Slutrapport / Final report

Foga samman plast – vad händer på lång sikt?

Joining plastics together – what happens over time?

En jämförande studie av limning av styrenplast och dess långtidspåverkan.

A comparative study of seven different adhesives for adhering polystyrene and their long-term effect.

Författare / Authors:
Thea Winther, Riksantikvarieämbetet
Judith Bannerman, Riksantikvarieämbetet
Hilde Skogstad, Riksantikvarieämbetet
Mats KG Johansson, Kungliga Tekniska Högskolan
Karin Jacobson, Swerea KIMAB
Johan Samuelsson, Swerea KIMAB

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Riksantikvarieämbetet 2013
Box 1114
621 22 Visby
www.raa.se
riksant@raa.se

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Abstract

To guide conservators in their decisions in active conservation of polystyrene materials, seven adhesives were tested before and after light ageing. The material was investigated through the assessment of working properties, appearance, colour measurement, tensile testing, hardness measurement, assessment of break type, SEM-imaging, ATR-FTIR-imaging and assessment of reversibility. Based on a survey among conservators, the adhesives included were acrylates (Paraloid B72 in acetone:ethanol, or ethanol, Paraloid B67 in isopropanol, Primal AC-35, Acrifix 116), epoxies (Hxtal NYL-1, Araldite 2020) and one cyanoacrylate (Loctite Super Attak Precision). Adhesives were tested on extruded sheets of transparent, general purpose polystyrene and white HIPS applied on joined edges and as an open layer. The study showed that there is an effect on the plastic from the solvent-borne acrylics and the cyanoacrylate based adhesive. Damage to the plastic could be seen for Acrifix 116 and Loctite Super Attak Precision. The cyanoacrylate was weakened on transparent polystyrene while Acrifix 116 and Primal AC-35 on HIPS were strengthened after ageing. In general, the cyanoacrylate was the strongest and Paraloid B67 the weakest. Most adhesives showed yellowing after ageing apart from Acrifix 116 and Hxtal NYL-1. Reversibility was only shown for the Paraloids and Primal AC-35.

Summery

Plastic materials are a part of our cultural heritage and therefore are present in our museum collections. Damage such as cracks and breakage will occur with handling and the process of time, and there are occasions when an adhesive bonding is necessary. For preservation purposes it is important to choose an adhesive that will be stable over time and have as little impact as possible on the object. In order to contribute with knowledge to guide conservators in their

decisions in active conservation of polystyrene materials seven adhesives have been tested for their effect on the plastic material before and after light aging.

The Swedish National Heritage Board has, together with KTH, Royal Institute of Technology and the research institute Swerea KIMAB, investigated the impact of adhesives for treating general purpose and high impact polystyrene in the museum environment studying such factors as stability, impact on original material, working properties, aesthetics and aging of the adhesive join. Furthermore, the question of reversibility has been considered and some of the tested adhesives were applied to three-dimensional objects.

Methods applied before and after light ageing were visual assessment, colour measurement, ATR-FTIR-imaging, SEM-imaging, tensile testing, assessment of working properties, type of break and hardness testing.

The chosen adhesives were three acrylates in solvent (Paraloid B72 in acetone: ethanol, or ethanol, Paraloid B67 in isopropanol and Acrifix 116), one acrylate in dispersion (Primal AC-35), two epoxies (Hxtal NYL-1, Araldite 2020) and one cyanoacrylate (Loctite Super Attak Precision). They have been tested on extruded sheet material of transparent general purpose polystyrene and white high impact polystyrene (HIPS) applied on adhered edges and as an open layer.

Results showed an effect on the plastic from the solvent-borne acrylics and the cyanoacrylate. A damaging effect to the plastic could be seen for Acrifix 116 and Loctite Super Attak Precision. The effect of solvents on the plastic is noticeable in FTIR-imaging and to a greater extent for the two-phase system of HIPS. For the samples with cyanoacrylate a surface pattern on the plastic was visible in the SEM.

The strength of the adhesive joins was not severely affected by light ageing for most of the tested adhesives in terms of tensile strength. The cyanoacrylate was weakened on the transparent plastic, but for Acrifix 116 (on both transparent and HIPS) and Primal AC-35 on HIPS, the bond was strengthened. In general, the cyanoacrylate was the strongest and Paraloid B67 the weakest. None of the adhesives resulted in a cohesive break in the plastic. Adhesive breaks could be seen for the epoxies. The epoxies did not adhere well to polystyrene.

Most adhesives showed visible yellowing apart from Acrifix and Hxtal NYL-1. None of the tested adhesives matched the refractive index of polystyrene which results in visible bonds on transparent polystyrene. The bonds of the adhered edges for the cyanoacrylate and Aralditite 2020 showed visible yellowing.

Reversibility was possible for the Paraloids and the dispersion Primal AC-35. It was possible to remove the epoxies and Acrifix manually with some difficulty. The cyanoacrylate was not possible to remove.

Keywords: polystyrene, PS, adhering, light ageing, HIPS, GPPS, adhesives, plastics.

1. Introduction

Plastic objects and materials have become a large part of our cultural heritage in the last hundred years. Objects of plastic, or containing parts of plastic material, are present in collections of art, cultural history and design. They tell us about our history and contribute to the understanding of our culture. Research for their preservation has to a great extent, focused on preventive measures and now the need for the investigation into active preservation methods is evident.

Damage such as cracks and breakage will occur with handling and the progress of time, and there are occasions when an adhesive bonding is necessary. For preservation purposes it is important to choose an adhesive that will be stable over time and have as little impact as possible on the object. This report will cover a project investigating the long term effects of adhesive joining of polystyrene.

1.1 Background

During 2011 a review within the field of preservation of plastic materials was performed at The Swedish National Heritage Board (Dnr 351-949-2011 Probleminventering och förstudie inom vård och konservering av plastmaterial). The starting point for this review was the prior FoU-project Morgondagens kulturobjekt performed at The Swedish National Heritage Board 2005-2008. The project concerned damage, degradation and analysis of plastic materials in Swedish museum collections. A survey including fifty-one Swedish museums and a more extensive damage assessment at nine museums was performed. The museums in the survey have collections of art, design and cultural history objects.

The survey showed that 10% of the objects were damaged and 3% were in such a state that they were regarded as a loss. The most commonly observed damage were cracks, discolouration, dirt accumulation and abrasion. The project concluded that there was a need for research in active conservation methods for the preservation of plastic materials.

The review in 2011 included a literary survey, a research overview, and contact with conservators, curators and researchers. Considering the damage present in various collections, the type of damage and what needs were expressed by conservators, the area of adhesive joining was chosen. An application for FoU-funding was submitted and accepted for this project. The preservation of plastic materials is in congruence with the focus theme of modern materials stated in Riksantikvarieämbetets FoU-program 2012-2016 (Riksantikvarieämbetets FoU-program 2012-2016 för kulturmiljöområdet).

1.2 Objectives and aim

The aim of the project is to contribute with knowledge within the field of active conservation of plastic materials. It will also provide guidance in choosing the best method and material for the preservation of polystyrene objects in collections today. The investigation has focused on the following questions:

- How stable are the adhesives that are used by conservators? What will happen to the join upon ageing?
- What effect do the adhesives have on the original material? What chemical and mechanical changes will take place?
- How suitable and compatible are the adhesives with this specific plastic?

Furthermore, the question of reversibility has also been considered.

1.3 Relevance and usefulness of project

During the last 100 years plastic materials have become an important part of human life and are now a part of our cultural heritage. Plastic objects or objects containing plastic material are represented in museum collections within a wide variety of classifications. There is a need for further research into active conservation methods for the preservation of plastic materials.

There are occasions when an adhesive bonding of these materials is essential. Joining of objects can be considered necessary for several reasons such as increasing the understanding and readability of the object or as a measure to prevent further degradation. For preservation purposes it is important to choose an adhesive that will be stable over time and have as little impact as possible on the object. The conservator will need to know what adhesive can be used for what kind of plastic, how it can affect the object and how it will age. This project contributes with knowledge of the long-term effects of adhesives on polystyrene objects. Polystyrene is one of the most common plastics and a damage survey of Swedish collections shows it to be one of the most frequent plastics with breaks and cracks (Nord et al., 2008). The need for finding appropriate adhesives for polystyrene has been pointed out by conservators (Moomaw et al., 2009). Furthermore, there has been little research into repair of these objects. This study is designed to look at the interaction between substrate and adhesive and not only at the performance of the adhesive. The results will give conservators guidance in choosing adhesives in their daily work.

1.4 Previous research

Surveys and research on the preservation of plastic materials in the museum context have taken place since the 1980's and their numbers have been rising steadily. Research has focused on issues of identification, surveying damage, degradation, preventive measures and storage. Structured research on active conservation has taken place more recently.

The latest research was presented in the EEC project POPArt, Preservation of plastic artefacts 2009-2012 (Lavedrine et al., 2012). The focus of this project was identification, damage assessment and survey, assessment of the degree of degradation and the cleaning of plastics. In addition, studies of consolidation, mainly for foamed polyester, was also included.

In Sweden the project Morgondagens kulturobjekt took place between 2005 and 2008 at the Swedish National Heritage Board in collaboration with several museums (Nord et al., 2008). This project looked into damage, degradation and analysis of plastics.

Specific research studying the adhesive joining of plastics from a preservation perspective has been performed mainly for poly (methyl methacrylate) and unsaturated polyester (Sale, 1995, 2011)(Roche, 2011)(Lagana and van Oosten, 2011)(Comiotto, 2009). In addition, studies have also been conducted on the adhesion of polyolefins (Comiotto, 2007).

For work investigating and systemizing synthetic adhesives used within conservation and how they function and age, the work of Jane Down, Velson Horie and Stephen Koob should be mentioned (Down, 2001)(Down et al., 1996, 2009)(Koob 2009)(Koob et al., 2010)(Horie, 2010). Relevant for the adhesives in the current investigation are specifically the paper by Down (2001) on cyanoacrylates and epoxy.

Within the conservation community there are several papers describing testing of adhesives in the context of a case study or for a particular kind of object/s. Relevant observations on the adhesives tested in this investigation or for polystyrene in particular can be found in Comiotto et al., (2009) and Moomaw et al., (2009).

In addition, relevant information on the deterioration and the impact on the properties of adhesive joins can be found in adhesives research or other scientific literature (Drain et al., 1985)(López-Ballester et al., 1999).

1.5 Scope and delimitations

Based on the damage survey of the previous FoU-project Morgondagens kulturobjekt (Nord et al., 2008), polystyrene was chosen as the plastic of study. One transparent general purpose polystyrene (GPPS) and one white high impact polystyrene (HIPS) were chosen to represent the two major types of rigid polystyrene found in museum collections. Furthermore, they represent differences in regard to polymer material behaviour and aesthetics. For further reasoning on the choice of plastic see chapter 3.1. In order to limit the number of factors to fit the time frame these investigations have been performed without any pre-treatment of the sample material.

Based on a questionnaire from approximately 20 conservators on what adhesive they would use or think of using for polystyrene, together with what is recommended by the industry and in the literature, 20 adhesives were first considered for experimentation. After initial testing and through discussions with the reference group, it was narrowed down to seven. See chapter 3.2 for choice of adhesives.

1.6 Methods

The project is a comparative study of seven adhesives and their effect on polystyrene with both quantitative and qualitative methods before and after light ageing. For a detailed experimental set-up see chapter 3.3. The project has investigated the effect of accelerated light ageing on the polystyrene substrate and the seven different adhesives through comparison before and after ageing and joining.

Degradation processes have been studied quantitatively by observing the strength of the bond during tensile testing, the effect on hardness of both plastic and adhesive and visual changes through colour comparison. Qualitatively, degradation effects have been studied by molecular characterization using Fourier Transform Infrared Spectroscopy (FTIR) microscopy imaging and by imaging micro scale changes induced by the adhesive join in the Scanning Electron Microscope (SEM). Moreover, degradation phenomena and type of break have been assessed visually in the stereomicroscope.

Compatibility of adhesive and plastic was assessed through break type observed during tensile pull-to-break testing. Furthermore, compatibility was indicated through hardness testing, assessment of working properties and reversibility. Based on the results from the above testing some adhesives were chosen and applied to real three-dimensional objects.

1.7 Organisation of project

The time frame for the project has been one year with about 90 % of a full time work force.

Project leader	Thea Winther, Riksantikvarieämbetet
Scientific manager	Judith Bannerman, Riksantikvarieämbetet
Project participants	Hilde Skogstad, Riksantikvarieämbetet
	Karin Jacobsson, Swerea KIMAB
	Johan Samuelsson, Swerea KIMAB
	Mats KG Johansson, KTH
SEM operators	Kathrin Hinrichs Degerblad, Riksantikvarieämbetet
	Kaj Thuresson, Riksantikvarieämbetet
Administrator	Maria Rossipal, Riksantikvarieämbetet

External reference group of conservators: Maria Franzon and Veronica Eriksson Nationalmuseum, Lena Wikström, Moderna Museet, Karin Björling-Olausson and Kerstin Jonsson, Nordiska Museet; and Christina Halldén Tengnér and Anna Ehn Lundgren from Armémuseum.

Internal reference group: the unit of Conservation science at Riksantikvarieämbetet.

2. Adhesion of plastics

Adhesive bonding is one method where materials are joined and an assembly created. Adhesion can be looked upon as a system with a function for the transferring of stress. For adhesion to take place between an adherent and an adhesive they need to come in close contact for secondary attraction forces between the molecules of the adherent and of the adhesive to develop. In order to create this secondary attraction force the adhesive needs to wet the surface and spontaneously spread. For good wetting, a reduction of the total energy state for the substances needs to be achieved. The surface tension of the adherent needs to be greater than that of the adhesive to allow the adhesive to float out and reach a good contact surface and wetting. Wettability can be affected by contaminants and the bond strength will depend on bond type, distance and contact surface area. Wetting behaviour also depends on surface tension, viscosity, temperature and surface roughness. Some plastics such as polyethylene and polypropylene have very low surface tensions and need some kind of surface treatment prior to adhesion. The surface tension of polystyrene is 33 mN/m at 20°C (Shashoua, 2008).

A join will mainly function by mechanical interlocking at a microscopic level (Figure 1). Intimate contact is needed between adhesive and adherent for this interlocking to take place. The viscosity of the adhesive is very important as wetting into pores and an expulsion of air from the pores will provide a strong bond. Most adhesive joins work with interlocking mechanisms; however, for some of the adhesives in this experiment there can be an element of diffusion.

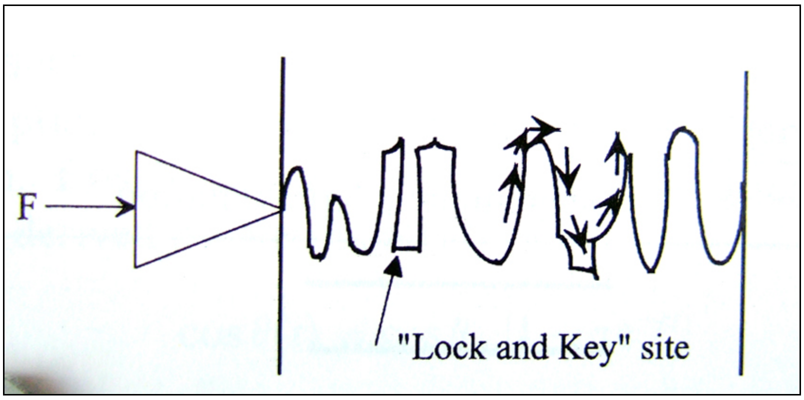

Figure 1. Mechanical interlocking and adhesion. F – Force. From Pocious.

Diffusion can occur when the solvent in an adhesive dissolves the adherent's surface to some extent, and the molecules of the adhesive diffuse into those of the adherent (Pocius, 1997).

A bonding process can be described as first designing the join, considering the type of stress, size and strength needed. Then there is the selection of adhesive, preparation, fabrication of assembly and lastly testing its function. When selecting an adhesive, it is important to consider such factors as the mechanical and physical traits of the materials and the degree of permanence sought (Sheilds, 1984). Curing of an adhesive can occur through physical drying, chemical reaction or cooling as for hot melt adhesives.

To test the strength of a join, different stresses can be applied; shear, tensile and cleavage etc. In this case, the joins are subjected to tensile stress. Furthermore, there are descriptions of the kind of assembly – angle join, tee join, butt join or surface join. In this case, the test pieces are first subjected to pull-to-break in the tensile tester, then the edges are adhered and lastly pull-to-break is performed again with the weakest point being the adhesive join. This method is most similar to a butt join.

3. Experiment

3.1 Choice of plastic

Based on the damage survey of the previous FoU-project, Morgondagens kulturobjekt, discussions with the reference group and what plastic material found in conservation for which we know the least, a rigid polystyrene plastic was chosen for this study. Polystyrene is one of the most common plastics represented in various collections in museums today and is known for its brittleness. In this study, extruded plastic sheets of 1 mm thickness were chosen. A transparent general purpose polystyrene (GPPS) and a white high impact polystyrene (HIPS) were chosen as they present differences in regard to material behaviour and aesthetics.

Polystyrene is made up of styrene monomer (figure 2), and HIPS is a two-phase system with some rubber particles, most often cis-polybutadiene 5-10%, grafted into the polystyrene matrix to make the plastic less brittle. Polystyrene has been in production since the 1930s, the earliest documented production is from 1931 by BASF in Europe and from 1938 by Dow chemicals in the US.

It is an amorphous thermoplastic that can be both transparent and coloured, with a glass transition temperature (Tg) of around 100°C. As the plastic is brittle the tougher variant of HIPS was developed and has been widely used since the 1950s (Sheirs and Priddy, 2003) (Brydson, 1999).

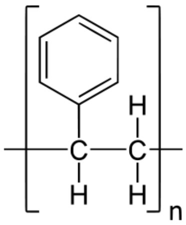

Figure 2. Styrene monomer.

See appendix I for manufacturer's data sheets.

3.2 Choice of adhesives

Based on a questionnaire filled out by approximately 20 conservators on what adhesive they would use or think of using for polystyrene together with what is recommended by the industry and in the literature, 20 adhesives were considered for experimentation. After initial testing of these 20 adhesives and through discussions with the reference group, it was narrowed down to seven. See appendix II for a complete list of adhesives in the initial screening and its results.

