projects concerning the conservation and restoration of contemporary art. He obtained in 2002 his diploma in Conservation and Restoration at the Berne University of the Arts. Since then he works also part time in his own conservation studio and is specialized in the conservation and restoration of contemporary art.

Regina Fröhlich

Dipl. Rest. Univ. Regina Fröhlich studied industrial design at the Federal University for Design, Media and Arts / HfG Karlsruhe, Germany (2001-2003) and Conservation, Arts Technological and Conservation Science at the Technische Universität München, Germany (2005-2010). Regina is interested in documentation, conservation and trans-

Regina Graner

Susanne Graner trained as a cabinetmaker in Munich from 1992 to 1995. After two years of internship she studied Conservation, Art Technology and Conservation Science at the Technical University in Munich (1997-2002). The topic of her diploma thesis was the conservation of “The Lemon Room by Bruno Paul in Faber-Castell Castle in Stein near Nuremberg”. Upon completing her de-

Elena Gómez-Sánchez

While finishing her PhD in Organic Chem-

Stephanie Grossman

Stephanie Grossman is currently at the University of Ap-

Margarita del Dolce

Margarita del Dolce has been the Director of the California Academy of Sciences’ Center for Scientific Illustration since 2005. Prior to this she worked as an artist and writer in Paris, New York, and Berkeley, California. She holds a B.S. in Biochemistry from the University of California, Berkeley and has been an active artist for more than 25 years.
KATHARINA HAIDER
Katharina Haider holds a diploma of the Technical University Munich in conservation, art technology and conservation science. Her final thesis was about the conservation of plastic bags. Focusing at modern and contemporary art she worked for the New National Gallery in Berlin and as a senior Time-based Media Conservator at Tate Gallery London and in museums such as the Museum of Modern Art Frankfurt/Main.
Currently she graduates in Polymer Science at the Technical University Berlin. Besides this she works as a tutor in the chemistry department and runs her own atelier in Berlin.
kath@hfbk-dresden.de

URSULA HALLER
Prof. Dr. Ursula Haller, born 1968, studied conservation and technology of paintings and polychrome sculptures at the Academy of Fine Arts and Design Stuttgurt and got her degree in conservation in 1994. 1994-2003 assistant lecturer at the University of Fine Arts Dresden and the Technical University Munich. 2004 PhD (Dr. phil.) at the Technical University Munich. 2004-2005 interim professor of painting conservation at the University of Fine Arts Dresden. 2005-2007 lecturer at the department of archaeometry and conservation science at the Academy of Fine Arts and Design Stuttgurt. Since 2007 professor of painting conservation at the University of Fine Arts Dresden.
kuller@thf-dresden.de

MINNA HAASKARRA
Minna Haaskarrainen finished her PhD in Polymer Technology in 1996 (Royal Institute of Technology, Sweden). She is now Professor in Polymer Technology at Royal Institute of Technology Stockholm, Sweden. Her main research interest is polymer degradation and long-term properties and especially the development of extraction methods and analytical techniques for studying degradation products and emissions from both inert and degradable polymers. She has been involved in several national and international projects concerning different aspects of polymer degradation. minna@kth.se

ANDREAS HOLLANDER
1984 Chemistry Diploma at Charles University Prague, Czech Republic. Work on polymerisation kinetics; 1990 PhD in chemistry, Teltow, Germany. Work on reactions on polymers and the preparation of semiconducting polymers. Postdoctoral Fellowship at the Ecole Polytechnique, Montréal, Canada; work on plasma technology and vacuum-ultraviolet photochemistry of polymers; since 1992 at Fraunhofer-Institut für Angewandte Polymersforschung, Potsdam, Germany; technology development for surface chemistry; since 2000 head of the Surface Technology Group at the Fraunhofer-Institut für Angewandte Polymersforschung, Potsdam, Germany.
andreas.holland@iap.fraunhofer.de

RUTH KELLER
After training in paper conservation she got an M.A. in history of art and chemistry; 1979 – 1984 she worked in several conserva- tion projects of poor paper from the 19th and early 20th century, of mainly modern art and Islamic manuscripts. 1986-89 she was Head of Conservation Department of the German Technical Museum Berlin and started to develop concepts and methods for the museum conservation of technical objects. Since 1993 she has been Professor for Conservation of Industrial Heritage and Modern Material, HTW Berlin, University of Applied Sciences, where she still continues to develop the subject in theory and practice.
ruth.keller@tuebingen-berlin.de

