Foreword of Bertrand Lavédrine, project coordinator and Yvonne Shashoua, conservation scientist

The development of synthetic polymers, or plastics, is one of the main achievements of the chemical industry during the 20th century. Due to their remarkable properties they have been used as an alternative to natural products and have allowed new applications that would have never been possible before. Plastics are today everywhere in our daily life; it is difficult to imagine a life without plastics whether it is our polyethylene carrier bags used to bring shopping home from the supermarket, poly(vinyl chloride) (PVC) waterproof clothing to protect us from the weather, polycarbonate compact discs and DVDs to store our favourite music and pictures or the acrylonitrile butadiene styrene (ABS) building bricks our children play with. Because plastic reflects daily life since the early 1900's and contemporary art since the 1960's, museums and galleries all over the world have growing collections of it. But any new discovery has its dark side, its weaknesses: plastics are not an exception and the downside is all about permanence. There are complaints about the environmental impact of plastics due to the highly stable polymer and their component residues that remain in land fill sites for centuries. This might lead to the common misconception that plastics last forever. The conservation community is desperate about the short life expectancy of plastics! Such apparently contradictory statements are reflecting the huge diversity of plastic families having very different behaviour: some plastics have a shorter lifetime than others, a brief three to thirty years. Being commercial products, plastics are simply not designed to last forever and such a demand is unrealistic. Plastics react with oxygen, water or pollutants and the reaction manifested as discolouration, stickiness or cracking. Unlike the development of new surfaces on bronze sculptures with time, discolouration in plastics is not called patina and valued like as on an antique bronze, but just the opposite. If we can often, by looking and touching, identify that the object is made of plastic, most of the time, it is much more difficult to guess what kind of plastic it is. This is one of the common problems for the recycling industry but also for museums to plan conservation issues. A survey carried at the Victoria and Albert Museum and in the British Museum identified more than 7500 synthetic polymer containing objects and among them more than 12% requires urgent conservation decisions. This number might be considered as a low figure, nevertheless it has to be realised that the survey takes into consideration final stage of deterioration process, when it is made visible by physical changes induced deformation, shrinkage, cracking, surface deposits, discoloration, gloss changes. This result does not mean that the 88% of the collection will stay in good condition for long. Museums have a responsibility to preserve their collections for the enjoyment and education of future generations and this is especially important with respect to plastics. The specialism we know today as plastics conservation was first established in the 1980's so is still relatively new compared with, say, textile conservation. In 1993, a committee of curators and conservators, representing six major museums of modern and contemporary art in the Netherlands concluded that there were no generally accepted methods and criteria for solving the conservation problems of non-traditional material objects of modern art and there was little insight into the nature and use of modern materials and knowledge concerning the composition and ageing of modern materials in art works was difficult to access. This committee was at the origin of the foundation of the conservation of modern and contemporary art, SBMK (www.SBMK.nl). A survey carried out in Canadian museums (http://www.cci-icc.gc.ca/about-apropos/nb/nb36/act-eng.aspx) recognised the treatment, identification, conservation methods, deterioration and storage materials for plastic artefacts as a most important conservation problem that should be addressed. Ten years ago, conferences about plastics took place every second year but interest and progress in plastic conservation are growing rapidly and today there are at least three conferences per year and most are sold out. The deterioration of plastics has a relatively long induction period followed by accelerating degradation and resulting in a rapid destruction of the object. Film archives have experienced this problem. It has been shown that cellulose triacetate deterioration takes around 40 years in a temperate climate before being detectable by an ethanoic acid (acetic acid) smell – the characteristic smell of vinegar – and physical distortion of film base (Reilly 1993). Before 1980, no film archives were really aware about this so called "vinegar syndrome". Twenty years later it became the major problem for film archives over the world.