Table 1. List of chosen adhesives, basic data, and their numbering in the testing. Composition, glass transition temperature (T_g), refractive index (RI) and viscosity (visc.) is collected from manufacturers and Horie, (2010). A general common viscosity for commercial cyanoacralates was found in Down, (2001).

No in test	Adhesive name	Adhesive type	Polymer composition	Ratio/solvent	T_g °C	RI	visc. mPa.s at 20 °C
1	Paraloid B72	Acrylate	ethyl methacrylate/ methacrylate, EMA/MA, 70/30	40% in 1:1 acetone :ethanol	40	1.48	-
8	Paraloid B72	Acrylate	ethyl methacrylate/ methacrylate, EMA/MA, 70/30	40% in ethanol	40	1.48	-
2	Paraloid B67	Acrylate	isobutyl methacrylate, iBMA	40% in 2-propanol	50	1.48	-
3	Primal AC 35	Acrylate dispersion	ethyl acrylate/ methylmethacrylat e, EA/MMA	-	-	-	300-600
4	Hxtal NYL-1	Epoxy 2 component	4,4-isopropylidenedicy clo-hexanol epichlorohydrin*	3:1 (resin : hardener)	-	1.52	80
5	Araldite 2020	Epoxy 2 component	epoxide from bisphenol A-(epichlorhydrin) + butanedioldiglycidy l ether (DGEBA)*	100g:30g (resin:hardener)	40	-	Ca 150
6	Loctite Super Attack Precision	Cyano-acrylate	Ethyl-2-Cyanoacrylate	-	-	-	Ca 6-10
7	Acrifix 116	Acrylate, in solution provided by manufac-turer		mix of solvents***	ca 100	-	ca. 650 - 900

* hardener: poly(oxy)(methyl ethanediyl), hydroaminomethylathoxy ether ethyl hydroxymethylpropanediol .
** hardener: isophorone diamine and trimethylhexamethylenediamine.
*** ethyl methanoate, nitroethane, 2-phenoxyethanol, ethyl acetate and n-butanol.

The seven adhesives selected for testing represent both variants commonly used by conservators and some more industrial products. They fall mainly into three categories; acrylates (solvent based or dispersion), epoxies and one cyanoacrylate. At a later stage Paraloid B72 which is only dissolved in ethanol, was included to observe differences compared to Paraloid B72 dissolved in the acetone:ethanol mixture reported previously. See table 1 for the basic data. See appendix III for data sheets of the adhesives.

3.3 Experimental plan and summery of methods

The experiments were conducted in two series (see figures 3 and 4, table 2). In series 1 (S1), 160 samples; 80 GPPS and 80 HIPS, 50x100x1mm in size, were subjected to pull-to-break in the tensile tester before being adhered with the adhesives; 10 GPPS and 10 HIPS for each adhesive. In addition, GPPS and HIPS were included in the tensile testing before and after ageing as reference samples. For the initial pull-to-break a notch of 0.3 mm for GPPS and of 0.2 mm for HIPS was needed as otherwise the samples slipped out of the clamps. The broken edges of the plastic were then abutted and joined using the seven different adhesives. Working properties and visual appearance were assessed prior to half of the unaged samples (n=40+40) being subjected to pull-to-break in the tensile tester. The other samples were (n=40+40) subjected to light ageing before a new visual assessment followed by tensile testing. Break force values were compared and the type of break assessed. In S1 all adhesives were applied on break edges with a brush except for Loctite Super Attak Precision (Loctite SAP) which was applied directly from the nozzle of the tube. After application, the adhered pieces were pressed together and laid flat to cure (figure 5). Tensile testing of unaged samples was performed after five days of curing.

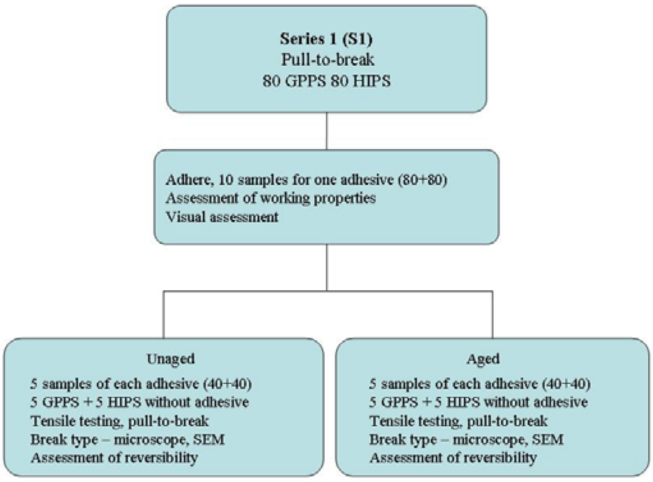

Figure 3. Flow chart of sample testing of adhered edges, series 1 (S1).

In series 2 (S2, figure 4), 1 mm thick adhesive layers of the seven different adhesives were applied with a draw-down technique (figure 6 and 7) to cover the centre of 16 samples; 8 GPPS, 8 HIPS, 108x215x1mm. Due to different shrinkage rates, the adhesive layers after curing, differed in thickness. The epoxies had a thickness of 1mm after curing, Paraloid B72 in acetone: ethanol 0,30 mm, Paraloid B72 in ethanol 0,50 mm, Paraloid B67 0,30 mm, Primal AC35 0,60 mm, Loctite SAP 0,50 mm and Acrifix 116 0,25 mm. All samples were cut in half, and one half was subjected to light ageing. Visual assessment, hardness testing, colour measurement, SEM-imaging of the border area between adhesive and plastic and FTIR-imaging of cross-sections of the interface between adhesive and plastic were conducted and compared on both unaged and aged samples. For colour measurements, a set of the adhesives with glass as a substrate was included. One sample was subjected to an elemental analysis in Energy Dispersive X-ray Spectroscopy (EDS). Colour measurements were taken after eight days of curing for the unaged samples with 3-5 measuring points. Hardness testing was performed after nine days for the unaged samples. The hardness testing was done with the MS-O 0209 pencil head designed for softer materials like textiles, rubber and gums. In this case it is believed that the MS-O type will give the most accurate readings since the thinness of the adhesive layer requires a very sensitive measuring head. Three measuring points were taken for each sample and the average calculated.

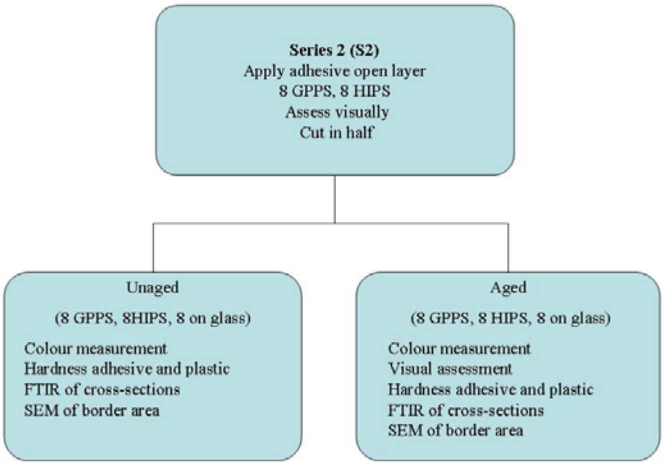

Figure 4. Flow chart of testing samples with an open layer of adhesive, S2.

Table 2. Experimental set-up and number of samples for each adhesive and type of plastic sheet.

Method	**Series 1**		**Series 2**	
	Unaged	Aged	Unaged	Aged
FTIR microscope imaging			x	x
Tensile tester	5 samples	5 samples		
Type of break	5 samples	5 samples		
Spectrophotometer			3-5 points	3-5 points
Assess working properties	10			
Assess visually	10		x	x
Hardness pencil test			3 points	3 points
SEM imaging	x	x	x	x

3.3.1 Sample preparation

For series 1 (S1), all adhesives were applied on break edges with a very fine brush except for Loctite SAP which was easier to apply directly from the nozzle of the tube. After application, the adhered pieces were pressed together for approximately one minute and then left to cure lying flat and supported on two thin wooden sticks to avoid any surplus adhesive adhering the plastic to the underlying table surface (figure 5).

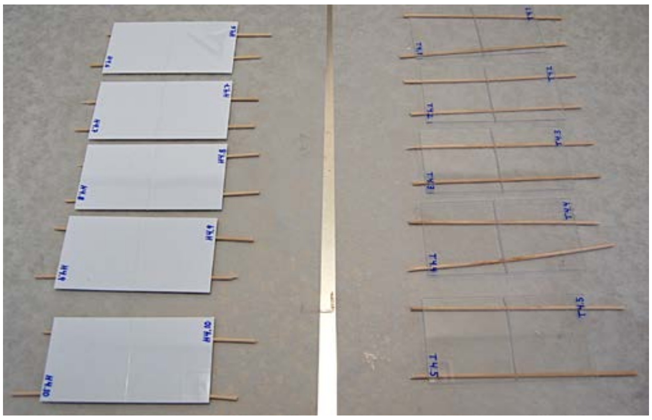

Figure 5. S1 curing.

In series 2 (S2), 1 mm thick adhesive layers of the seven different adhesives were applied with a draw-down technique to cover the middle area on 16 samples (8 transparent polystyrene, 8 HIPS, 108x215x1mm) (figures 6, 7 and 8). For times between preparation and testing for the various adhesives and tests see table 3.

Figure 6. Example of Hxtal-Nyl 1 on transparent GPPS before ageing and before cutting.

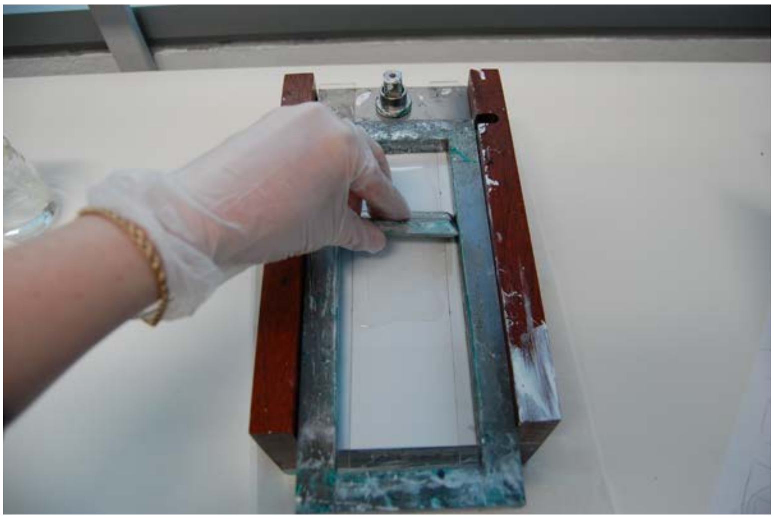

Figure 7. Box for draw-down of adhesive layer.

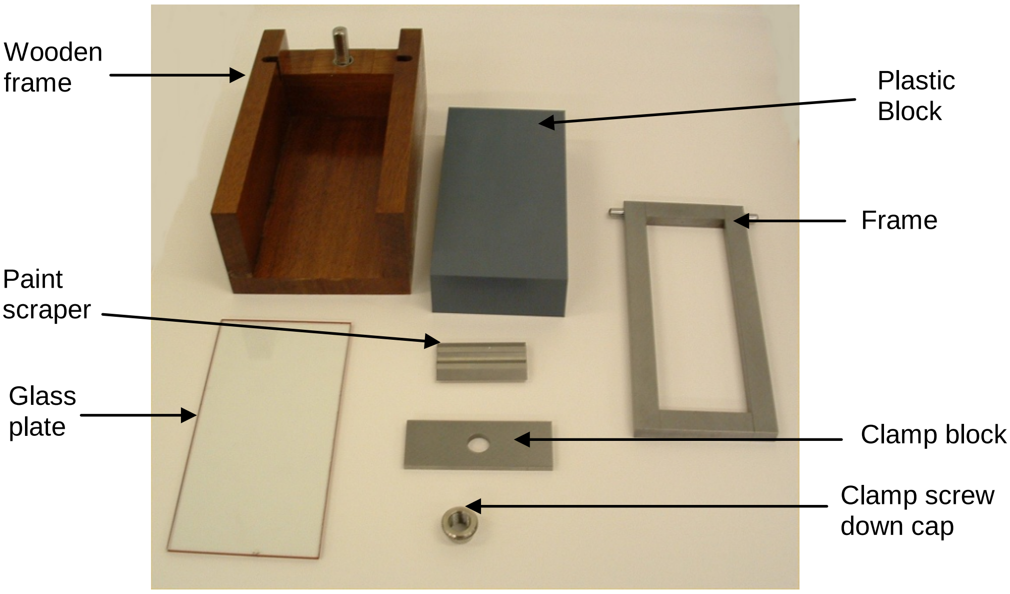

Figure 8. Parts of the box for draw-down of adhesive layer.

Table 3. Time after preparation for the adhesives before being subjected to tests. The 'aged' samples were exposed to 24 days in the light ageing chamber.

Drying/curing time for adhesives before being subjected to tests:		
Test	Unaged samples	Aged samples
S1 Tensile testing	5 days	30 days
S2 colour measurements	8 days	35 days
S2 Hardness testing	9 days	37 days

3.3.2 Experiences draw-down

Samples of each adhesive and each plastic were used with 1 mm thick plastic shims under the frame of the draw-down box. For all seven adhesives their relatively low viscosities led them to be drawn under the plastic shims in the draw-down box which resulted in an uneven thickness of the adhesive layer. As a solution to this problem masking-tape was used as shims instead. This worked out well for all adhesives except for Loctite SAP where the adhesive adhered to the masking-tape so strongly that the tape left residue/material upon removal. Since this residue could result in misinterpretation in the SEM, it was decided, as a precaution, to perform the SEM imaging on both samples created with plastic shims and masking-tape shims, after investigation under the regular microscope to find areas free from tape residues. A double set of S2 SEM samples therefore exists for the Loctite SAP adhesive.

Due to different shrinkage rates (appendix IV), the adhesive layers in S2 after curing differed in thickness. The epoxies had a thickness of 1 mm after curing, Paraloid B72 in acetone: ethanol 0,30 mm, Paraloid B72 in ethanol 0,50 mm, Paraloid B67 0,30 mm, Primal AC35 0,60 mm, Loctite SAP 0,50 mm and Acrifix 116 0,25 mm. These differences may affect the spectrophotometer measurements and hardness testing measurements to some degree.

3.4 Ageing

The samples were subjected to accelerated light ageing, a common practice for studying the ageing of plastics (Lavedrine et al., 2012). The lamp used for the light ageing was a Sol 500 from Hönle UV technology with a metal halide light bulb and radiation efficiency in the ultraviolet and visible range (295-780 nm) and a bulb power of 430W. On the basis of the first calculation of average lux levels in the light ageing area, the ageing period was set to 24 days, which for the visible component corresponds to 60 years with 100 lux exposure, 8 hours per day, 7 days a week, 365 days per year (museum exposure). UVA was included as there are instances when plastic objects are exhibited where they will be subjected to UV radiation. Furthermore, as this is a comparative study between the adhesives, UVA was included to further accelerate the deterioration processes. Lux levels, UVA levels, RH and temperature were measured at 22 measuring points once a week and the samples were rotated to create even exposure. See figure 9 for samples in the accelerated light ageing area and table 4 for the temperature, RH, average UVA and lux levels during light ageing of S2. The same measuring points were used for S1 and the same average lux and UVA levels observed.

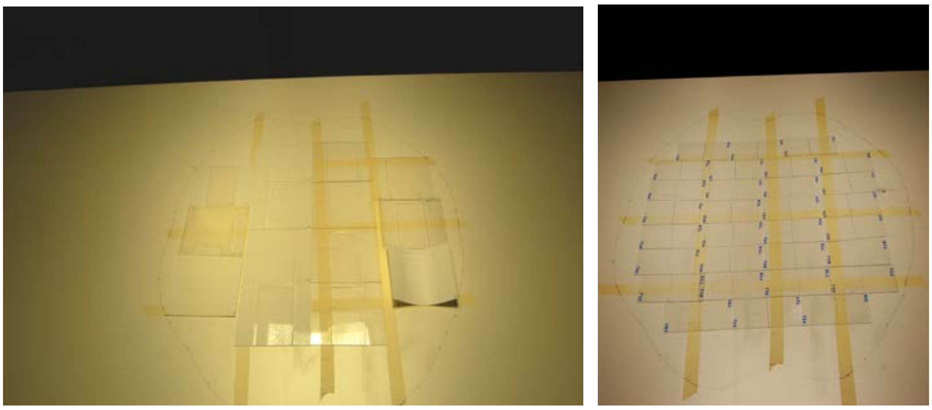

Figure 9. Open layer samples (left) and samples of adhered edges (right) in the ageing chamber set up.

Table 4. Lux, UVA in W/m2, average temperature and RH for S2. STDV – Standard deviation.

Lux measurements S2			
Measuremer	2012-03-20	2012-03-27	2012-04-03
1	32600	32600	31300
2	31700	31600	31400
3	35200	34500	34600
4	34000	33600	33600
5	34300	34000	34000
6	33700	33700	33000
7	30800	30100	31000
8	30100	30200	30000
9	32000	32400	31900
10	34500	33500	34300
11	32700	31300	31800
12	33300	33200	31000
13	34400	34200	33100
14	32000	32200	32500
15	29500	30300	28500
16	28900	29200	28900
17	25500	26200	24700
18	23900	24200	24000
19	27900	27900	28400
20	28500	29000	29000
21	24500	24600	24600
22	25100	25300	25900
STDV	3523,97171	3247,73647	3240,32025
Medel	30686,3636	30627,2727	30340,9091

UVA measurements S2			
Measuremer	2012-03-20	2012-03-27	2012-04-03
1	13	14	13
2	13	14	13
3	15	15	14
4	15	15	15
5	16	15	15
6	15	15	15
7	14	14	14
8	15	13	14
9	13	14	13
10	12	14	14
11	15	14	14
12	14	15	15
13	15	15	15
14	15	14	14
15	11	13	13
16	12	13	13
17	12	12	12
18	11	10	10
19	12	12	12
20	11	12	11
21	10	10	11
22	10	10	10
STDV	1,85922294	1,67293195	1,59273241
Medel	13,1363636	13,3181818	13,1818182

Temperature and RH				
Date	Temp. Room	Temp. Table	RH table	RH room
2012-03-20	23 C	27 C	44,50%	61%
2012-03-27	22 C	26 C	43,30%	58%
2012-04-03	21 C	28 C	44,00%	61%
2012-04-10	22 C	27 C	42,30%	61%

3.5 Assessment of working properties and visual appearance.

3.5.1 Series 2

Before ageing

All adhesives were transparent in colour before ageing except for Primal AC 35 which was slightly pale yellow and Loctite SAP which was pale white. Loctite SAP also had an uneven, grainy texture.