KATHRIN KESSELER
Kathrin Kesseler is objects conservator and currently head of Conservation at Museum Ludwig, Cologne. After her study of conservation at the University of Applied Science in Cologne, she worked at the technique museum in Mannheim and got an advanced fellowship in geometry in Objects Conservation at the Isabella Stewart Gardner Museum in Boston/USA. The subject of her diploma thesis were preservation methods for objects made of celluloid that introduced her into the challenges and fields of plastic conservation that she still pursues. From 2003-2008 she was in charge of the ‘AXA Art Conservation Project in Coopera- tion with the Vitra Design Museum’. kesseler@museum-ludwig.de

LARS-CHRISTIAN KOCH
Prof. Lars-Christian Koch is since 2003 the Head of Department of Ethnomusico- logy and Berlin Phonogramm Archiv at the Museum of Ethnology in Berlin. Since 1987 he has conducted field research in India and South Korea regularly. After habilitating in 2002 with a study on Rabindra Sangeet, ’My Heart Sings Rabindra Sangeit‘ R. Die Lieder Rabindranath Tagores zwischen Tradition und Modernen’, he has been professor in the Universities of Vienna, Cologne and Chicago.
lkosch@mmb-spk-berlin.de

MARINA LEVI
Stewart Gardner Museum in Boston/USA. 2003-2007 as coordinator of Conservation science in Cologne, she worked at the museum conservation at the Istituto di Restauro (ISCR) in Rome, Italy. In 2006 she did a Master in Conservation Teaching at the Centro Conservazione e Restauro La Venaria Reale (CCR) in Turin and an internship on modern materials at the IGN. She has worked as a conserver since 1998 and in 2007-2008 as coordinator of the Conservation department of the CCR. Specialized on plastics conserva- tion, she is disseminating her knowledge teaching at universities and in other institutes.
anna.lag@tiscali.it

ANNA LAGANÀ
Anna Laganà is a conservator/researcher of modern materials, currently working at the Cultural Heritage Agency of the Netherlands (RCE) for the EU project POPART (Preservation Of Plastics ARFacts in museum collections). She graduated as a paintings and modern materials conservator at the Istituto Superiore per La conservazione ed il restauro (ISCR) in Rome, Italy. In 2006 she did a Master in Conservation Teaching at the Centro Conservazione e Restauro La Venaria Reale (CCR) in Turin and an internship on modern materials at the IGN. She has worked as a conserver since 1998 and in 2007-2008 as coordinator of the Conservation department of the CCR. Specialized on plastics conserva- tion, she is disseminating her knowledge teaching at universities and in other institutes.

DIETMAR LINKE
After training as measuring and controlling engineering he studied automation techniques / technical cybernetics. He was working as test engineer in Industry, later in a mechanical and model maker’s workshop. From 1984 he was engineer in Industry, later in a mechanical and model maker’s workshop. From 1984 he was engineer and later conservator at the Filmmuseum Potsdam. Following Conservation studies he got a Diploma in metal Conservation at FH (later HTW) Berlin. He has been teaching conservation of technical objects with emphasis on metal and modern materials at HTW Berlin since 1995 He was involved in conservation and research projects and has been supervisor of many diploma theses. He is working as freelance now.
3480-9@online.de

ANDRES LEGARRA
Born 1964 in Buenos Aires, Argentina. He obtained his M.A. in 1986 from the Universidade Federal de Santa Catarina, Brazil. From 1986-1988 he worked at the Centro de Encuentros de Artes Plasticas, RFK, Mexico City. From 1988-1990 he was the Director of the National Museum of Modern Art, Buenos Aires. From 1990-1992 he was the Director of the Museo de Arte Moderno del Conurbano (MAMCO) in Buenos Aires. From 1992-1993 he was an Assistant Professor at the Universidad de Buenos Aires. Since 1993 he has been head of the School of Arts at the Universidad de Buenos Aires, Argentina.
andres.legarra@ruba.edu.ar

RUTH KELLER
After training in paper conservation she got an M.A. in history of art and chemistry; 1979 – 1984 she worked in several conserva- tion projects of poor paper from the 19th and early 20th century, of mainly modern art and Islamic manuscripts. 1986-89 she was Head of Conservation Department of the German Technical Museum Berlin and started to develop concepts and methods for the museum conservation of technical objects. Since 1993 she has been Professor for Conservation of Industrial Heritage and Modern Material, HTW Berlin, University of Applied Sciences, where she still continues to develop the subject in theory and practice.
ruth.keller@tuebingen-berlin.de