It must be accepted that the degradation of plastics is due to irreversible chemical reactions. Although it cannot be reversed it can, given the right conditions, be slowed down. It is nowadays a priority to develop a strategy for the preventive conservation and maintenance of modern material artefact collections. That is the reason why, from 2008 to 2012, the European Commission established and part funded the Preservation Of Plastics ARTefacts research project, so called POPART project (Grant agreement n° 212218) a unique opportunity to develop at a European scale a strategy for the preventive conservation and maintenance of modern material artefacts collections. The project focussed on four priorities: the identification of plastics in museums, the plastic collection survey, the degradation assessment of plastics and the active conservation. These four priorities serve as the backbone for the content of this book.

The first chapter gathers research results carried out on plastic identification. Prior to any decision, the main issues are to identify the different types of plastics in order to suggest correct treatment and storage strategies and risk assessment. Some plastics can be harmful when in contact with other materials; some are sensitive to cleaning with water, etc. An experienced conservator can distinguish one plastic from another by the smell, sight or feel. However, for most of conservation professionals, destructive tests that include sampling, burning and dissolving samples are necessary. The goal was to develop and evaluate analytical tools and methodologies for identification the nature of polymer of plastics art objects in museums. Plastics can be identified by using infrared spectroscopy and Raman spectroscopy. The use of IR spectroscopy to identify the polymer materials has become widespread in the conservation field. However, apart from some references by the Infrared and Raman Users Group (IRUG) see http://www.irug.org few extensive reference spectral sources of synthetic and historical polymer materials are available. There exists, portable infrared spectrometers for in-situ analysis, such instruments can been taken to museums to non-destructively analyse artefacts. In recent years Near Infrared (NIR) spectroscopy has developed considerably for the food and pharmaceutical industries and in polymer research. In particular, it is suitable for identifying polymers that were used in the production of plastic artefacts now found in museums. NIR was investigated and a data base of spectra was produced. Also, spectroscopy in the mid infrared region is a powerful method for identifying materials, because the of the so called fundamental vibrational modes, which are expected in this region, that offer a "fingerprint" spectrum of molecules or crystals and allow an identification of the material under investigation. Furthermore, the technique was well suitable for multivariate analysis of the recorded spectra in order to assign a given artefact to a set of possible constituting materials. Finally, some destructive analytical tests were necessary to fully characterise the plastics. Pyrolysis gas chromatography-mass spectroscopy (Py-GCMS) analysis was applied to cover and evaluate the broad spectrum of possibilities that are offered to museum staff, scientists or conservators. Pyrolysis alone is a useful and rapid procedure for subsequent gas chromatography-mass spectroscopy (GC-MS) analysis of the organic fraction present in polymer based objects. Its principal advantages are the small sample sizes required for analysis and the possibility of simultaneously characterising different classes of organic and some inorganic components. It helps to complete the characterisation of many additives. Other analytical techniques were also evaluated such as Evolved Gas Analysis. In order to assess the advantages and limitations of those analytical approach, a sample collection of plastics artefacts of about a hundred standard and reference plastic objects representing the major polymer families was assembled (SamCo: Sample Collection).

Chapter two gathers work carried out on museum collections. During ageing, many plastic artefacts exhibit typical deterioration patterns. Any modification of the physical or chemical properties may lead to loss of stability of the overall formulation. This causes blooming and exudation at the polymer surface of some chemicals. A survey form was established, and conservators investigated collections of plastics based objects in order to assess the most common visible deterioration problems found in these collections. Chemical and physical degradation in the form of discoloration, change in opacity, crazes, cracks or changes to surface texture and distortion were documented. Five museum collections were selected for surveying. Such surveys help to determine future priority and to provide samples for analysis of degradation products or for cleaning tests. It serves as a reference to assess frequency and type of deteriorations found in collections. Analyses were carried out to identify the nature of deposit found on some objects and any off gassing products. An object constituted of different polymers in a shape of a doll so called “Polly” was conceived in the framework of the project and displayed in order to assess and monitor changes and degradations during natural ageing in different environmental conditions.