The two Paraloids were the only adhesives that formed a substantial amount of bubbles in S2. Paraloid B67 formed more bubbles than Paraloid B72 in acetone:ethanol and had in general a very uneven surface after curing. Paraloid B72 in acetone:ethanol and Paraloid B72 in ethanol only formed approximately the same amount of bubbles. Ways of reducing the amount of bubbles can be found in Koob (2011).

With both of the epoxies, delamination from the plastic surface after curing occurred. The epoxies did not adhere well to these smooth polystyrene surfaces. Delamination was a little more distinct on transparent polystyrene than on HIPS.

All adhesives, except for the epoxies experienced substantial shrinkage after curing. This occurred to a greater extent for Acrifix 116 and the Paraloids due to the evaporation of solvents.

Acrifix 116 caused visible damage to the plastic by bending it in a concave shape upon curing (figure 10). The white polystyrene was bent more severely than the transparent material. Loctite SAP caused some slight bending of the plastic but less so than Acrifix. During ocular inspection it was observed that none of the other adhesives caused any deformation or damage.

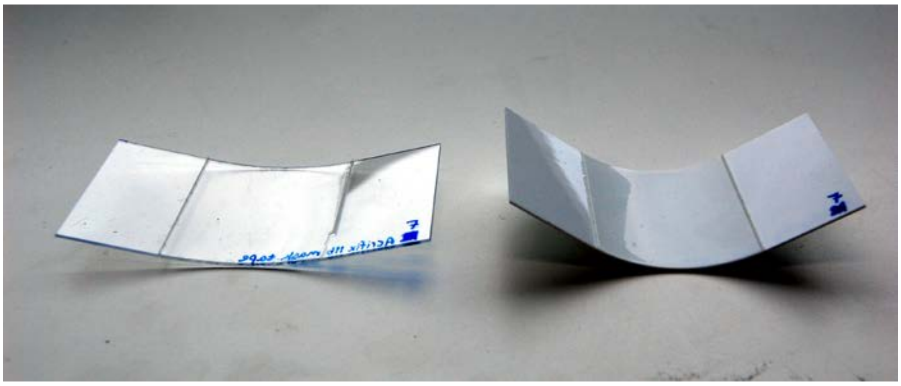

Figure 10. Bending of the plastic samples in S2 by Acrifix 116.

After ageing

The most apparent visible change in S2 after ageing was colour change. Both the control samples of plastic without adhesive yellowed visibly as a result of ageing, HIPS to a greater extent than the transparent.

Among the adhesives, the Loctite SAP and Araldite 2020 showed severe yellowing after ageing (figure 11) whilst Hxtal NYL-1 and Acrifix 116 showed no visible colour change (figure 12). Primal AC 35 showed some slight colour change as did the Paraloids.

When assessing the colour change of the adhesives in S2 it proved difficult to decide if it actually was the colour of the adhesive that had changed or if it was the colour of the plastic substrate that was showing through. To document if the adhesive was yellowing, a set of adhesives on glass was created, see chapter 3.6.

Figure 11. Loctite SAP (left) and Araldite 2020 (right) on transparent polystyrene before (bottom) and after (top) ageing.

Figure 12. Acrifix 116 (left) and Hxtal NYL-1(right) on HIPS before (bottom) and after (top) ageing

Some increased brittleness of the transparent polystyrene with Loctite SAP, Acrifix 116 and Paraloid B67 was observed. This was noticed through an increased tendency to fracture in the plastic and the adhesive layers when cutting the samples in preparation for SEM.

There was also a tendency for increased delamination of the epoxies from the plastic after ageing, and was observed when cutting/preparing samples for SEM.

3.5.2 Series 1, adhesives on adhered edges

Two of the most important factors in deciding which adhesives were the easiest to apply were the viscosity and working-time of each individual adhesive. A third consideration which is important in any conservation effort is the best appearance after application (most “clean” result, least spill). The epoxies and the Loctite SAP had very low viscosities which made them difficult to apply in a controlled way. The Paraloids had a higher viscosity which increased during application and resulted in a relatively thick application layer.

Paraloid B72 was easier to use dissolved in ethanol only than in acetone:ethanol, since ethanol increased the working time and kept it from thickening too fast during application. This gave more control and led to a visually cleaner result. Among the seven adhesives Acrifix 116 was the easiest to use and most controllable during application, mainly because it had a relatively high viscosity and long working time. Primal AC 35 was also relatively easy to use. For more detailed observations/notes on experiences for each adhesive, see S1 assessment table in appendix IV.

3.5.3 Visual observations before and after ageing Series 1

Before ageing

All adhesive bonds were visible after curing, to a greater extent on the transparent polystyrene than on the HIPS. For the transparent polystyrene, when viewed lying flat against a coloured or white background, a white line was observed to varying degrees depending on thickness and type of adhesive used. When viewed without being in contact with any sort of substrate, the bonds looked less white but the break was still clearly visible. The visibility of the bond showed that none of the adhesives had the same refractive index as the polystyrene. For the HIPS the visibility was related to the amount of excess adhesive around the break edges since the plastic is white in itself.

In general, Acrifix 116 had the least visible and the thinnest adhesive bond. The other adhesives were relatively similar to one another in visibility. Loctite SAP had a tendency to be more visible than the others on transparent polystyrene since it was white in colour and had a visibly grainy texture. Any spill from the Paraloids also had a tendency to be quite visible because the higher viscosity of the adhesives made it difficult to create a thin application.

Using a microscope, the study of the different adhesive applications also confirmed that Acrifix 116 gave the thinnest bond. See appendix X for microscopy images of the bonds of S1. Visible cracks originated from the initial pull-to-break experiment in the tensile tester. They also showed that the two Paraloids had the largest amount of bubbles, where Paraloid B72 had many small bubbles and Paraloid B67 had fewer but larger bubbles. The amount or size of bubbles in Paraloid B72 was not dependent on whether it was mixed in acetone: ethanol or just ethanol. The epoxies and Primal AC 35 showed basically no bubbles while Acrifix had some bubbles and Loctite only a few.

After ageing

All adhesive bonds showed almost the same degree of visibility and gave the same general impression after ageing as before ageing.

Araldite 2020 and Loctite SAP showed some increased visibility through minute yellowing or discolouration of the adhesive bond. Acrifix 116 was also slightly more visible after ageing on the white polystyrene; not because of any yellowing or discolouration of the adhesive itself, but rather because the plastic had yellowed while the adhesive had not, thereby creating a visible contrast where the adhesive bond appeared lighter than the plastic.

3.6 Colour measurement

Spectrophotometer values were taken with a Spectrophotometer CM-2600/2500d (Minolta) to measure the adhesives on both plastics, the adhesives on a glass substrate and on the plastics without adhesive. Measurements were taken with white A4 paper under the substrates, and three measurement points were taken for each sample. The ΔE* value is a single value based on calculations of the differences between the a*, b* and L* value of a measured sample and a chosen standard or target. For the adhesive measurements, the standards or targets used were unaged transparent polystyrene and unaged HIPS respectively. The ΔE* calculations used the ΔE*76 standard. See reflectance curves and values from measurements of the different adhesives in appendix V for more details.

The spectrophotometer measurements mirrored the visible colour changes before and after ageing to a large extent. The greatest colour change could be seen for Loctite SAP on transparent polystyrene and the least for Acrifix 116 (figure 13). The difference in the b* values (b* scale measures yellowness[+b] and blueness [-b]), when comparing before and after ageing, differed the least for Acrifix 116 and the most for Loctite SAP and Araldite 2020 (table 5 and figures 14 and 15). There was a medium amount of difference for the Paraloids and Primal AC 35.

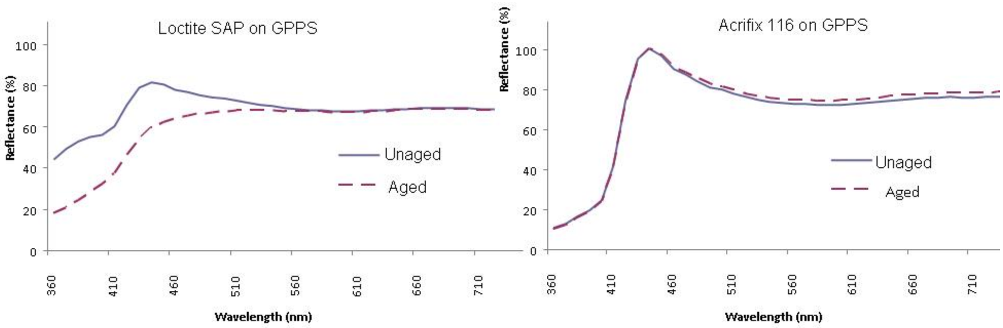

Figure 13. Curves showing % reflectance in the visible spectrum before and after ageing on transparent polystyrene (GPPS). The greatest colour change could be seen for Loctite SAP and the least for Acrifix 116.

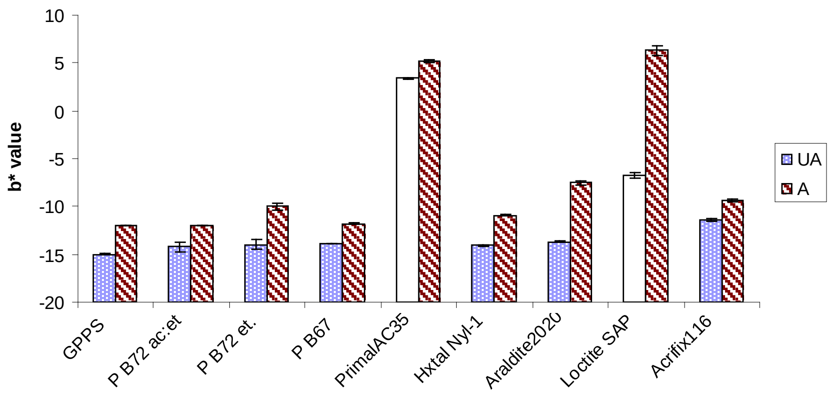

Figure 14. The b* values for adhesives on transparent polystyrene before and after ageing, U-unaged, A-aged. GPPS – transparent plastic without adhesive.

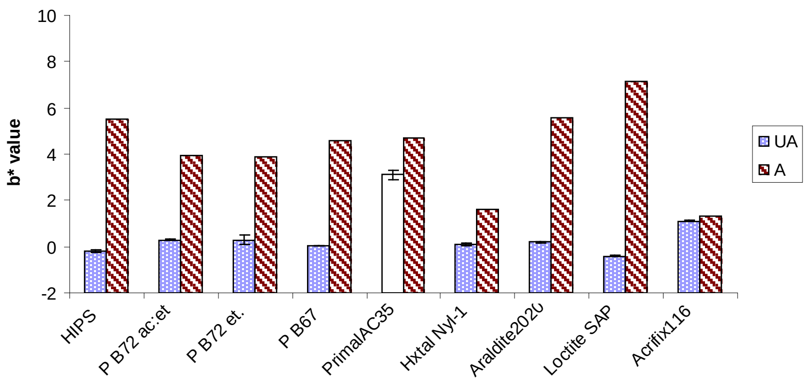

Figure 15. The b* values for adhesives on HIPS before and after ageing, U-unaged (blue), A-aged (red). H0- HIPS without adhesive.

The reflectance curves and b* values also differed between the same adhesive on the two different plastics. Hxtal NYL-1 showed a general diminishing reflectance on the transparent polystyrene which is not visible for Hxtal NYL-1 on HIPS (figure 16). Paraloid B72, Paraloid B67 and Araldite 2020 demonstrated the largest difference of b* values between aged and unaged on HIPS, while Primal AC35, Hxtal NYL-1, Loctite and Acrifix 116 demonstrated the largest difference of b* values on transparent polystyrene. It appears that in some cases the plastics are "protected" from light ageing, for example for Acrifix 116 as seen in figure 12.

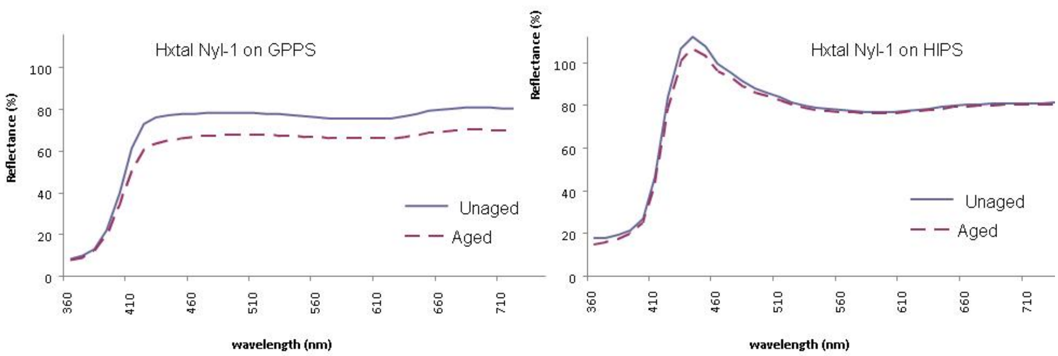

Figure 16. Curves showing % reflectance in the visible spectrum before and after ageing for Hxtal NYL-1 on transparent polystyrene (GPPS) and HIPS.

Table 5. The spectrophotometer L* a* b* and ΔE* values for adhesives on open layer samples (S2), on transparent polystyrene (T1-T7), on HIPS (H1-H7), and on reference samples of plastic (T0 and H0). U - unaged. A – aged. Unaged plastic used as target. ΔE* calculated on ΔE*76 standard.

Sample	L* U	L* A	a* U	a* A	b* U	b* A	ΔE* U	ΔE* A
GPPS (T0)	92 ±0.3	93 ±0	2. 7 ±0	2. 0 ±0	-15 ±0.1	-12 ±0	0. 12 ±0	3. 0 ±0.1
HIPS (H0)	94 ±0.1	93 ±0	-1. 2 ±0	-2. 7 ±0.1	-0. 2 ±0.1	5. 5 ±0.3	0. 05 ±0	6. 0 ±0.3
T1 Paraloid B72 ethanol: acetone	92 ±0.4	92 ±0.1	2. 8 ±0	2. 1 ±0	-14 ±0.5	-12 ±0	0. 56 ±0.3	2. 5 ±0
H1 Paraloid B72 in ethanol: acetone	93 ±0.1	93 ±0	-1. 2 ±0	-2. 4 ±0	-0. 30 ±0	4.0 ±0	0. 60 ±0.1	4. 5 ±0
T8 Paraloid B72 in ethanol	91 ±0.5	92 ±0.1	2. 8 ±0	2. 0 ±0.1	-14 0.5±	-10 ±0.3	1.1 ±0.1	3. 4 ±0.4
H8 Paraloid B72 in ethanol	92 ±0.4	92 ±0.1	-1.0 ±0.2	-1. 6 ±0	0. 30 ±0.2	3. 9 ±0.2	0.60 ±0.2	4. 6 ±0.2
T2 Paraloid B67	91 ±0.2	92 ±0.3	2. 5 ±0	2. 1 ±0	-14 ±0	-12 ±0	1.1 ±0.2	2. 8 ±0.1
H2 Paraloid B67	93 ±0.2	92 ±0.5	-1. 3 ±0	-2. 5 ±0.1	0. 05 ±0	4. 6 ±0.1	1. 0 ±0	5. 3 ±0
T3 Primal AC 35	89 ±0.3	90 ±0.2	1.1 ±0	4.9 ±0.2	3. 4 ±0.1	5. 2 ±0.2	17 ±0.2	19 ±0.4
H3 Primal AC 35	92 ±0.1	92 ±0.1	-2. 4 ±0	-2. 5 ±0	2.1 ±0.2	4.4 ±0.1	3. 9 ±0	5. 1 ±0
T4 Hxtal NYL-1	92 0.2±	92 ±0.3	2. 6 ±0	1. 9 ±0	-14 ±0.1	-11 ±0.1	0. 75 ±0.2	3. 7 ±0.2
H4 Hxtal NYL-1	90 ±0.3	85 ±0.2	-1. 2 ±0	-1. 3 ±0	0.09 ±0	1. 5 ±0.1	3. 5 ±0.3	8. 9 ±0.5
T5 Araldite 2020	91 ±0.2	92 ±0.3	2. 6 ±0	0. 97 ±0	-14 ±0.1	-7. 5 ±0.2	1. 2 ±0.2	7. 1 ±0.2
H5 Araldite 2020	87 ±0.4	90 ±0.5	-1. 0 ±0	-2. 3 ±0	0. 24 ±0	5. 6 ±0.3	6.2 ±0.4	6.8 ±0.5
T6 Loctite SAP	87 ±0.4	85 ±0.4	0. 2 ±0	-3. 1 ±0.1	-6.8 ±0.2	6. 3 ±0.5	9. 8 ±0	23 ±0.3
H6 Loctite SAP	94 ±0	93 ±0	-1. 2 ±0	-3. 0 ±0	-0. 38 ±0	7. 1 ±0.1	0. 21 ±0	7. 7 ±0.1
T7 Acrifix 116	88 ±1.4	91 ±0.4	1. 9 ±0	1. 5 ±0	-11 ±0.2	-9. 4 ±0.1	4.1 ±0.7	5. 4 ±0.2
H7 Acrifix 116	92 ±0.2	93 ±0.4	-1. 6 ±0	-1. 4 ±0	1.1 ±0	1. 3 ±0	2. 0 ±0.2	1.9 ±0.2

The a* values (a* measures redness [+a] –greenness [-a]) showed the same tendencies as the b* values in terms of greatest change before/after ageing. Loctite SAP and Araldite 2020 changed the most, towards greenness, after ageing.