KATHRIN KESSELER
Kathrin Kesseler is objects conservator and currently head of Conservation at Museum Ludwig, Cologne. After her study of conservation at the University of Applied Science in Cologne, she worked at the technique museum in Mannheim and got an advanced fellowship in geometry in Objects Conservation at the Isabella Stewart Gardner Museum in Boston/USA. The subject of her diploma thesis were preservation methods for objects made of celluloid that introduced her into the challenges and fields of plastic conservation that she still pursues. From 2003-2008 she was in charge of the ‘AXA Art Conservation Project in Cooperation with the Vitra Design Museum’. kesseler@museum-ludwig.de

LARS-CHRISTIAN KOCH
Prof. Lars-Christian Koch is since 2003 the Head of Department of Ethnomusico- logy and Berlin Phonogramm Archiv at the Museum of Ethnology in Berlin. Since 1987 he has conducted field research in India and South Korea regularly. After habilitating in 2002 with a study on Rabindra Sangeet, ‘My Heart Sings Rabindra Sangeit‘ R. Die Lieder Rabindranath Tagores zwischen Tradition und Modernen’, he has been professor in the Universities of Vienna, Cologne and Chicago.
lkosch@mmb-spk-berlin.de

ANNA LAGANÀ
Anna Laganà is a conservator/researcher of modern materials, currently working at the Cultural Heritage Agency of the Netherlands (RCE) for the EU project POPART (Preservation Of Plastics ARFacts in museum collections). She graduated as a paintings and modern materials conservator at the Istituto Superiore per La conservazione ed il restauro (ISCR) in Rome, Italy. In 2006 she did a Master in Conservation Teaching at the Centro Conservazione e Restauro La Venaria Reale (CCR) in Turin and an internship on modern materials at the IGN. She has worked as a conserver since 1998 and in 2007-2008 as coordinator of the Conservation department of the CCR. Specialized on plastics conserva- tion, she is disseminating her knowledge teaching at universities and in other institutes.
anna.lag@tiscali.it

DIETMAR LINKE
After training as measuring and controlling engineering he studied automation techniques / technical cybernetics. He was working as test engineer in Industry, later in a mechanical and model maker’s workshop. From 1984 he was engineer and later conservator at the Filmmuseum Potsdam. Following Conservation studies he got a Diploma in metal Conservation at FH (later HTW) Berlin. He has been teaching conservation of technical objects with emphasis on metal and modern materials at HTW Berlin since 1995 He was involved in conservation and research projects and has been supervisor of many diploma theses. He is working as freelance now.
3480-9@online.de

ANDRES LEGARRA
Born 1964 in Buenos Aires, Argentina. He obtained his M.A. in 1986 from the Universidade Federal de Santa Catarina, Brazil. From 1986-1988 he worked at the Centro de Encuentros de Artes Plasticas, RFK, Mexico City. From 1988-1990 he was the Director of the National Museum of Modern Art, Buenos Aires. From 1990-1992 he was the Director of the Museo de Arte Moderno del Conurbano (MAMCO) in Buenos Aires. From 1992-1993 he was an Assistant Professor at the Universidad de Buenos Aires. Since 1993 he has been head of the School of Arts at the Universidad de Buenos Aires, Argentina.
andres.legarra@ruba.edu.ar
 Objects Conservation at the Metropolitan Museum of Art in New York. Currently, she is Assistant Conservator for Modern and Contemporary Art at the Denver Art Museum in Denver, Colorado.


Dana Melchar is a Senior Furniture Conservator at the Victoria & Albert Museum. As a generalist within the Furniture Conservation studio, she works on many different types of organic materials including wood, plastic, bone, ivory and turtle shell. She graduated with a Masters in Science in Art Conservation, with a specialization in Furniture Conservation, from the Winterthur/University of Delaware Program in Art Conservation. Additionally, she holds a Bachelor of Arts in English Literature from Roger Williams University and a Bachelor of Science in Chemistry from University of Rhode Island. She started her education as a trainee in Cologne (private workshop), Berlin (private workshop) and Hamburg (Museum für Kunst und Gewerbe, private workshop). In 2006, she started her diploma studies at the University of Applied Sciences Cologne. In the course of her studies she spent her practical semester in the National Museum in Copenhagen in 2007. Since spring 2008 Anja has been employed at The National Museum of Denmark in the Conservation Department’s Building and Artifacts section. She usually works with the more practical side of conservation and restoration of church inventory but accepted the opportunity to participate in the POPART project in September 2009. Anja has contributed to pilot projects focusing on the effects of mechanical cleaning of PMMA and PVC.