Chapter three focuses on degradation assessment. Conservators of plastics and scientists agree that some synthetic polymer types in museum collections require more attention. Degradation paths for poly(vinyl chloride) have been investigated and reported along with cellulose nitrate and cellulose acetate among others (Wypych, 2008). These polymers have been studied extensively, primarily in the field of conservation of movie films. This prior knowledge was extended to three dimensional objects through this project. Different polymers were thermally or photo chemically artificially aged and then characterised by using chemiluminescence, thermogravimetry, differential scanning calorimetry, Fourier Transform Infrared spectroscopy etc. Headspace Solid Phase Micro Extraction (SPME) coupled to GC-MS has been used for volatile organic compound extraction, concentration, separation and characterisation. Such non-invasive analytical techniques proved to be suitable not only for identifying plastics but also for the estimation of the degradation extent.

Lastly, chapter four addresses repair and interventive conservation of plastics which is so far underdeveloped. Almost all plastic artworks need surface cleaning during their useful lifetime. However, many plastics are highly sensitive, especially when deteriorated, to solvents including water. Inappropriate treatments may result in irreversible damage. Often, the affected plastics exhibit chemical or physical degradation manifested by shrinkage, crazing, stress cracking, discolouration, surface deposits, brittleness or tackiness. If not removed, dust and other residues may act as initiation points for additional deterioration. Dust may also change the significance and understanding of the object. Nonetheless, there has been very little research in the field of surface cleaning of polymers and in the project we have evaluated mechanical, aqueous and non-aqueous cleaning techniques for their effectiveness at removing contaminants and their long term effects on stability, thereby contributing to the work currently being done by conservators to care for modern materials. A large number of cleaning techniques were evaluated. Some exploration on consolidation processes using aminoalkylalkoxysilane, drying oil, acrylic resins were investigated for their effect on deteriorated polyurethane foam. For such cases, only a strengthening of the object can prevent its total destruction. This "last chance" approach consists in treating porous material with consolidants. Coatings on objects that require a protective layer are also reported in the last chapter.

All these results, on identifying, exhibiting, storing, documenting and cleaning plastics objects in museum are contributing to establish a strategy for improving the life expectancy and reducing the speed of degradation of museums objects made of plastics. Benefit will be measurable in terms of better assessment of the impact of environment and then produce information about effect of the museum environment. The value of this approach was to bring together experts from different fields in natural science but also small and medium enterprises (SMEs) that are able to introduce tools to better assess plastic composition for museum purpose along with a data base posted on the web containing all information dealing with polymer identification. The awareness for conservation of plastic objects is new in Europe and there is a growing interest in the conservation community. In some places the research has been very active for many years, in other, this task is newly addressed. The outputs of this project have been made widely accessible and contribute to the efficient use of resources by avoiding duplicate research and help bring together researchers. This will help to bring the community to the front edge of knowledge and a common agreement of strategy for conservation. Such an ambitious project was not only the opportunity to increase the volume and depth of knowledge in the field of preservation of plastics but also to increase the general public awareness of plastic preservation and the needs of more research needed. This was the opportunity to develop and strengthen a network of professionals and create new synergies between conservators and scientists. In total, more than 50 professionals have been involved for 42 months on this task and this book gathers the results that will interest conservation scientists, conservators and curators. The project was carried out within 12 partners in 8 countries. We have to express our gratitude to the Getty Conservation Institute (USA) who joined the POPART project and contributed its own resources to the successful outcomes of POPART.

Other results have been published and disseminated in different scientific journals and conferences; nevertheless we found it was necessary to present significant knowledge and results gained during this project in a conference and in this book. I would like to take the opportunity to thank all the partners who have contributed and the project advisory committee. The advisory committee was constituted of four individuals selected for their scientific expertise of the subject: Oscar Chiantore (Italy), Marina Pugliese (Italy), Friederike Waentig (Germany), Colin Williamson (UK). They played an important role in advising and following the project as the work package leaders who collected and organised all the chapters content: Thea van Oosten, Mauro Bacci, Jozef Rychlý and Yvonne Shashoua.

We do hope that many similar international projects will follow since it is now the time of caring our modern and contemporary heritage.