For the adhesive measurements in question, the standards or targets used were unaged transparent polystyrene and unaged HIPS. The ΔE* values before ageing showed the greatest difference between the transparent polystyrene target and Primal AC35 corresponding to Primal AC-35's pale yellow colour. Loctite SAP differed the most from the T0U-target both before and after ageing. Paraloid B72 in ethanol/acetone is closest to T0U-target both before and after ageing.

All adhesives differed substantially from the HIPS-target after ageing, the mentioned yellowing of the aged HIPS also occurring under most of the adhesive layers was not surprising. Acrifix 116 differed the least among the adhesives from the H0U-target after ageing.

Both epoxies gave high values in ΔE* on HIPS before ageing, 3.9 for Hxtal NYL-1 and 5.7 for Araldite 2020. It is also notable that Hxtal NYL-1 differed the most from the target after ageing out of all of the adhesives tested, although visually and in b* and a*, it showed little numerical change. The explanation may lie in a somewhat larger change in the L* value than for most of the other adhesives, (L* value describes black/white on the colour scale), with the epoxies for some reason being closer to black than the other adhesives and Hxtal NYL-1 moving even more towards black upon ageing (table 5). This is not visually apparent, but might be responsible for the rather big change in the ΔE* values.

The adhesives were also subjected to ageing with glass as a substrate to ensure colour measurements of the adhesives themselves and not the plastics, see table 6 and figure 17.In correspondence with the previous results, Acrifix116 showed the least change while Loctite SAP showed the largest change in the b* value.

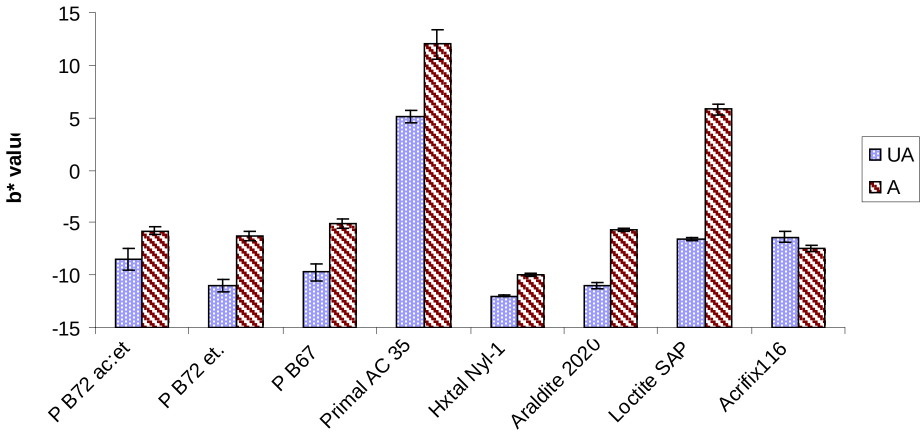

Figure 17. The b* values for adhesives on glass before and after aging, U-unaged, A-aged.

Table 6. The spectrophotometer L*, a*, b* and ΔE* values for adhesives on glass. U - unaged. A – aged. Unaged transparent polystyrene used as target. ΔE* calculated on ΔE*76 standard.

	L* U	L* A	a* U	a* A	b* U	b* A	ΔE* U	ΔE* A
Paraloid B72 in acetone: ethanol	70 ±1.4	61 ±1.4	0.0 ±0	0.3 ±0.1	- 8.5 ±1.1	- 5.8 ±0,4	23 ±1.4	32 ±1.5
Paraloid B72 in ethanol	80±1.7	77±1.6	1.9±0	1.4±0.1	- 11 ±0.6	-6.3 ±0.4	14±1.8	18±1.6
Paraloid B67	75±1.0	64±1.5	0.04±0	0.4±0	- 9.3 ±0.8	- 5.1 ±0.4	19±0.1	29±1.6
Primal AC 35	71±2.0	55±0.7	-1.5 ±0	1.3±0.6	5.1±0.6	12±1.4	29±1.1	47±1.1
Hxtal NYL-1	93±0.2	89±0.1	1.3±0.1	1.4±0	- 12 ±0,1	- 10 ±0,1	2.1±0.1	5.4±0.1
Araldite 2020	92±0.1	87±0.1	0.9±0	0.9±0	- 11 ±0.3	- 5.7 ±0.1	3.4±0.3	10±0.2
Loctite Super Attack Prec.	64±0.3	49±1.0	-0.9±0	-1.6 ±0.1	- 6.6 ±0.1	5.8±0.5	30±0.3	48±1.1
Acrifix 116	91±1.2	90±0.4	-0.2 ±0.1	-0.3 ±0.1	- 6.4 ±0.5	- 7.4 ±0.3	7.9±0.8	7.1±0.3

3.7 Tensile testing

Series S1 was subjected to pull-to-break in the tensile tester, five samples before ageing and five samples after ageing. Tensile testing was conducted with an AGS-x 10N-10kN tensile tester (Shimadzu), the data being processed by Trapezium Lite X software. Tensile testing was performed at 100mm/min. See appendix VI for detailed data.

The average break force sensitivity for the unaged transparent polystyrene (T0) was 970(110) N and for the unaged HIPS (H0) 800(80) N (Standard deviation within parenthesis). The average break force for aged transparent polystyrene was 1070(70) N and 790(80) N for aged HIPS.

3.7.1 Observations during initial pull-to-break

The first method used for breaking the plastics without adhesive in the tensile tester had to be adjusted from the original planned 3-point-bending due to shattering of the transparent polystyrene and bending without breaking for the HIPS. Normal pull-to-break was also a problem; both plastics had a tendency to slip out of the grips instead of breaking. An attempt was made to use narrower samples but resulted in the transparent polystyrene shattering into many pieces and the HIPS stretching and becoming distorted at the ends.

The solution was to first make a cut with a cutting template across the center of the samples to create a controlled flaw where the samples would then create a clean break during pull-to-break in the tensile tester. In order for the transparent polystyrene to break, the cut had to be ca 0, 3 mm deep and for the HIPS ca 0, 2 mm deep. This manual surface cutting of the plastics could be the reason for the standard deviation being approximately 10-30% in break force sensitivity as the manual cuts differ +/- 0.1 mm in depth. The surface cut in the S1 samples can be seen in both SEM and normal microscopy images as a smooth line whereas the rest of the break edge has a more uneven ragged surface.

3.7.2 Observations during pull-to-break of S1

Before ageing

All adhered plastic samples appeared, to the naked eye, to break homogeneously. Any stress-cracks along the break edge, visible especially on the transparent plastic, were a result of the initial pull-to-break of the plastic or samples with no adhesive. All samples broke in the adhered area with no visible damage to the plastic such as shattering, stress cracks or loss of material. There was no visible stretching or distortion of any of the plastics during or after pull-to-break. All breaks happened over the entire adhered area at once. For Loctite SAP and Acrifix 116 one sample among both transparent and HIPS plastic did not break on the first test, but instead slipped out of the grips. After a re-tightening of the grips, a pull-to-break test was achieved.

After ageing

Similar to the unaged samples stress-cracks were visibly on the transpartnt plastic due to the initial pull-to-break without adhesive and all samples broke in the adhered area without damage or distortion of the plastics. For Paraloid B67 only four instead of five of the aged samples were broken in the tensile tester since one sample broke in the adhesive bond during fastening of the sample in the tensile testing grips. This in itself gives a clear indication of the weak bond of Paraloid B67.

Table 7. Average break force of tensile testing of samples from S1. n =5. Standard deviation within parenthesis in break force columns.

Sample	Break force unaged, (N)	Break force aged, (N)
Transparent polystyrene		
Transparent polystyrene without adhesive (T0)	970 (110)	1070 (70)
Paraloid B72 in acetone:ethanol (T1)	350 (50)	330 (140)
Paraloid B72 in ethanol (T8)	380 (50)	420 (40)
Paraloid B67 in isopropanol (T2)	100 (30)	90 (20)
Primal AC 35 (T3)	170 (20)	210 (60)

Hxtal NYL-1 (T4)	270 (90)	310 (130)
Araldite 2020 (T5)	350 (70)	310 (140)
Loctite SAP (T6)	750 (190)	530 (170)
Acrifix 116 (T7)	360 (150)	500 (140)
HIPS		
HIPS without adhesive (H0)	800 (80)	790 (80)
Paraloid B72 in acetone: ethanol (H1)	400 (50)	380 (40)
Paraloid B72 in ethanol (H8)	280 (50)	340 (80)
Paraloid B67 in isopropanol (H2)	100 (30)	130 (40)
Primal AC 35 (H3)	210 (60)	320 (50)
Hxtal NYL-1 (H4)	440 (50)	440 (70)
Araldite 2020 (H5)	480 (110)	470 (60)
Loctite SAP (H6)	650 (20)	670 (20)
Acrifix 116 (H7)	470 (160)	560 (160)

3.7.3 Summarized results from pull-to-break S1 in the tensile tester

Note that the standard deviation (STDV) in break force sensitivity differs between the different adhesives and is relatively high for some of them (table 7). For most, the STDV lies between 10-30 %. The reason for a high STDV could originate from small differences in original break of the plastic samples and the application of adhesive. See table 7 for average break force sensitivity of the seven adhesives and represented as bar charts in figures 18 and 19.

The adhesives did not behave the same for the transparent polystyrene as for the HIPS, but there was nevertheless some similarity: Loctite SAP was the strongest adhesive; Paraloid B67 and Primal AC 35 were the weakest while Araldite 2020, Acrifix 116, Hxtal NYL-1 and Paraloid B72 (both mixed in ethanol and acetone: ethanol) were relatively close together in the middle range.

All adhesives were on average stronger when applied to HIPS than for the transparent polystyrene except for Loctite SAP, Paraloid B72 in ethanol and Paraloid B67.

After ageing

See table 7, figure 18 and 19 for the average break force sensitivity of the seven adhesives.

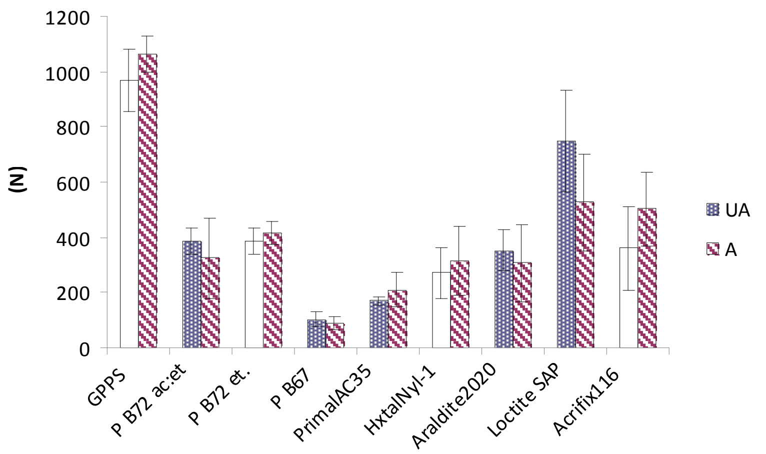

Figure 18. Break force sensitivity for adhered joins (S1) of adhesives on transparent polystyrene before and after ageing. GPPS plastic without adhesive. UA-unaged. A-aged.

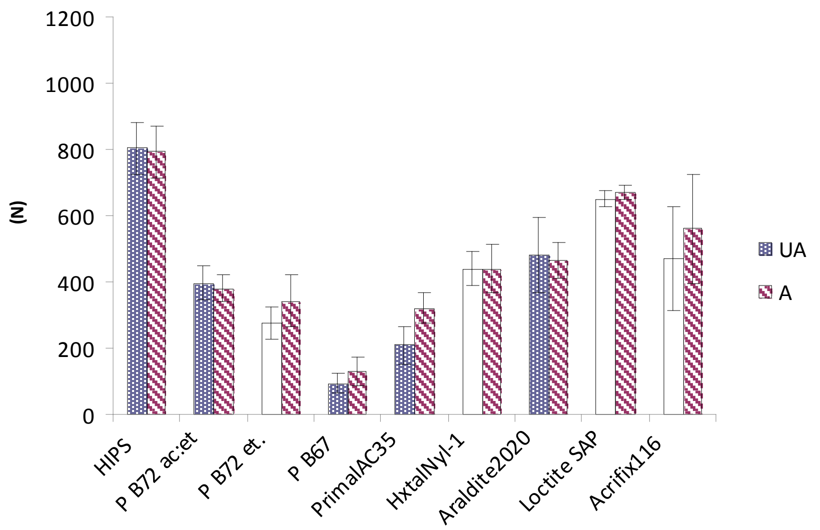

Figure 19. Break force sensitivity for adhered joins (S1) of adhesives on HIPS before and after ageing. HIPS plastic without adhesive. UA – unaged. A – aged.

The aged adhesives showed the same general tendency (ranging; highest to lowest) in break force sensitivity as before ageing; Loctite SAP was the strongest adhesive and Paraloid B67 and Primal AC 35 were the weakest, while Acrifix 116, Araldite 2020, Hxtal NYL-1 and Paraloid B72 were relatively close together in the middle range.

Comparing before and after ageing; all adhesives had, on average, almost the same break force sensitivity after ageing as before ageing. Exceptions were Loctite SAP on the transparent polystyrene which has weakened considerably, and Acrifix 116 and Primal AC 35 which on the contrary showed increased break force sensitivity after ageing on both plastics. All adhesives were stronger on HIPS than on the transparent polystyrene after ageing except for Paraloid B72 in ethanol.

3.8 Type of break

3.8.1 Assessment break type using SEM-imaging and microscopy

SEM analysis was performed using a LEO 1455VP (Oxford Instruments) with Inca 400 software. Conditions: EHT ranging from 20 kV, iprobe 1.0 nA, backscattering. Samples were sputtered with gold for 60 seconds at 18mA. SEM-imaging was also done on unsputtered samples.

Samples from break edges after pull-to-break were looked at under the light microscope and SEM to decide whether the break happened in the adhesive (cohesive break), between the adhesive and plastic (adhesive break) or in the plastic (cohesive break in the plastic). Samples were looked at in the regular microscope directly onto the break edge and in profile. For SEM images see appendix VII.

The SEM samples were looked at using un-sputtered and gold-sputtered techniques. Samples were sputtered with gold for 60 seconds at 18mA. Images were then taken looking directly down onto the break edges using a range of magnifications; x18, x100, x250 and x1000.

Before ageing

Note: The dust particles visible on the samples in some of the SEM images (T/H1, T/H2, T3) are from the sputtering chamber in a first unsuccessful attempt to sputter the samples, and are therefore not to be mistaken as material from the adhesives or plastics themselves.

When assessing the type of break in the SEM, it was difficult in the epoxies and Primal AC 35 samples to interpret what was adhesive and what was plastic since a negative impression of the plastic surface in the adhesive could be mistaken for the plastic itself. However, by also looking at the samples under a regular microscope it was possible to distinguish between the plastic and adhesive.

None of the samples experienced a break in the plastic. The results showed either a break in the adhesive bond (cohesive in the adhesive, figure 22) or between the adhesive and plastic (adhesive break, figure 21).

Table 8. Assessment of the type of break during tensile testing (S1) before and after ageing.

Adhesive	For transparent polystyrene	For HIPS
Paraloid B72 in acetone: ethanol	cohesive in the adhesive	cohesive in the adhesive
Paraloid B72 in ethanol	cohesive in the adhesive	cohesive in the adhesive
Paraloid B67 in isopropanol	cohesive in the adhesive	cohesive in the adhesive
Primal AC 35	cohesive in the adhesive / adhesive	cohesive in the adhesive / adhesive
Hxtal NYL-1	adhesive	adhesive
Araldite 2020	adhesive	adhesive
Loctite SAP	cohesive in the adhesive / adhesive	cohesive in the adhesive / adhesive
Acrifix 116	cohesive in the adhesive	cohesive in the adhesive

All acrylates in solvent; the Paraloids, and Acrifix 116 experienced a break in the layer of adhesive (cohesive break). This interpretation is based on negative impressions of bubbles visible on both break edges.

Both epoxies experienced a break between the adhesive and plastic (adhesive break). This interpretation is based on negative impressions of plastic surfaces in the adhesive and delamination of the adhesive from the plastic and was especially visible when observed with a light microscope. It is interesting to note that the tendency to delaminate from the plastic as seen in S2 was also occurring on a rough break edge surface and not only on a smooth polystyrene surface (figure 20).

Figure 20. Epoxy loosened from S1.

Primal AC 35 and Loctite SAP experienced a combination of a break in the adhesive and between adhesive and plastic. This interpretation is based on areas with negative impressions of bubbles in the adhesive on both break edges. This indicated a break in the adhesive, but SEM imaging also showed other areas with negative impressions of the plastic surface in the adhesive on only one break edge, which indicated a break between the adhesive and plastic.

After ageing

All samples showed a similar type of break after ageing as before ageing in a standard microscope and SEM imaging.

Figure 21. Sample H4 (Hxtal NYL-1) unaged in regular microscope. Example of adhesive break.

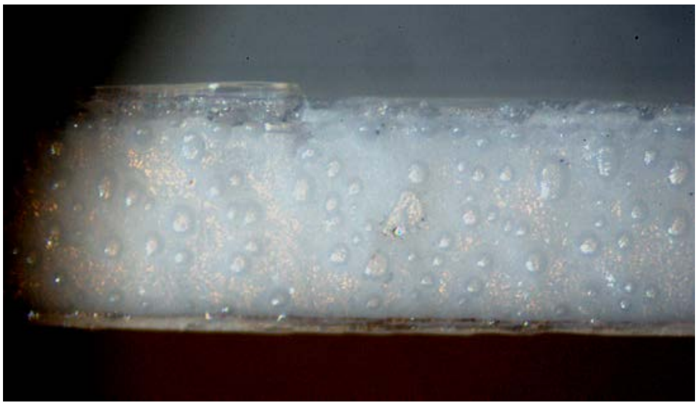

Figure 22. Sample H7 (Acrifix 116) unaged in regular microscope. Example of cohesive break in the adhesive.

3.9 SEM- imaging of S2

SEM analysis was performed using a LEO 1455VP (Oxford Instruments) with Inca 400 software. Conditions: EHT ranging from 20 kV, iprobe 1.0 nA, backscattering. Magnifications were x18, x100, x250, x1000. Samples were sputtered with gold for 60 seconds at 18mA. SEM-imaging was also done on unsputtered samples. EDS mapping time was 820 seconds. X18 and x100 of the SEM images can be seen in appendix VII.