Anja Liss Petersen graduated with a Master Degree from The Royal Danish School of Conservation in Copenhagen in 2007. Since spring 2008 Anja has been employed at The National Museum of Denmark in the Conservation Department’s Building and Artifacts section. She usually works with the more practical side of conservation and restoration of church inventory but accepted the opportunity to participate in the POPART project in September 2009. Anja has contributed to pilot projects focusing on the effects of mechanical cleaning of PMMA and PVC.

Dana Melchar

Kate Moomaw

MARIÉ-ANNE LOEPER-ATTIA


Dana Melchar

Kate Moomaw

ROSSIN MORRIS

Rossin Morris trained at The Textile Conservation Centre, Southampton University, receiving an MA in Textile Conservation in 2003. After graduating she worked for Glasgow Museums, The British Museum, Konserveringsafdelingen Langelands Museum Denmark and the National Museums of Scotland in Edinburgh, before joining the Victoria and Albert Museum in 2006. She currently works within the Furniture, Textiles and Frames section of the Conservation department. Main research interests and specialisms are in modern materials as well as composite objects constructed from organic materials such as feather, fur, straw and leather.

Dana Melchar

Kate Moomaw

ROBERTO OLLAI

Degree in Physics in 1983. He is currently a senior researcher of the Institute of Applied Physics of the Italian National Research Council (CNR), and President of ELab Scientific srl, a spin-off enterprise of CNR. His main research interest are currently in electromagnetic, dielectric spectroscopy (in particular applied to the cultural heritage) and in microwave theory and techniques. Responsible of the CNR research group on “Advanced instrumentation for diagnostics and monitoring of cultural heritage and environment”, his scientific activity is documented by about 90 publications and 5 patents.

Rossin Morris

Dana Melchar

Thea van Oosten

THEA VAN OOSTEN

Dr. Thea B. van Oosten is senior conservator scientist employed by the Cultural Heritage Agency of the Netherlands (RCE), Science department since 1989. She is currently engaged in Fourier Transform Infrared Spectroscopy (FTIR) analyses of plastics in objects of cultural heritage and modern materials in modern and contemporary art objects. In 1989 she started the research programme on modern materials and she has been developing that ever since. Specialised in the conservation of modern and contemporary art and design objects of Cultural Heritage she has contributed to several publications and books, such as ‘Modern Art, who Cares’, ‘Plastics, Collecting and Conserving’ and ‘Plastics in Art’. Currently the research is focused on the POPART (EU) project. She is treasurer of the Directory Board of ICOM-CC.

Thea van Oosten

REBECCA PLOEGER

Rebecca Ploeger, holds a B.Sc. and M.Sc. in Engineering Chemistry from Queen’s University, Canada, and a Ph.D. in Chemical Sciences from the University of Torino, Italy. Her research has mainly focused on artists’ acrylic and acrylic paints, and she is now broadening her research to many types of other modern materials. Currently she has a post-doctoral research position at the Institute of Applied Physics “Nello Carrara” IFAC-CNR, Florence. He has been working on spectroscopic investigations of works of art since 1991. His main focus is on pigment characterization using totally non-destructive spectroscopic, imaging and X-ray techniques.

Rebecca Ploeger

MARCELLO PICOLLO

Marcello Picollo is a Researcher at the Institute of Applied Physics “Nello Carrara” IFAC-CNR, Florence. He has been working on spectroscopic investigations of works of art since 1991. His main focus is on pigment characterization using totally non-destructive spectroscopic, imaging and X-ray techniques.

Marcello Picollo

THEA VAN OOSTEN

Dr. Thea B. van Oosten is senior conservator scientist employed by the Cultural Heritage Agency of the Netherlands (RCE), Science department since 1989. She is currently engaged in Fourier Transform Infrared Spectroscopy (FTIR) analyses of plastics in objects of cultural heritage and modern materials in modern and contemporary art objects. In 1989 she started the research programme on modern materials and she has been developing that ever since. Specialised in the conservation of modern and contemporary art and design objects of Cultural Heritage she has contributed to several publications and books, such as ‘Modern Art, who Cares’, ‘Plastics, Collecting and Conserving’ and ‘Plastics in Art’. Currently the research is focused on the POPART (EU) project. She is treasurer of the Directory Board of ICOM-CC.