3.9.1 SEM images for S2 before and after ageing

The SEM images of unaged samples were observed at the edge of the adhesive on the plastic after being gold sputtered. Gold sputtering ensures sharp and detailed SEM images since unsputtered plastics alone are not very good conductors. The aged samples were looked at both with and without gold coating due to some temporary technical issues with the sputtering machine. At magnification x1000 melting of the adhesives occurred for all aged, unsputtered adhesives, except for the epoxies. For the aged and sputtered adhesives only the two Paraloids experienced melting at x1000. All images show the adhesive surface to the right and the plastic surface to the left. The focus was to determine whether the adhesives caused any damage to the plastic on a microscopic level.

T/H1 (Paraloid B72 in ethanol:acetone)

No clear damage to the polystyrenes as a result of the adhesive was observed in the border area along the edge. Sample T1 unaged (Paraloid B72 on transparent polystyrene) showed some trace of mechanical damage in the plastic along the edge of the adhesive and could be due to the metal scraper used during the draw-down process or during removal of the masking-tape shim rather than as an effect of the adhesive itself. There was no clear difference between the unaged and aged samples apart from a slight tendency to increased cracking from cutting in the aged samples.

T/H2 (Paraloid B67 in isopropanol)

There was no damage to any of the polystyrenes as a result of the adhesive that could be seen in the border area along the edge of the adhesive. There was no clear difference or change between the unaged and aged samples. All samples demonstrated an uneven adhesive surface.

T/H3 (Primal AC 35)

Damage to any of the polystyrenes could not be seen in the border area along the edge of the adhesive. T3 unaged, H3 unaged and T3 aged showed some trace of mechanical damage or cut in the plastic along the edge of the adhesive. However, this effect could have been caused during draw-down or during removal of the masking-tape shim rather than an effect of the adhesive itself.

There was no clear difference or change between the unaged and aged samples. All samples demonstrated an even and homogenous adhesive surface.

T/H4 (Hxtal NYL-1)

Damage to any of the polystyrenes as a result of the adhesive could not be seen in the border area along the edge of the adhesive. There was no clear difference or change between the unaged and aged samples. All samples demonstrated an even and homogenous adhesive surface.

T/H5 (Araldite 2020)

No clear damage to any of the polystyrenes as a result of the adhesive could be seen in the border area along the edge of the adhesive. There was no clear difference or change between the unaged and aged samples. All samples demonstrated an even and smooth adhesive surface.

T/H6 (Loctite Super Attack Precision)

Some of the T/H6 samples differed from the others by having a thinner and less straight adhesive layer due to the issues with the shims in the draw-down process (see 3.2.2). A decision was taken to assess the material in the same way as the other samples within this study.

For unaged H6 at x100 and x250 (using plastic shims), there were some irregular surface features in the plastic along the observed edge which could be interpreted as damage to the polystyrene caused by the adhesive (figures 23-25). There were also some cracks in the plastic along the observed edge in the same image that might be interpreted as stress cracks caused by strain due to shrinkage during the curing process (see this in relation to the slight concave bending of the plastic after curing mentioned earlier). Irregular surface features were visible in a thicker adhesive layer (tape as shims), both before and after ageing, even at only x18 magnification (figures 24 and 25). It is more recognizable on the HIPS than on the transparent polystyrene. This surface pattern was also observed during examination under the light microscope.

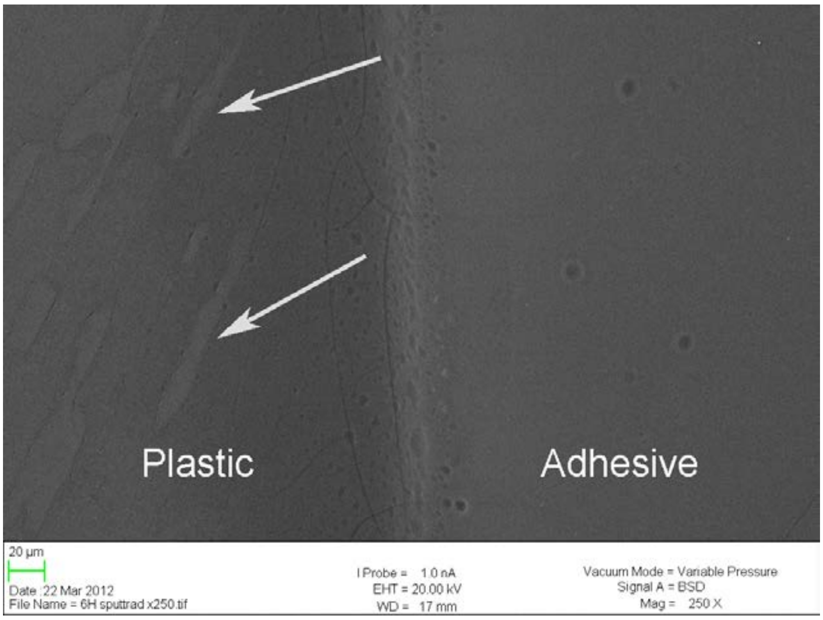

Figure 23. Unaged Loctite SAP on HIPS. Adhesive to the right. Possible damage to the plastic in left area. Visible crack along the edge of the adhesive.

Figure 24. Unaged Loctite Super Attack Precision on HIPS. Adhesive to the right. Possible damage to the plastic in left area.

Figure 25. Aged Loctite Super Attack Precision on HIPS. Adhesive to the right. Possible damage to the plastic in left area.

One sample of unaged Loctite SAP was subjected to EDS analysis to determine whether the irregularities observed on the plastic surface in SEM could be adhesive spill rather than damage to the plastic (figure 26). It was expected that more nitrogen in the adhesive than in the plastic would be observed during EDS analysis. The nitrogen mapping however gave inconclusive results. The carbon-mapping on the other hand gave indications that the irregularities observed are in the plastic itself and not adhesive spill. Had the pattern of darker and lighter banded areas, seen in the upper right hand area of the SEM image, been a spill of cyanoacrylate, the same pattern would have been visible as less carbon in the mapping, and possibly as more oxygen.

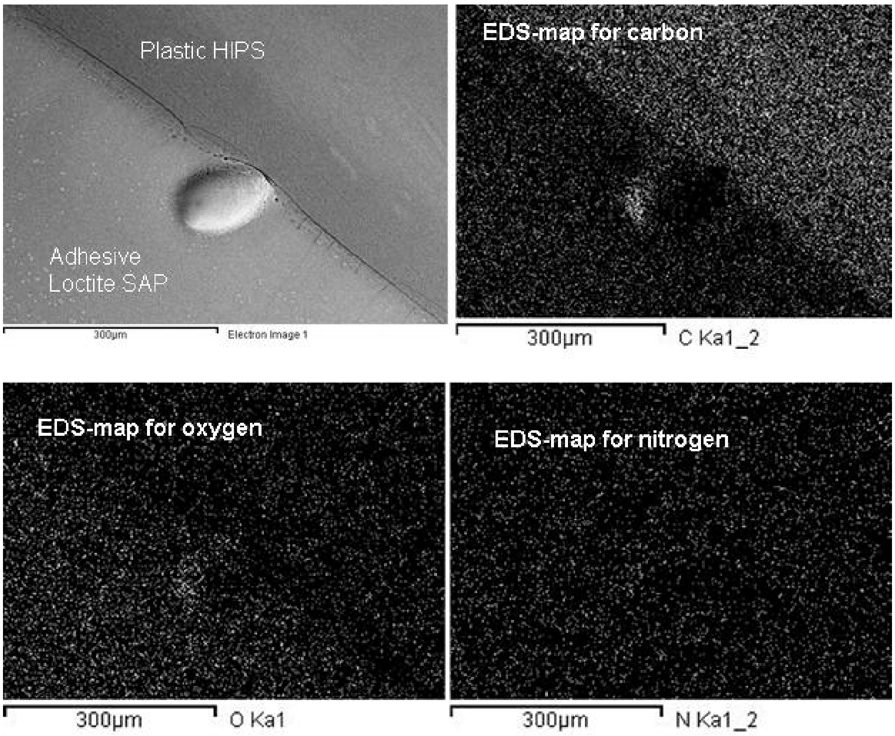

Figure 26. Sample with Loctite SAP on HIPS in EDS-mapping for carbon, oxygen and nitrogen. Corresponding SEM image in upper left hand corner (the centre shape is a conglomeration of adhesive). Adhesive layer in lower left hand corner on all four images. Had the bands of darker and lighter areas, seen in the upper right hand area of the SEM image, been a spill of cyanoacrylate, the same pattern would have been visible as less carbon in the mapping, and possibly as more oxygen. Cracks in the plastic visible in the SEM image.

T/H7 (Acrifix 116)

Both unaged and aged samples showed cracks in the plastic at the border area along the edge of the adhesive (figures 27 and 28). The cracking was more prominent in the HIPS than in the transparent polystyrene and the cracking was slightly worse after ageing. Also visible in both unaged and aged samples were some surface irregularities in the plastic right at the edge of the adhesive where it looked like some of the plastic surface was delaminating from the underlying plastic.

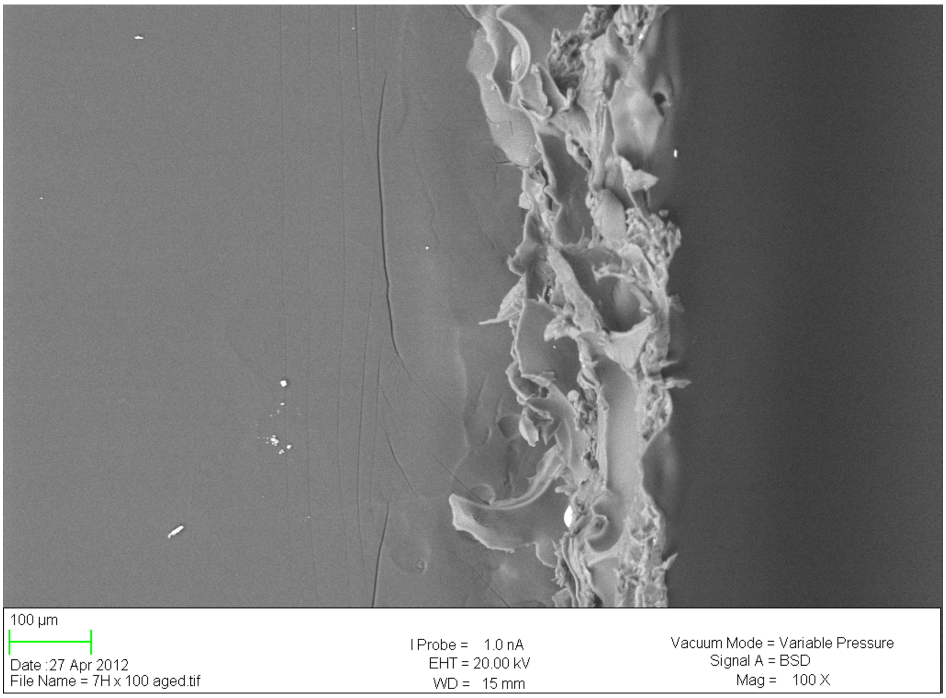

Figure 27. Aged Acrifix 116 on HIPS. Adhesive to the right. Stress cracks in the plastic along edge of adhesive.

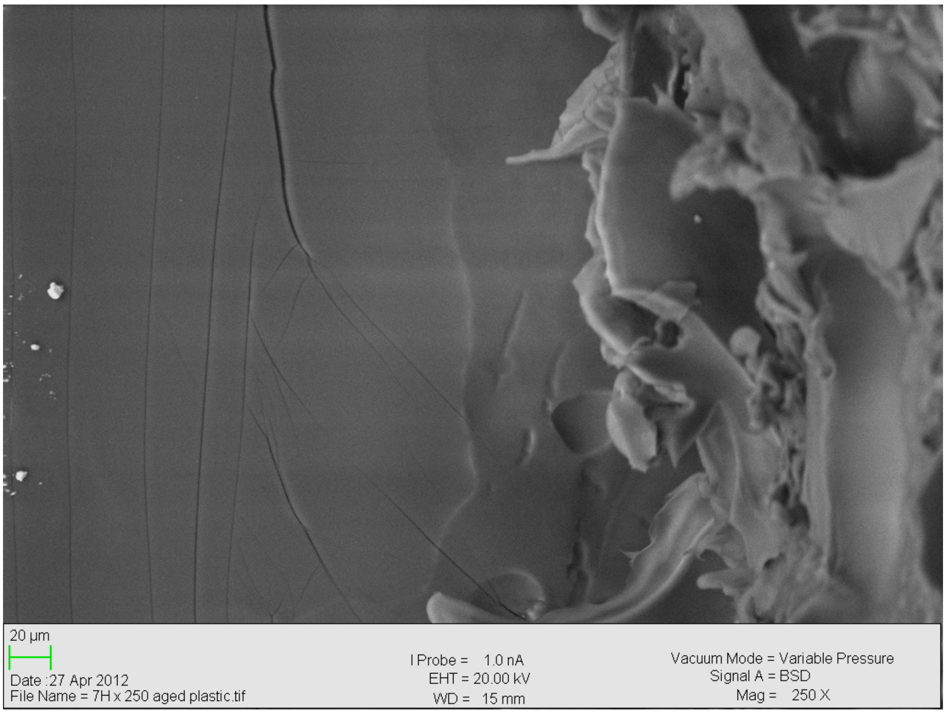

Figure 28. Aged Acrifix 116 on HIPS. Adhesive to the right. Stress cracks in the plastic.

T/H8 (Paraloid B72 in ethanol)

No clear damage to the polystyrenes as a result of the adhesive was observed in the border area along the edge of the adhesive.

3.10 FTIR

3.10.1 Instrumental

The FTIR-imaging was performed using a Spotlight 400 microscope (Perkin Elmer) equipped with a geranium ATR* -crystal with a resolution of 16 cm^{-1}, 1 cm/s, pixel size of 1.56 µm and imaging was performed with an area ranging from 50 to 200 x 200 µm of the cross-section.

3.10.2 Method

The samples were studied by ATR-FTIR microscope imaging. Microtomed cross-sections of a thickness of 100 µm from the S2 series were used (see example figure 29). The area of interest was where the plastic met the adhesive. For the samples with the dispersion, and the epoxies, the adhesive layer delaminated during the microtoming process. This also occurred for Paraloid B67 on HIPS before ageing. If delamination occurred, the area where the plastic had been in contact with the adhesive was studied. Control samples of plastic without adhesive were also included. An alternative would be to cast them in embedding material and then polish them for clearer imaging. Embedding was not chosen as there is a risk that the embedding material would interfere with the samples.

The plastic area in the mapping of the sample was examined to identify significant peak changes compared to reference spectra of the plastic (tables 9 and 10). A comparative image of every single spectra of the mapped area to that of a reference spectrum of plastic without adhesive was studied. The degree of similarity to the reference spectrum is represented by various colours (figure 29

* Attenuated Total Reflectance

and appendix VIII). The size of the zone of change in µm (Δzone) was measured (figure 29 and tables 9 and 10). The size of the zone is assumed to reflect the impact of the adhesive on the plastic.

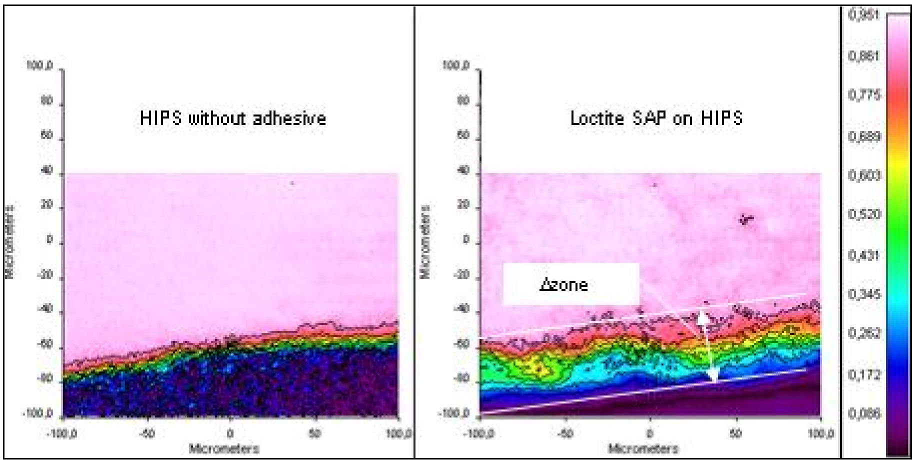

Figure 29. Comparative FTIR images of cross-sections of HIPS without adhesive (left) and HIPS with Loctite SAP (right). Top is plastic (pink indicates a match with spectrum for HIPS reference, correspondence scale in percent to the right and bottom is adhesive or air (HIPS without). Arrows indicate the change zone (Δzone).

Table 9. Zone of change (Δzone) and peak changes for the transparent polystyrene. New rising (ris.) or diminishing (dim.) peaks compared to reference plastic and before and after ageing are noted. n – No major differences between unaged and aged. Vs (versus) = compared to.

	P. B72 acetone: ethanol	**P. B72 ethanol***	**P. B67 2-propa-nol**	**Primal AC35**	**Hxtal Nyl**	**A2020**	**Loc. SAP**	**Acrifix 116**
Δzone (µm) unaged	25	15 20 for C=O	15	10	11	12	20	15 25 for C=O
Δzone (µm) aged	18	-	15	15	15	15	25	20
ris. peaks unaged vs. ref. (cm^{-1})	1730 1230 1160	1720 1240 1150	1410 1260 1100		2880 1100	940	2990 1740 1240 840	1720 1240
ris. peaks aged vs. unaged (cm^{-1})	n	-	1420 shoulder	n	n	n	n	n
dim. peaks. unaged vs. ref. (cm^{-1})		2915 3025						
dim. peaks aged vs. unaged (cm^{-1})	n	-	n	n	n	n	n	1720, 1240

*Paraloid B72 in only ethanol after ageing was not available

Table 10. Zone of change (Δzone) and peak changes for HIPS. New rising (ris.) or diminishing (dim.) peaks compared to reference plastic and before and after ageing are noted. n – no major differences between unaged and aged. Vs (versus) = compared to.