Thea van Oosten
Barbara Schertel graduated from the London Metropolitan University with a Higher National Diploma (HND) in Furniture Restoration and a Bachelor of Science (BSc) in Furniture and Design in Berlin, Germany. She is currently working as a freelance conservator of Modern Art, Architecture and Design in Berlin, Germany.

Barbara Sommermeyer is working since 2000 at the Hamburger Kunsthalle / Gallery of Contemporary Art. After a graduate degree in art history and archaeology and a 3 years pre-program in conservation studios and museums in Munich, Brunswick, Cologne and Hamburg she finished a master degree as paintings and sculpture conservator in 1998 at the State Academy of Arts and Design Stuttgart. With a two years grant from the State Baden-Württemberg she also worked in Liverpool at the Conservation Centre and in London at Tate Modern. She was co-founder of the working group of modern art and modern materials (MKKM) of the German Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Barbara Sommermeyer is a professor at the Academy of Fine Arts Dresden. Internships in Burghausen, Bavaria with private conservator M.Kueffner, followed by internships in Karlsruhe’s State Museum and Berlin’s Old National Gallery. In 2003, she began her five-year study in technology, conservation and restoration of paintings on canvas at the Academy of Fine Arts Dresden. In Burghausen, Dresden, Boston USA, Dunedin in New Zealand, and Copenhagen in Denmark followed. Her scientific thesis evolved from collaboration with Yvonne Shashoush within POPART on the cleaning of PMMA, with support of a COST-STSM-stipend. Currently, she is finishing her diploma-thesis.

Maxim Tafelski After first practical experiences in several workshops she studied Conservation of Industrial Heritage at HTW Berlin. Several practical internships gave her experiences. She wrote her thesis on a rescue apparatus from the German Mining Museum. A large diversity of materials had to be scientifically tested, searched and conserved. Because of the importance of elastomer materials in rescue technique her diploma thesis, which has been published in metallia 2009 gave the idea for the project ‘antiaging’. She is now conservator at the Filmmuseum in Berlin. She is now a fellow researcher at the Department of Chemistry of the University of Turin, focusing on the characterization of the production technology of ancient ferrous artefacts. Since January 2009 she has been working as PhD student in Materials Engineering. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Lucia Toniolo Since 2006 is associate professor of Material Science and Technology at the Faculty of Civil Architecture of the Politec- nico di Milano. Former Senior Researcher of the italian National Research Council, is now the vice-president of the Centre for the Con- servation and Valorisation of Cultural Her- itage of the Politecnico di Milano. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Claire Valageas has a master degree of physics applied to the conservation of Cultural Heritage and a degree of art his- tory, specialized in contemporary art. She and Alain Colombini have developed the research programme on the characterization and degradation of fluorescent colours in works of art.

ClaireValageas@hotmail.com

Francesca Toja received her MSc in Science and Technology for Cultural Heritage at the University of Torino (Italy) in 2008. From July to December 2008 she has been working as a fellow researcher at the Département of Chemistry of the University of Turin, focusing on the characterization of the production technology of ancient ferrous artefacts. Since January 2009 she has been working as PhD student in Materials Engineering. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Lucia Toniolo Since 2006 is associate professor of Material Science and Technology at the Faculty of Civil Architecture of the Politec- nico di Milano. Former Senior Researcher of the italian National Research Council, is now the vice-president of the Centre for the Con- servation and Valorisation of Cultural Her- itage of the Politecnico di Milano. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Claire Valageas has a master degree of physics applied to the conservation of Cultural Heritage and a degree of art his- tory, specialized in contemporary art. She and Alain Colombini have developed the research programme on the characterization and degradation of fluorescent colours in works of art.