	P. B72 acetone: ethanol	**P.B72 ethanol***	**P.B67 isopropanol**	**Primal AC35**	**Hxtal Nyl**	**A2020**	**Loc. SAP**	**Acrifix 116**
Δzone (µm) unaged	22	15	13	10	9	11	37	24
Δzone (µm) aged	21	-	17	17	12	16	30	20
ris. peaks unaged vs. ref. (cm^{-1})	1720 1475 1380 1230 1140	1725 1240 1140	1410 1260 1100				174 0 124 0	1725 1240 1140
ris. peaks aged vs. uaged (cm^{-1})	n	-	n	1410	n	n	n	n
dim. peaks. unaged vs. ref. (cm^{-1})		2915 3025		960		960		
dim. peaks aged vs. unaged (cm^{-1})	n	-	n	n	n	n	n	n

* Paraloid B72 in only ethanol after ageing was not available.

3.10.3 Results

It was possible to observe that all plastics were affected in the contact zone between plastic and adhesive. Viewing the comparative images, the Paraloids, Loctite SAP and Acrifix 116 showed the largest change before ageing. Acrifix 116 had less change for the transparent polystyrene and more change for HIPS. After ageing Loctite SAP, the acrylates and Araldite 2020 showed the largest Δzone for HIPS. For the transparent polystyrene they were at a fairly equal level with the exception of the cyanoacrylate which had a slightly larger Δzone.

For the Acrifix 116 and Paraloid B72 it is possible to see how the carbonyl peak, C=O, of about 1725 cm^{-1} increased in the plastic surface area to a greater extent than for the control and other adhesives. For Loctite SAP the increase was more shifted towards 1740 cm^{-1}. There were no greater changes detected during the comparison of the unaged and aged Δzones.

3.11 Hardness measurement

Hardness pencil testing was performed on S2 before and after ageing. See appendix IX for Excel tables with durometer measurements. Hardness testing was done with a Rex Durometer (Rex Gauge Company, INC), Model MSDD-3-A, B, O in accordance with ASTM D-2240.

Since the S2 adhesive layers are only 1 mm (or less), there is a risk that the underlying surface will interfere with the measurements of the hardness of the adhesive. It is here assumed that the measurements taken can be used to compare the adhesives because the underlying surface was the same for every measurement, even though the exact values by themselves might be affected by the underlying material. The hardness testing was done with the MS-O 0209 pencil head designed for softer materials like textiles, rubber and gums. In this case it is believed that the MS-O type will give the most accurate readings since the problem with the thickness of the adhesive layers requires a very sensitive measuring head. Three measurement points were taken for each sample and the average calculated.

A general observation was that the hardness values of the different adhesives were all close to each other and also do not differ that much from the hardness of the plastics. The transparent polystyrene was harder than HIPS and both plastics were harder than most of the adhesives, except for the epoxies (T4, H4, T5, H5) which were almost as hard as the plastics (figures 30 and 31).

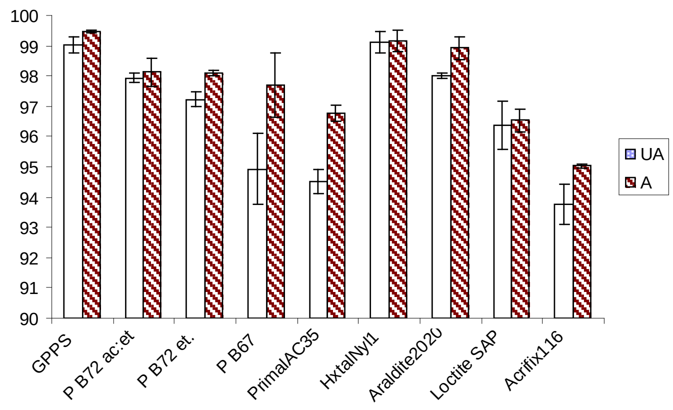

Figure 30. Hardness before and after ageing on tranparent polystyrene. U – unaged (blue). A – aged (red). T0 –plastic without adhesive. T7 (Acrifix 116) value might be incorrect due to the concave shape of the sample.

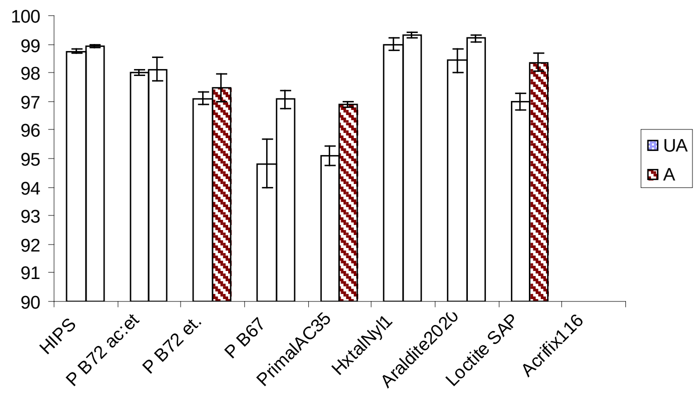

Figure 31. Hardness before and after ageing on HIPS. U – unaged. A – aged. HIPS – plastic without adhesive. Acrifix 116 value was not possible to measure due to the concave shape of the sample.

The softest adhesives were Acrifix 116, Primal AC 35 and Paraloid B67. The measurements of Acrifix 116 may be incorrect because of the bending of the plastic which made measuring difficult. For Paraloid B67 miniature fractures caused by the durometer pencil during hardness testing were visible. The durometer did not cause fractures in any of the other adhesives.

Both plastics and all adhesives hardened with ageing. Paraloid B72 and Hxtal NYL-1 changed the least after ageing while Paraloid B67 and Primal AC 35 changed the most.

3.12 Assessment of reversibility

The possibility to remove the adhesive was assessed by attempting to remove/dissolve the adhesive left on the break edges of S1 samples with a scalpel, wooden toothpick, water, ethanol, acetone and isopropanol. Results were observed under the microscope. Any possible damage or dissolving of the plastics was also assessed. There was no apparent difference in reversibility between the same adhesive on the two polystyrenes. See table 11 for results. The different adhesives demonstrated the same reversibility results after ageing as before ageing, apart from the fact that it in general took approximately 10 minutes longer time for the adhesives to dissolve and a larger amount of solvent was needed after ageing.

Table 11. Results for trials of removing on S1. Red indicates not possible to remove, yellow- possible but with damage to plastic and green- possible to remove with no visible damage. Exposure for water, ethanol and isopropanol was ca.15 min.

	Wooden toothpick	Scalpel	Water	Ethanol	Acetone	Isopropanol
Paraloid B72 in ethanol/ acetone	Partially possible to remove. Difficult to remove all residue from an uneven break surface	Possible to remove but with risk of damage to the plastic	Possible to remove if exposed for up to 8 hours due to swelling and softening of adhesive	Possible to remove. Takes some time for the adhesive to dissolve/soften	Possible to remove. Visible damage to/dissolving of plastic	Possible to remove. Takes some time for the adhesive to dissolve/soften
Paraloid B67	Partially possible to remove. Difficult to remove all residue from an uneven break surface	Possible to remove but with risk of damage to the plastic	Not possible to remove. Some softening of the adhesive	Possible to remove. Takes some time for the adhesive to dissolve/soften	Possible to remove. Visible damage to/dissolving of plastic	Possible to remove. Takes some time for the adhesive to dissolve/soften
Primal AC35	Possible to remove	Possible to remove but with risk of damage to the plastic	Possible to remove. Takes some time for the adhesive to dissolve/soften	Possible to remove. Takes some time for the adhesive to dissolve/soften	Possible to remove. Visible damage to/dissolving of plastic	Possible to remove. Takes some time for the adhesive to dissolve/soften
Hxtal NYL-1	Possible to remove. Difficult to remove all residue from an uneven break surface	Possible to remove but with risk of damage to the plastic	Not possible to remove. Some softening of the adhesive	Not possible to remove	Not possible to remove. Some softening of adhesive. Visible damage to/dissolving of plastic	Not possible to remove

Araldite 2020	Possible to remove. Difficult to remove all residue from an uneven break surface	Possible to remove but with risk of damage to the plastic	Not possible to remove. Some softening of the adhesive	Not possible to remove	Not possible to remove. Some softening of adhesive. Visible damage to/dissolving of plastic	Not possible to remove
Loctite SAP	Not possible to remove	Possible to remove but with risk of damage to the plastic	Not possible to remove. Some softening of the adhesive	Not possible to remove	Partially possible to remove through softening of adhesive. Visible damage to/dissolving of plastic	Not possible to remove
Acrifix 116	Partially possible to remove. Difficult to remove all residue from an uneven break surface	Possible to remove but with risk of damage to the plastic	Not possible to remove. Some softening of the adhesive	Not possible to remove. Some softening of adhesive	Possible to remove. Visible damage to/dissolving of plastic	Not possible to remove
Paraloid B72 in ethanol	Partially possible to remove. Difficult to remove all residue from an uneven break surface	Possible to remove but with risk of damage to the plastic	Possible to remove if exposed for up to 8 hours due to swelling and softening	Possible to remove. Takes some time for the adhesive to dissolve/soften	Possible to remove. Visible damage to/dissolving of plastic	Possible to remove. Takes some time for the adhesive to dissolve/soften

3.13 Tests on objects

Based on the results from the different experiments on S1 and S2, four of the adhesives were chosen for some empirical testing on real polystyrene objects. The intention was to empirically and visually assess whether the impression from working properties and visual assessment in Series 1 would apply to the same degree on actual objects. Hxtal NYL-1 was chosen for its ageing stability and refractive index, Loctite SAP for its strength, Primal AC35 for good working properties, reversibility and as a representative of a weaker adhesive and Paraloid B72 in ethanol for its medium strength and good working properties. The adhesives were tested on a transparent water pitcher (figures 32 and 33), a white egg cup (figure 37) and a red egg cup (figure 38), all intentionally broken by dropping them from a height of 1 meter. The objects were found on flee markets and thought to be about 30 to 20 years old.

The tests on real objects correlated to the tests on S1 to a great degree. All adhesive bonds were visible on the transparent water pitcher as in S1. This was visible to a greater extent for Paraloid B72 due to bubbles in the adhesive bond (figure 36). However, a positive factor regarding its visual appearance was the easiness in removing spill around edges with just a wooden toothpick after curing. Least visible was Hxtal NYL-1. Primal AC35 was clearly visible on the white egg cup because of its pale yellow colour, but not however on the red egg cup where this colour was unrecognizable. Loctite SAP gave a visually good result both on the white and red egg cup although some spill was nearly impossible to remove after curing. Its short curing time was experienced as a positive factor when adhering parts that needed to be held manually while curing. No damage to the plastic could be observed when looking at the area around the bonds in regular microscope. Difficulties in achieving tight bonds in general was experienced on the white egg cup due to some distortion of the plastic upon breaking which resulted in the pieces not fitting perfectly together. No bond failure was experienced for any of the adhesives during some normal handling after curing.

Figure 32. Broken water pitcher.

Figure 33. Bonds of Paraloid B72 in ethanol (8), Loctite SAP (6) and Hxtal NYL-1(4).

Figure 34. Bond of Loctite SAP

Figure 35. Bond of Hxtal NYL-1

Figure 36. Bond of Paraloid B72 in ethanol

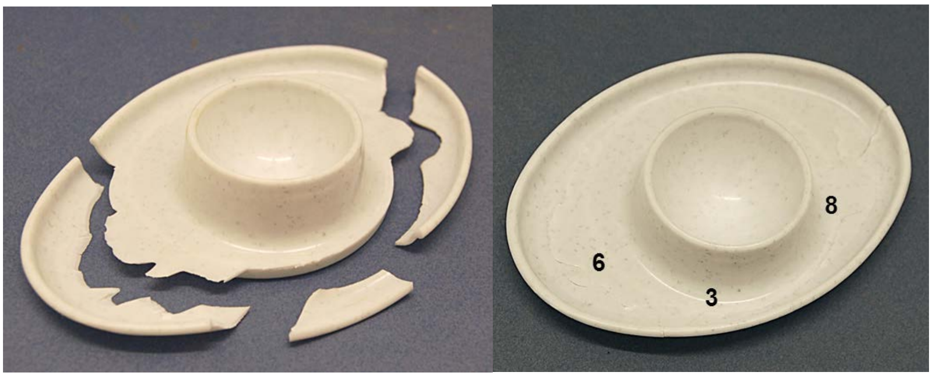

Figure 37. Bond of Loctite SAP (6), Primal AC35 (3), ParaloidB72 (8) in ethanol

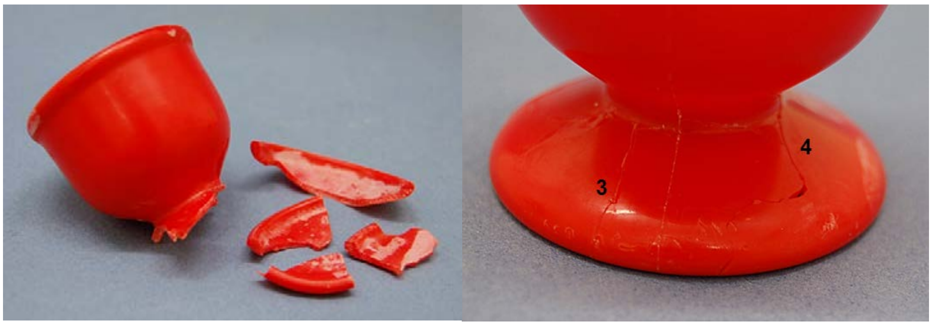

Figure 38. Bond of Primal AC35 (3), and Hxtal NYL-1 (4).

4. Discussion

4.1 Damaging effect from adhesive

Damage to the plastic material was most notable in the deformation effect from Acrifix 116 on S2 samples. This was also seen on a microscopic level in the cracking observed in the SEM-images. Furthermore, a large change zone was noted in the FTIR imaging for several of the samples. This is likely to be caused by a combination of factors. The solvent mixture in the adhesive dissolves the polystyrene lowering its Tg which increases the possibility for the polymer chains to move. When the adhesive contracts or shrinks during evaporation of the solvent, a tension is created giving rise to this deformation. The HIPS is softer or more flexible and therefore more easily affected by this strain. Furthermore, the extruded plastic materials in this investigation will have inherent tension from production as they were subjected to temperatures upwards of 110˚C that could be released during dissolution contributing to this deformation.

Damage to the plastic was also seen for Loctite SAP in bending and cracking of S2 samples. Another possibly damaging effect was seen for Loctite SAP in the SEM-images as a surface pattern. It has been shown that cyanoacrylates can mix with a plastic, (polycarbonate) while curing and a similar process might be indicated here (Drain et al., 1985). Internal shrinkage of cyanoacrylates upon curing has been shown to occur (Vestergaard and Horie, 1996), which is a contributing factor to the cracking in the samples of Loctite SAP together with possible diffusion into the plastic. The surface phenomenon was more apparent on the HIPS and possibly the small molecules of the cyanoacrylate or its additives could more easily diffuse into the HIPS where the polybutadiene phase creates more free volume in comparison to the general purpose polystyrene.

For the damaging effect viewed in the SEM images it should be remembered that this is performed on samples with a layer of adhesive. In conservation the adhesives of this investigation, in these concentrations, are more often used for the joins of S1. The curing process of adhered edges is different from that of the open layer. For an edge join, less adhesive material is introduced and the evaporation process is slower, which might reduce stresses. On the other hand there could be longer exposure to solvent action.

4.2 Tensile testing

The epoxies have a medium break force sensitivity among the tested adhesives, even though epoxies in general are considered to be very strong. This is also seen in the apparent delamination of the epoxies from the plastics observed in S2 and in the microtoming. It is evident that the epoxies do not adhere well to polystyrene surfaces and this might explain why they do not get higher values during tensile testing. The apparent weakness of the epoxies could arise from their lack of affinity with non-polar surfaces. The non-polar surface of polystyrene repels the adhesive upon application which results in no good contact and a weakened bond. This is reflected in the fact that the surface tension value of polystyrene is lower than that of epoxy, 33 mN/m compared to 47 mN/m at 20° C for epoxy. Acrylics have 32 mN/m and cyanoacrylates 37 mN/m and should hence wet the substrate more efficiently (Shashoua, 2008). It has to be remembered that this was tested on unaged material. The aged plastics of a museum collection could be of higher polarity due to deterioration.

It has been reported that the strength of Araldite 2020 increases during light ageing and is thought to be a result of cross-linking (Coutinho et al., 2009). This is not reflected in the tensile strength of the bonds. On the other hand the hardness values for Araldite 2020 increase which could indicate cross-linking. This again shows the importance of looking at the adhesive and substrate as a system and not solely at the adhesive. The epoxy bonds are stronger on the HIPS, possibly as a result of the butadiene phase introducing a greater polarity.

It is interesting to note the difference in break force sensitivity between the two Paraloids, with Paraloid B72 being stronger than B67. Both Paraloids have a lot of bubbles in the adhesive bond and there were more for Paraloid B67. The apparent brittleness of the B67 as observed during hardness testing adds a weakness to the bond as it shatters during tensile stress rather than show some flexibility. The brittleness of B67 has been shown in earlier studies (Down et al., 1996, 2009).

The only adhesive that is significantly weakened by light ageing, is the cyanoacrylate for the transparent plastic. It has been noted that cyanoacrylate adhesives are prone to photo-induced ageing with possible chain scission and this could be the process occurring here (Horie, 2010). The transparency of the plastic enables the radiation to reach the adhesive of the join.

The Acrifix 116 (acrylate in solvent mix) and the Primal AC-35 (acrylate dispersion) showed an increase in strength which could be attributed to a prolonged drying process. It should be taken into account that there is a great spread in values which gives some uncertainty to these results.

Investigating the relation between the strength of the bonds and the interference with the plastic surface seen in the FTIR imaging it is not clear. This might be the case for the cyanoacrylate with its element of diffusion into the surface, but many of the samples from the solvent carried systems are in the middle range together with the epoxies. The polar affinity with polystyrene, the viscosity and the flexibility of the adhesives need to be taken into account.

Break force sensitivity was higher for both polystyrenes without adhesives, which indicated that a break in the plastic was highly unlikely. Loctite SAP however showed a maximum break force sensitivity of 980 N for one sample on transparent polystyrene, which was higher than the average break force sensitivity of both transparent polystyrene and HIPS. This showed that Loctite SAP was the only adhesive tested where there was a small risk of a break happening in the plastic rather than in the adhesive bond if subjected to enough stress.

The fact that all adhesives have higher break force sensitivity for the softer HIPS could depend on various factors. The more open structure of the two-phase system with grafted polybutadiene contributes to more surface area resulting in a greater possibility for contact. It also allows for more flexibility when subjected to tensile stress. Furthermore, the degree of polarity can play a part.

4.3 Colour change

Yellowing was more apparent in the layers of adhesive on S2 and to a lesser extent for the bonds of S1. This is not surprising as the light radiation had more difficulty in reaching the adhesive in the adhered edges. There was, however, distinct yellowing in S1 for Araldite 2020 and Loctite SAP. The Araldite 2020 has been shown to yellow in earlier investigations and cyanoacrylates are as mentioned above prone to photo induced deterioration (Drain et al., 1985)(Horie, 2010). Severe yellowing for epoxies could be attributed to the amine-structure present in a catalyst (Down, 2001). The DGEBA† component of the Araldite 2020 was also noted to yellow during light ageing (Horie, 2010).

The two epoxies show a difference in colour change where the Hxtal NYL-1 did not visibly yellow while Araldite 2020 did. The non-yellowing quality of Hxtal NYL-1 has been shown in earlier studies (Down, 2001)(Coutinho et al., 2009)(Sale, 2011). Looking at the colour measurement on the glass substrate, the Hxtal NYL-1 here showed less colour change compared to Hxtal NYL-1 on plastic which indicated that the plastics yellow during ageing rather than the adhesive. It is also worth noting that Loctite SAP was the only adhesive which went from – (blue) to + (yellow) in b* value after ageing when measured on a glass substrate.

The values from the spectrophotometer mirror what was seen by the human eye. The two Paraloids experienced the same amount of visible yellowing. In earlier ageing studies B72 was shown to yellow more than B67 during light ageing (Down, 2009). Acrifix 116 differed the least among the adhesives from the HIPS-target after ageing and appeared to act as a protective layer.

4.4 Hardness

A general tendency is that both plastics and all adhesives harden with ageing. Paraloid B72 and Hxtal NYL-1 have hardened the least after ageing while Paraloid B67 and Primal AC 35 hardened the most. This could be a result of cross-linking in the adhesives caused by the light ageing but could also be a result of the continuing process of curing. It has been pointed out by Wolbers (2008) in relation to long term ageing of acrylics, that there is a process of loss

† Diglycidyl ether of bisphenol A

of solvent over time which will affect their flexibility and Tg resulting in increased brittleness. Acrylics have also been shown to become less flexible during dark ageing (Down et al., 1996).

A measurement of hardness and a comparison between different adhesives can, from a conservator's point of view, be of interest as a means of understanding how the adhesive and substrate age and function over time. The ideal would be that the adhesive should not be harder than the plastic; this was the case for most of the investigated adhesives apart from the epoxies.

4.5 FTIR

A large Δzone could be seen for the cyanoacrylate on HIPS. The two-phase system of HIPS could allow the small cyanoacrylate monomer to have an affect on the plastic. The SEM-images of the plastic with Loctite SAP showed that a surface pattern was present, indicating a change was induced by the adhesive. The surface phenomenon for the cyanoacrylate was more apparent on HIPS than on the transparent polystyrene, which could indicate that the small molecules of the cyanoacrylate or its additives can diffuse more easily into the HIPS. The polybutadiene phase creates more free volume in comparison to the transparent polystyrene. It has been shown that cyanoacrylates can mix with polycarbonate while curing (Drain et al., 1985) and a similar process might be indicated here.

In the reference spectrum for the plastic without adhesive there was no carbonyl peak. For the samples with Acrifix 116 and Paraloid B72 it was possible to see how the carbonyl peak at around 1725 cm^{-1} increased at the surface of the plastic to a greater extent than for the samples with other adhesives. For Loctite SAP the increase in the carbonyl peak was more shifted towards 1740 cm^{-1}. The increase at about 1725 cm^{-1} for Acrifix 116 and the Paraloids can be attributed to the carbonyl in the adhesive. The peaks at approximately 1720 (C=O), 1230-40 and 1150-60 cm^{-1} (C-0 and C-C stretch), found in the surface area of the

Paraloid B72 samples, were probably originating from the adhesive as they were still present in the aged material where the presence of solvent should be negligible. These peaks were similar to the Paraloid B67 reference spectra but were not seen for the B67 samples in the surface zone. This indicated that the mix of B67 and isopropanol did not affect the surface area to the same extent. A similar pattern could be seen for the cyanoacrylate with the carbonyl peak shifted to 1740 cm^{-1}; typical of a cyanoacrylate. The dispersion and the epoxies had the least affect on the plastic substrate.

There was no significant correlation between the size of the Δzone and the strength of the bond. However, a slight tendency for this relation can be seen if the strength of the tensile testing is plotted against the size of the change zone (figure 39). The four adhesives with the largest Δzone were Loctite SAP on HIPS before and after ageing, Loctite SAP on the transparent general purpose polystyrene after ageing and Paraloid B72 in acetone:ethanol on HIPS before ageing.

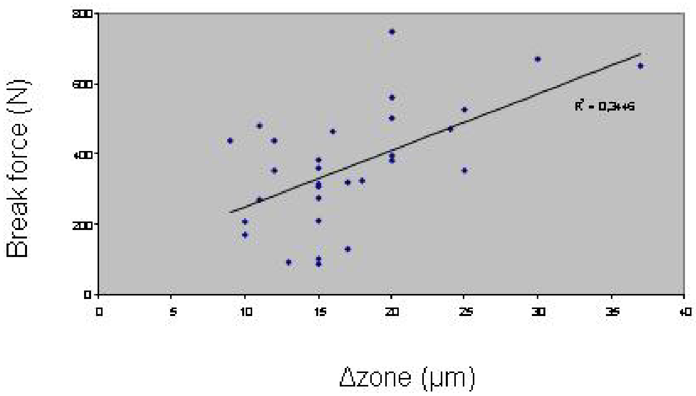

Figure 39. Break force sensitivity in relation to extent of Δzone in FTIR-imaging. No consistent relation (Linear regression 0.34) but a slight tendency can be seen.

Previously in the literature it has been reported that light ageing of epoxy will result in the formation of amides. A peak at 1660 and 1604 cm^{-1} indicates a carbonyl to amide bond (Lazzari et al., 2011). This was not seen in the surface area of the aged samples of plastic with epoxy which could be attributed other formulations of adhesive and less light reaching the investigated area.

4.6 Effect of solvent action

The diffusion of solvents with a dissolving effect on the plastics is probably a contributing factor to the strength of the adhesion as seen in tensile testing and also in the microtoming process. For instance, on HIPS, Paraloid B72 in acetone: ethanol is stronger than Paraloid B72 in ethanol only, which may be related to the dissolving of the HIPS with acetone as a solvent. To some extent the diffusion of solvents can contribute to the adhesion of the adhesives and more so for the softer HIPS. As the dissolving effect increases the movability of the polymer chains, greater surface contact is created resulting in greater possibility for attraction forces between the substrate and the adhesive. When microtomed Paraloid B72 and Acrifix 116 remained on the plastic substrate and they had the least adhesive breaks during tensile pull-to-break testing. Delamination was seen in the B67 sample and could be attributed to its inherent brittleness. The cyanoacrylate remained in place when microtomed, reflecting the strength of the bond to polystyrene observed during tensile testing. In addition, there might be an element of mixing with the plastic as discussed above.

This dissolving effect can be damaging to the original material as seen when the Acrifix 116 adhesive was applied to the polystyrene substrate. Looking at Hildebrand solubility parameters, the 18.6 $MPa^{½}$ of the ethyl acetate in Acrifix 116 is very close to that of polystyrene at 18.7 $MPa^{½}$. Also that of acetone at 20.4 $MPa^{½}$ is within the 2 $MPa^{½}$ difference range for dissolution and the large Δzone assumed to reflect the impact of the adhesive seen in the FTIR-imaging for Paraloid B72 in acetone: ethanol can be attributed to this. Ethanol and water have Hildebrand solubility parameters of 26.6 $MPa^{½}$ and 47.7 $MPa^{½}$ respectively (Shashoua, 2008). Even though ethanol is not supposed to dissolve polystyrene, the FTIR-imaging for Paraloid B72 in ethanol indicated that some dissolution may occur. On the other hand no damage could be seen during visual inspection using microscopy or SEM imaging for these samples. For the dispersion, no damage was observed. It should be noted that the solubility of the plastic can change with ageing. It was seen in the results that choosing adhesives commonly used for glass or PMMA might not be suitable for polystyrene as it is very solvent sensitive.

4.7 Overall assessment of the different adhesives

Based on all of the different tests in series 1 and 2, no single adhesive appeared as clearly superior to the others or to be recommended in general for use on all polystyrene plastics. This was not only because all of the adhesives had some areas or tests where they demonstrated some clear weaknesses, but also because the choice of adhesive must be seen in relation to the object in question (See tables 12 and 13 for a schematic summery of results). For instance, Loctite Super Attack Precision is not necessarily "better" than Primal AC 35 just because it has a much higher break force sensitivity – it depends on whether a strong bond is the priority when adhering the relevant plastic. Sometimes a weaker bond is wanted. Still, some conclusions can be drawn based on the testing presented here, at least in relation to which adhesives should not be recommended from a heritage perspective.

Even though Acrifix 116 showed some very good qualities both in relation to ageing (no colour change, very little hardness change) and general look and usage, it showed a damaging effect in the plastic through severe bending seen in series 2, micro-cracking seen in the SEM and a noted change in FTIR-imaging. The clearly increased break force sensitivity after ageing might also indicate some unwanted strengthening of the bond.

Table 12. Overall assessment of adhesives on transparent polystyrene.

Adhesive	Health-aspects	Working prop.		Colour		Hardness		Bond strength		Type of break		Damage/affect to plastic		Noted change FTIR*	
		U	A	U	A	U	A	U	A	U	A	U	A	U	A
Paraloid B72 in acetone:ethanol *Acrylate*	Irritant	F		G	G	1	1	2	2	Cohesive in adh.	Cohesive in adh.			x	
Paraloid B72 in ethanol *Acrylate*	Irritant	G		G	G	1	1	2	2	Cohesive in adh	Cohesive in adh.		-		-
Paraloid B67 in 2-propanol *Acrylate*	Irritant	F		G	G	3	1	3	3	Cohesive in adh.	Cohesive in adh.				
Acrifix 116 *Acrylate*	Irritant	G		G	G	3	3	2	1	Cohesive in adh.	Cohesive in adh.	x	x	x	
Primal AC35 *Acrylate dispersion*	Slight irritant	G		F	F	3	2	3	3	C/A	C/A				
Hxtal NYL-1 *Epoxy*	Corrosive	P		G	G	1	1	2	2	Adhesive	Adhesive				
Araldite 2020 *Epoxy*	Corrosive	P		G	P	1	1	2	2	Adhesive	Adhesive				
Loctite Super Attack Prec. *Cyanoacrylate*	Irritant	F		F	P	2	2	1	1	C/A	C/A	x	x	x	x
Transparent Polystyrene				G	F	1	1								

***** A change larger than 20 µm difference compared with the control. C/A – Cohesive break in the adhesive and adhesive break. Aged Paraloid B72 in ethanol was not available for SEM and FTIR

Hardness values
1 = 97,1–100 (hardest)
2 = 95,1–97,0
3 = 93,1–95,0

Abbreviations in table
U – Unaged
A – Aged

Bond strength values
1 = 500 – 750 N
2 = 250 – 499 N
3 = 0 – 249 N

Assessment
F – Fair
G – Good
P – Poor

Table 13. Overall assessment of adhesives on HIPS.

Adhesive	Health aspects	Working prop.		Colour		Hardness		Bond strength		Type of break		Damage/affect to plastic		Noted change FTIR*	
		U	A	U	A	U	A	U	A	U	A	U	A	U	A
Paraloid B72 in acetone:ethanol *Acrylate*	Irritant	F		G	G	1	1	2	2	Cohesive In adh.	Cohesive In adh.			x	x
Paraloid B72 in ethanol *Acrylate*	Irritant	G		G	G	2	1	2	2	Cohesive In adh.	Cohesive In adh.		-		-
Paraloid B67 in 2-propanol *Acrylate*	Irritant	F		G	G	3	2	3	3	Cohesive In adh.	Cohesive In adh.				
Acrifix 116 *Acrylate*	Irritant	G		G	G	3	3	2	1	Cohesive In adh.	Cohesive In adh.	x	x	x	x
Primal AC35 *Acrylate dispersion*	Slight irritant	G		F	F	2	2	3	2	C/A	C/A				
Hxtal NYL-1 *Epoxy*	Corrosive	P		G	G	1	1	2	2	Adhesive	Adhesive				
Araldite 2020 *Epoxy*	Corrosive	P		G	P	1	1	2	2	Adhesive	Adhesive				
Loctite Super Attack Prec. *Cyanoacrylate*	Irritant	F		F	P	2	1	1	1	C/A	C/A	x	x	x	X
HIPS				G	P	1	1								

*A change larger than 20 µm difference compared with the control. C/A – Cohesive break in the adhesive and adhesive break. Aged Paraloid B72 in ethanol was not avalaible for SEM and FTIR.

Hardness values
1 = 97,1–100 (hardest)
2 = 95,1–97,0
3 = 93,1–95,0

Abbreviations in table
U – Unaged
A – Aged

Bond strength values
1 = 500 – 750 N
2 = 250 – 499 N
3 = 0 – 249 N

Assessment
F – Fair
G – Good
P – Poor

Epoxies are generally known to be a very strong adhesive on other materials however when applied to polystyrene this strength was not so apparent. This could be seen in the delamination experienced both in Series 1 and Series 2, and the medium break force sensitivity observed during tensile testing. It can be assumed that an epoxy will be especially prone to delamination from the plastic if applied on a smooth break edge. Among the epoxies, Hxtal NYL-1 yellows far less than Araldite 2020 when aged. Loctite Super Attack Precision should also be avoided if yellowing is unacceptable.

However, if a strong bond is needed, a cyanoacrylate might be the best alternative among the tested adhesives, but the risk of a future break in the plastic rather than in the adhesive bond must be considered. Moreover, the possible damaging affect to the plastic seen in FTIR-imaging and SEM, raises questions on its suitability. In addition, yellowing of the adhesive after curing needs to be considered.

Both Paraloids showed good ageing qualities, but Paraloid B72 appeared superior to B67 based on the extremely weak bond and brittleness of the latter both before and after ageing. However, it should be considered, that using Paraloid B72 in ethanol only as apposed to ethanol:acetone would be advised as the latter could damage the plastic due to the presence of acetone. Testing also demonstrated the enhanced working properties of Paraloid B72 when mixed with ethanol only, largely due to a prolonged working time as ethanol has a slower evaporation rate. If choosing a Paraloid, one should be aware of the difficulty in achieving a very clean, thin bond due to the large amount of bubbles in the adhesives. Techniques to avoid bubbles for Paraloid B72 can be found in Koob (2011). If a relatively weak bond and a white or pale yellow colour is wanted or accepted, Primal AC 35 could be an alternative based on its good working properties and reversibility.

It should be noted that none of the tested adhesives match the refractive index (RI) of polystyrene and therefore all bonds are visible. The difference for a match should be less than RI 0.02 and this should be included in future studies. Augerson et al., (1993) has shown that mixing various adhesives could be a way to match the refractive index of the object. As the RI of polystyrene is high, 1.59, the possibility of mixing common adhesives for conservation purposes is limited. Looking at an adhesive with an RI 1.59 would be of interest for future studies.

5. Summery and conclusions

In order to contribute with further knowledge to guide conservators in their decisions in active conservation of polystyrene materials, seven adhesives were tested for their effect on the plastic material before and after light ageing.

The main aim of this investigation was to investigate:

- The stability of the adhesives that are used by conservators and how the join will age.
- The effect of the adhesives on the original material and to study what chemical and mechanical changes may occur.
- How suitable and compatible the adhesives are for polystyrene.

Furthermore, the question of reversibility was considered and some of the adhesives were tested on three-dimensional objects.

The methods applied before and after ageing were visual assessment, colour measurement, ATR-FTIR-imaging, SEM-imaging, tensile testing, assessment of working properties, type of break and hardness testing. Accelerated ageing was performed by visible spectrum light exposure with a UVA component.

The chosen adhesives were three acrylates in solvent (Paraloid B72 in acetone: ethanol, or ethanol, Paraloid B67 in isopropanol and Acrifix 116), one acrylate dispersion (Primal AC-35), two epoxies (Hxtal NYL-1, Araldite 2020) and one cyanoacrylate (Loctite Super Attak Precision (SAP)). They were tested on extruded transparent general purpose (GPPS) and white high impact (HIPS) sheets of polystyrene with the adhesives applied on the edge joins and as an open layer.

A damaging effect to the plastic was seen for Acrifix 116 and Loctite SAP. In addition, an effect on the plastic by these adhesives and for the Paraloid B72 in acetone: ethanol could be seen in the FTIR-imaging. Stress-cracking of the plastic at joins of adhered edges was not visible on visual inspection or in the stereomicroscope. For the cyanoacrylate a surface effect on the plastic was visible in the SEM.

The tensile strength of the adhesive joins was not severely affected during ageing for most of the adhesives tested. The cyanoacrylate on transparent general purpose polystyrene was weakened and for Acrifix 116 (on transparent and HIPS) and Primal AC-35 on HIPS the bond was strengthened. In general, the cyanoacrylate was the strongest and Paraloid B67 the weakest. Most bonds were stronger for HIPS when compared to adhesive bonds on the transparent general purpose polystyrene. None of the adhesives resulted in a cohesive break in the plastic. Adhesive breaks could be seen for the epoxies. The epoxies did not adhere as strongly to the polystyrene as it is known to on other materials, which was attributed to the non-polar quality of polystyrene.