ClaireValageas@hotmail.com

Francesca Toja received her MSc in Science and Technology for Cultural Heritage at the University of Torino (Italy) in 2008. From July to December 2008 she has been working as a fellow researcher at the Département of Chemistry of the University of Turin, focusing on the characterization of the production technology of ancient ferrous artefacts. Since January 2009 she has been working as PhD student in Materials Engineering. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Lucia Toniolo Since 2006 is associate professor of Material Science and Technology at the Faculty of Civil Architecture of the Politec- nico di Milano. Former Senior Researcher of the italian National Research Council, is now the vice-president of the Centre for the Con- servation and Valorisation of Cultural Her- itage of the Politecnico di Milano. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Claire Valageas has a master degree of physics applied to the conservation of Cultural Heritage and a degree of art his- tory, specialized in contemporary art. She and Alain Colombini have developed the research programme on the characterization and degradation of fluorescent colours in works of art.

ClaireValageas@hotmail.com

Francesca Toja received her MSc in Science and Technology for Cultural Heritage at the University of Torino (Italy) in 2008. From July to December 2008 she has been working as a fellow researcher at the Département of Chemistry of the University of Turin, focusing on the characterization of the production technology of ancient ferrous artefacts. Since January 2009 she has been working as PhD student in Materials Engineering. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Lucia Toniolo Since 2006 is associate professor of Material Science and Technology at the Faculty of Civil Architecture of the Politec- nico di Milano. Former Senior Researcher of the italian National Research Council, is now the vice-president of the Centre for the Con- servation and Valorisation of Cultural Her- itage of the Politecnico di Milano. Her research activity is completely devoted to the knowledge and conservation of materials in arts, architecture and design. She has recently been appointed scientific coordinator for the conservation of Michelangelo’s Pietà Ron- danini and the Milan Cathedral façade. She is member of the scientific advisory board of the ‘Conservators Association (VDR) in 2001 and joined the board as treasurer (2007-2009). sommermeyer@hamburger-kunsthalle.de

Claire Valageas has a master degree of physics applied to the conservation of Cultural Heritage and a degree of art his- tory, specialized in contemporary art. She and Alain Colombini have developed the research programme on the characterization and degradation of fluorescent colours in works of art.
ROBERTA VERTERARO
Roberta Verteraro is a freelance conservator of modern and contemporary art with a focus on the conservation of plastic materials. Among her major collaborations as a conservator are: MAP (Museo Arte Plastica) di Castiglione Olona, Museo Nazionale del Cinema of Torino, Triennale Design Museum of Milan and GAM (Galleria d’Arte Moderna) of Torino. For many years she has been conducting research on the conservation of plastics in collaboration with the University of Torino.
roberta.verteraro@triennale.it

FRIEDERIKE WAENTIG
Professor for the Conservation of Wooden Artifacts and Modern Materials at the University of Applied Sciences Cologne. Friederike was previously: Senior Conservator at the Art and Exhibition Hall Bonn; Conservator at the Conservation Center Düsseldorf; Conservator at the Museum for Applied Art Cologne. She obtained her degree at the Otto-Friedrich-University of Bamberg majoring in Heritage Preservation, with minor studies in folklore and building history. Her Ph.D. thesis was entitled “Synthetic Materials in Art: research from the conservation point of view”. Her Master’s thesis in Heritage Preservation, Otto-Friedrich-University Bamberg, was “Technical and Industrial Monuments – Definition, History and Preservation” and her Master’s degree from the University of Applied Sciences Cologne, was on Conservation specialising in Wooden Artifacts. She spent a practical semester in East-Berlin (former GDR) at the Museum for Applied Art Berlin and wrote a thesis: “History of Furniture Coatings in the 20th Century - especially the Coatings of the Bauhaus-Time”
friederike.waentig@fh-koeln.de

CHRISTOPH WENZEL
Christoph Wenzel (Dipl. Rest. (FH), M.A.) graduated from the University of Applied Sciences Cologne in the Department for the Conservation of Wooden Artifacts and Modern Materials in 2005 with his diploma thesis about emergency planning for museums (published in 2007). During 2010 - 2011 he attended the master program in conservation and restoration at the University of Applied Sciences Cologne where he received his degree with his thesis about the inherent vice of viewer participation in Fluxus art objects. After working as freelance conservator he became the head of the newly established department of preventive conservation at the Bavarian Administration of Palaces, Gardens and Lakes in Munich in 2006. Since June 2009 he works as a research assistant on the project “Preservation of the GDR-culture of everyday life made of plastics” at the University of Applied Sciences Cologne.
christoph.wenzel@fh-koeln.de

SHUYA WEI
Shuya Wei is a scientist at the Academy of Fine Arts in Vienna, Austria. Her work focuses on the study of organic materials used in artworks by a combination of Py-GC/MS, GC/MS and FTIR techniques.
syueyi66@hotmail.com

QUNXI ZHANG
Qunxi Zhang is a conservation scientist at the Lab. for Conservation and Restoration of Shaanxi History Museum.
ACKNOWLEDGEMENTS

This publication was made possible with the financial support of the following institutions and companies:

Gerda Henkel Stiftung Düsseldorf.
Schenker Deutschland AG
Deffner und Johann
Alphaform AG
Halbe Rahmen
Kremer Pigmente
Hausenkamp Internationale Transporte GmbH
Plank

This publication was printed with the support of the Gerda Henkel Stiftung, Düsseldorf

PHOTO CREDITS

The publisher and authors would like to thank the following photographers and copyright holders for the use of their material (page numbers are given in parentheses):

(6, 8, 10 – 14) The Metropolitan Museum of Art, New York; (16) SF MOMA, Ian Reeves; (18) SF MOMA, © Diller + Scofidio; (20) SF MOMA, Ian Reeves; (22, Fig. 4) SF MOMA, © Thom Fougères and Anna Rauber; (22, Fig. 5) SF MOMA, © Marcel Wanders; (23) Felix Kempf, Munich; (40, Fig. 7) The Neue Sammlung, The International Design Museum Munich; (42) Felix Kempf, Munich; (60, 62, Fig. 1, 2) Museum Ludwig, Cologne; (68, 81, 82, 83, Fig. 7) Die Neue Sammlung, The International Design Museum Munich; (69) Felix Kempf, Munich; (71) Fotografie, Die Neue Sammlung, The International Design Museum Munich; (72) Tabakmuseum Bild 183-40576-0001-001, Stolp; (73) Fotografie, Die Neue Sammlung, The International Design Museum Munich; (85, Fig. 1) The Neue Sammlung, The International Design Museum Munich; (85, Fig. 2) Frank Schreiner, Berlin; (86) Die Neue Sammlung, The International Design Museum Munich; (88) Felix Kempf, Munich; (92) © Marcel Wanders; (93) Alexander Laurenzo, Die Neue Sammlung, The International Design Museum Munich; (94) Felix Kempf, Munich; (96) © Diller + Scofidio; (97) © Diller + Scofidio; (99) © Diller + Scofidio; (100) Die Neue Sammlung, The International Design Museum Munich; (101) Die Neue Sammlung, The International Design Museum Munich; (102) Die Neue Sammlung, The International Design Museum Munich; (104, Fig. 1) Die Neue Sammlung, The International Design Museum Munich; (104, Fig. 2) Frank Schreiner, Berlin; (105–107) Die Neue Sammlung, The International Design Museum Munich; (108) Felix Kempf, Munich; (110, 112–118, 120–123) Victoria and Albert Museum, London; (125) MOCA Museum of Modern Art, New York; (144, 146, 147, 149) MOCA Museum Ludwig, Cologne; (145) Felix Kempf, Munich; (162) © The Metropolitan Museum of Art, New York; (163) © Diller + Scofidio; (164) Felix Kempf, Munich; (183) Felix Kempf, Munich; (185) © Diller + Scofidio; (187) Felix Kempf, Munich; (189) © Diller + Scofidio; (194) © Diller + Scofidio; (196) COAF-Archiv, 1978; (198, 199) Museum of Modern Art, New York; (200) Bergbau Museum, Bochum; (202, Fig. 1) Bergbau Museum, Bochum; (202, Fig. 2) AEG-Archiv, 1978; (203) Hotelmuseum Pestalozzi; (204) Hafenmuseum, Hamburg; (214) © KP Brehmer; (216) © KP Brehmer; (218–223) Musée de la Musique, Paris; (251, 252, 254) Alexander Laurenzo, Die Neue Sammlung, The International Design Museum Munich

Not all owners of rights relating to illustrations have been traced. Claimants to such rights are invited to contact:

Die Neue Sammlung, The International Design Museum Munich

FRONTISPIECE

Felix Kempf
FX68 München
FUTURE TALKS

THE CONSERVATION OF MODERN MATERIALS IN APPLIED ARTS AND DESIGN

OCTOBER 22/23 7:009

DIE NEUE SAMMLUNG THE INTERNATIONAL DESIGN MUSEUM MUNICH