Most adhesives showed visible yellowing, apart from Acrifix 116 and Hxtal NYL-1 on the open layer samples. The bonds at the edge joins for the cyanoacrylate and Araldite 2020 showed visible yellowing. None of the tested adhesives matched the refractive index of the polystyrene and this resulted in visible bonds. Deformation of the samples with an open layer of adhesive could be seen for Acrifix 116 and to a lesser extant for Loctite SAP. Reversibility was possible for the Paraloids and the dispersion Primal AC-35. It was possible to remove the epoxies and Acrifix 116 manually with a wooden toothpick with some difficulty. The other adhesives were not possible to remove without the risk of damaging the plastic. The cyanoacrylate was not possible to remove.

During this investigation none of the tested adhesives proved to be ideal for polystyrene. If a weak bond is acceptable the non-yellowing, epoxy (Hxtal NYL-1) or the acrylate dispersion (Primal AC-35) could be chosen as they caused the least damage to the polystyrene material. The dispersion also showed it was reversible which may be a desired characteristic. Possible disadvantages for these adhesives could be difficulty in application for the epoxy and a slight yellowing colour for the dispersion. The greatest potential for damage was indicated by Acrifix 116 and Loctite SAP.

Ideally an adhesive should be able to hold pieces together for the intended usage, and within conservation it should be able to be separated or reversed without damage. When choosing an adhesive for a object in a heritage collection one needs to consider aesthetic aspects, the history of the object, its condition as well as future use with expected stresses. Knowing the behaviour of the investigated adhesives and how they age together with polystyrene will guide conservators in making informed choices for polystyrene materials.

5.1 Further research

This investigation focused on light ageing as this is the factor most likely to affect objects in the museum environment. On the other hand it is necessary to study physical ageing and study the issue of free volume with other methods of accelerated deterioration to fully grasp the ageing process. It would also be of interest to age plastics and adhesives naturally i.e. leave them in a museum environment for a longer time period and monitor the chemical and physical changes over time.

The study only looked at seven of many possible adhesives and more adhesives need to be tested.. In addition, the possibility to first age the sample material, or use real objects in a systematic set-up, and then adhere naturally broken edges would be useful to investigate how the properties change and the damaging effect of the adhesive on the plastic over time. Lastly a further study of the phenomenon of a surface pattern in the plastic initiated by the cyanoacrylate adhesive would be interesting to perform.

5.2 Swedish summery/ Svensk sammanfattning

För att bidra med kunskap inom aktiv plastkonservering har sju adhesiver testats på styrenplast före och efter åldring. Syftet har varit att undersöka adhesivernas stabilitet samt deras påverkan på plastmaterialet på lång sikt och på så sätt kunna underlätta val av adhesiv utifrån bevarandeperspektiv. Mekaniska och kemiska förändringar av plastmaterial och fog har studerats före och efter ljusåldring. Även adhesivernas reversibilitet har undersökts.

Utifrån en enkät bland konservatorer, en initial testning samt diskussioner i en referensgrupp valdes sju olika adhesiver; akrylater i lösningsmedel (Paraloid B72 i aceton: etanol 1:1, eller i bara etanol, Paraloid B67 i isopropanol, Acrifix 116), en akrylat i dispersion (Primal AC-35) två epoxi-adhesiv (Hxtal NYL-1, Araldite 2020) samt en cyanoakrylat (Loctite Super Attak Precision (SAP)). De har testats på extruderat skivmaterial av antingen transparent polystyren eller vit slagtålig polystyren, även kallad HIPS (high impact polystyrene), i två testserier; en av fogar och en med ett lager av adhesiv ovanpå plastsskivan.

Använda metoder har varit bedömning av arbetsegenskaper och utseende, färgmätning, draghållfasthetsmätning, hårdhetsmätning, bedömning av brottyp, studie med SEM-mikroskopi samt infraröd mikroskopspektroskopi (FTIR) före och efter åldring. Accelererad nedbrytning utfördes genom ljusåldring med UVA-komponent.

En skadlig effekt syntes från två av adhesiverna; Acrifix 116 och Loctite SAP i form av sprickbildning synligt i SEM-mikroskopi av prover med ett lager adhesiv. Även en effekt av dessa samt från Paraloid B72 i acetone: etanol kunde ses i FTIR-bilder. Sprickbildning på provmaterialet med fogar var däremot inte synligt vid okulär inspektion eller vid förstoring upp till 40 gånger. För cyanoakrylaten kunde även ett ytfenomen i plasten ses i SEM-mikroskopin.

Draghållfastheten för fogarna försvagades bara i mindre utsträckning efter åldring med undantag för de med Loctite SAP på transparent styrenplast som försvagades i större utsträckning. För Acrifix 116 på båda plasterna och för dispersionen på HIPS var fogarna starkare efter åldring vilket kan tyda på ytterligare torkning/härdning. Generellt sett var cyanoakrylaten den starkaste och Paraloid B67 den svagaste. För ingen av plasterna gavs ett kohesivt brott i plasten. Däremot syntes adhesiva brott för epoxierna vilka inte fäste lika väl mot styrenplasten som de är kända för att göra på andra material, troligen pga. plastens ickepolära egenskaper.

De flesta adhesiverna uppvisade synlig gulning på proverna med ett lager adhesiv vid åldring förutom Acrifix 116 och Hxtal-NYL 1. För Loctite SAP och Araldite 2020 syntes gulning tydligt på proverna med fog. Inget av de testade adhesiverna har samma brytningsindex som styrenplast vilket ger synliga fogar på den transparenta plasten. Acrifix 116 och Loctite SAP gav upphov till deformation av proverna med ett lager adhesiv. Det visade sig möjligt att ta bort Paraloiderna och dispersionen. Cyanoakrylaten var svårast att ta bort.

Undersökningen har inte visat att något av dessa adhesiv är det bästa utifrån bevarandeperspektiv. Om en relativt sett svag fog är acceptabel kan den icke gulnande epoxin (Hxtal NYL-1) eller akrylatdispersionen (Primal AC 35) vara acceptabla då de uppvisade minst skadeeffekter. Dispersionen var också enkel att ta bort. En nackdel för epoxin var dock att den var svår att arbeta med pga. dess låga viskositet medan en nackdel för dispersionen var att den var svagt gul, vilket på vissa plaster blir synligt. Störst potential för skadeverkan på styrenplast uppvisade Acrifix 116 och Loctite SAP.

En fogning skall idealt sett hålla samman delar för deras avsedda bruk, och inom konservering är möjligheten till borttagning av stor vikt. När ett adhesiv skall väljas till ett kulturarvsföremål behöver estetiska överväganden och hänsyn till föremålets historia och tillstånd tas. Även förväntad belastning påverkar val av adhesiv. Den kunskap som denna studie av adhesiv för styrenplast ur bevarandeperspektiv givit kommer att underlätta för konservatorer att göra väl underbyggda val.

Denna undersökning har bara haft möjlighet att titta på sju olika adhesiver för styrenplast. Framtida studier behöver testa fler samt även se till andra åldringsmetoder. Även studier med naturlig åldring är intressant. Likaså vore en vidare fördjupning kring det ytfenomen som uppvisades för cyanoakrylaten intressant att undersöka.

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Appendices

I Data sheets plastic

II Initial screening of adhesives

III Data sheets adhesives

IV Assessment table working properties

V Spectrophotometer data

VI Tensile testing data

VII SEM images

VIII FTIR images

IX Hardness measurements

X Microscopy images adhesive bonds

XI List of suppliers

NUDEC®

Appendix I

Food and non-food packaging

Parts for household electrical goods

Consumer electronics

Household items

Toys

Bath and shower screens

Painting, poster and photo frames

Glazing

DIY

Displays

Showcases

Lamps and ceiling lights

NUDEC® PS

Polystyrene sheets

- Excellent dimensional stability to heat
- High rigidity
- Hardness
- Good mechanical characteristics
- Extraordinary dielectric values, making them excellent electrical insulators that can be used from low to high frequencies
- Low volatile substance content
- Termite and micro-organism resistant
- High brightness level
- 90% visible spectrum (400 - 800 nm) light transmission, with light absorption rapidly increasing in the ultraviolet band
- There no sharp variations in properties at low temperatures
- Low water absorption tendency
- They are suitable for use with food FDA (21 CFR 177.1315), United States (except the UV version)
- They comply with European EN 71 standard for toy safety

NUDEC® PS

Properties

Dimensional stability to heat

NUDEC®PS sheets can be briefly exposed to temperatures of 80°C without deformation or contraction.
Prolonged exposure must not exceed 80 to 85°C.

Stress cracking

As a consequence of a combination of pressure or stress and chemical attack, fissures may appear over time in function of the stress intensity, the chemical agent and sheet thickness.
Stress cracking in the case of bathroom screens
Stress: Pressure produced by the aluminium profile on the sheet.
Chemical agents: There may be three types:

- External lubricants: Products employed to facilitate the insertion of the sheet into the profile, such as Vaseline, oil or silicone etc.
- Aluminium cleaning agents. Degreasing agents employed to clean the aluminium once the screen has been assembled.
- PVC seal additives. Plastifying agents derived from pthalic acid that are used to provide the PVC with ductility; this plastifying agent migrates to the surface and attacks the PS.

Recommendations for preventing the formation of cracking:

- The sheet must not be subjected to any excessive pressure in the joint.
- Clean cutting of the NUDEC®PS sheets
- Lubricants should not be employed to insert the sheets and great care should be taken in cleaning the aluminium after assembly to employ a product that does not affect the sheet.
- Correct choice of sealing product

The following are recommended:

- Polyethylene + ethyl acetate (PE + EVA) seal
- Silicon rubber seal
- Hot bead or fill-in of neutral silicone

The following are not recommended:

- PVC seal, especially with plastifying agent deriving from pthalic acid

Better results are achieved using polymer plastifying agents.

Ageing

NUDEC®PS sheets are stabilised against ageing that can be produced by the oxygen in the air and high temperatures (up to a maximum of 80°C). On premises where there are normal temperature and illumination conditions, the NUDEC®PS sheets maintain their appearance and service qualities for many years.
Under outside weather conditions, deterioration is produced by the UV component of sunlight that directly strikes them, for which reason they are not recommended for prolonged use outside. Ageing shows up as progressive yellowing and the loss of surface brightness, together with a reduction in sheet mechanical properties.

STANDARD SPECIFICATIONS FOR PS RESIN

	CODE	UNIT	VALUE
PHYSICAL			
Density	ISO 1183	g/cm^3	1.05
MECHANICAL			
Tensile strength @ yield	ISO 527	MPa	(*)
Tensile strength @ breakage	ISO 527	MPa	59
Elongation @ breakage	ISO 527	%	3
Tensile modulus of Elasticity	ISO 527	MPa	3,250
Flexural strength	ISO 178	MPa	106
Charpy impact strength notched	ISO 179	kJ/m^2	1.47
Charpy impact strength un-notched	ISO 179	kJ/m^2	16
Rockwell hardness M/R scale	ISO 2039	MPa	150
OPTICAL			
Light transmission	ASTM D-1003	%	89
Refractive index	ASTM D-542		1.591
THERMAL			
Maximum Service temperature		°C	80
VICAT Softening temperature (10 N)	ISO 306	°C	106
VICAT Softening temperature (50 N)	ISO 306	°C	101
Heat deflection temperature, HDT A (1.8 MPa)	ISO 75-2	°C	86
Heat deflection temperature HDT B (0.45 MPa)	ISO 75-2	°C	98
Coefficient of linear thermal expansion	ISO 75-2	x10^{-5}/°C	8

These data correspond to raw material values.
(*) Non-applicable

CHEMICAL RESISTANCE

CHEMICAL PRODUCT	BEHAVIOUR		
	SATISFACTORY	REGULAR	UNSATISFACTORY
Mineral oil		X	
Vegetable oil	X		
Acetone			X
Acetic acid	X		
Water	X		
Turpentine			X
Ammonia	X		
Detergents	X		
Ethanol	X		
Petrol			X
Glycerine	X		
Methanol	X		
Toluene			X

REACTION TO FIRE

COUNTRY	CODE	CLASSIFICATION
FRANCE	NFP 92-507	M4

A NUDEC®PS safety file is available for any additional type of query.

Specifications valid for clear panels.

Handling

Cleaning

A solution of water and neutral detergent may be employed. They should always be cleaned and dried with a soft cloth with very little pressure.

Cutting

Important!
Do not remove the protective film from the sheets before cutting, and once this has been accomplished blowing or suction should be employed to eliminate any chips.
Manual cutting
Cutting should always be carried out with a fine-blade saw, with the sheet firmly held in place to prevent vibration. The teeth should be well-sharpened.
Cutting with a blade
When cutting with a blade, this should be passed several times in order to achieve the desired depth (this should be a minimum of half the thickness), employing a uniform pressure.
The sheet must be firmly secured to prevent sliding. Afterwards, the sheet should be placed on a flat surface and gentle pressure applied until it breaks. Sandpaper may be employed to eliminate any burrs.
Sawing
Cutting recommendations for NUDEC®PS sheets
- Disc diameter: 350 - 400 mm
- Number of teeth: 84 - 106
- Rotation speed: 2,800 - 4,500 rpm
- Advance speed: 12 - 18 m/min
Type of teeth
Alternate teeth or combined straight and trapezoid.
The sheet must be firmly secured to prevent them rising up and causing cracks when the disc passes.
The translation speed should be as uniform as possible.
The disc must be regularly sharpened.

Polishing

Pre polishing is required to eliminate any marking caused by the cutting disc.
The following may be used:
- Rotating rigid fabric discs with buffing paste.
- Rotating soft fabric discs with buffing paste for the final finish.

Drilling

Metal and wood drill bits may be employed. The larger the diameter, the lower the speed.
A hole diameter that is approximately 1.5 mm larger than that of the screw to be used should be drilled to take sheet dilation into account.
The sheet must be firmly secured to prevent breaking. A sharp object can be employed to start the hole. In addition, air or water can be used for cooling purposes.

Gluing

Important!
To prevent air bubbles, the glue should be allowed to stand for a while before application, until none can be seen.
Solvents
Various solvents can be used in the bonding of NUDEC®PS sheets. The most common is MEK (methyl-ethyl-ketone). In general, aromatic solvents can be used. These solvents can be applied using a syringe or fine paintbrush. An ideal adhesive is a mixture of two parts methyl chloride and one part toluene. To facilitate gluing, 10% PS chips can be added to the mixture to thicken the adhesive.
Before carrying out the actual gluing operation the surfaces to be glued must be cleaned must be cleaned with alcohol.
Glues
These are solvent-free adhesives, with two components based on polyurethanes. They are transparent, odour-free and do not attack the plastic. They permit different types of plastic to be joined together and also plastics to other materials, such as glass, aluminium and steel etc.
Welding
NUDEC®PS sheets may be welded together using ultrasound or heat pulses. The welding quality will increase when the distance between the sonotrodes is decreased. High frequency welding is not possible because the material has low dielectric losses.

Thermoforming

The stresses that can be produced during this process must be controlled since they could produce heavy stress-related cracking.
The thermoforming vacuum temperatures must be above 120°C, with prior pneumatic or mechanical stretching.
All NUDEC products use film to protect the surface from possible damage during production and transport. This protective film is not prepared to withstand high temperatures and must be removed prior to thermoforming or hot-bending.

Bending

The sheet should be locally heater with an electrical element and then quickly bent. It is a good idea to cool the part of the sheet that is closest to the bending line.
When bending thick sheets, it is recommended that both sides are heated, with the sheet being firmly secured after bending in order to maintain the exact position. Over time, it is possible for small cracks to appear in the area of the bend. We recommend that the smallest radius be twice the sheet thickness.
All NUDEC products use film to protect the surface from possible damage during production and transport. This protective film is not prepared to withstand high temperatures and must be removed prior to thermoforming or hot-bending.

Decoration

The sheet surface must be clean and free from grease, demoulding agents and any other contamination. Degreasing can be performed using a 50/50 mixture of isopropane and isobutanol.
NUDEC®PS sheets are easily printed, lacquered and painted using a wide range of products. They can also be decorated by means of silk-screening, lithography, metallisation or hot-marking. It should be ensured that the NUDEC®PS sheet will not be attacked by solvents incorporated in the lacquers or varnishes and paint manufacturers should be consulted about products designed to cover PS.
Vacuum metallisation
NUDEC®PS sheets can be vacuum metallised. It must be stressed that the obtained finish will depend of the surface shine of the sheet before this process is carried out.
The print film should be removed just prior to printing to prevent the surface from damage.

NUDEC®PS

Polystyrene sheets

Properties

Specifications

Handling

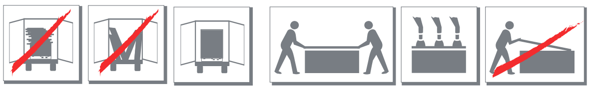
Transport

Storage

Responsibility clause

- NUDEC, S. A. supplies its products in accordance with the indications prepared by the purchaser with respect to the ordered material and quality. In this sense, NUDEC, S. A. provides its customers with all available professional and technical information deriving from its product analyses.
- Once the material has been delivered by NUDEC, S. A., the purchaser is fully responsible for all subsequent application, treatment, use and/or utilisation of this same material , whether by the actual purchaser or by third parties, with complete indemnity for NUDEC, S. A.
- The purchaser is wholly and soley responsible for carrying all tests or analyses, of any nature, which are required to verify that the product can be effectively applied for the purpose sought by the purchaser or by any third parties to whom the purchaser supplies the product or for whom its is installed.
- NUDEC, S. A. is exempt from any responsibility deriving from any inadequate or defective application of its products by the purchaser or subsequent third parties, and only accepts damages deriving directly from possible defects of its products at origin.

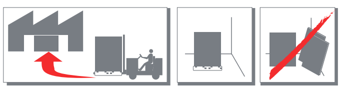
02/2012



Transport

Dirt and sharp angles may damage the surface in the case of friction.

- During transport, stable, flat pallets should always be used and the sheets secured to prevent sliding.
- The sheets must not be allowed to slide over each other during loading and unloading operations.
- They should be lifted by hand without any dragging or by suction-cup lifting equipment.



Storage

An incorrect storage position can lead to permanent deformation.

- The sheets should be stored in closed premises that guarantee normal environmental conditions.
- The sheets should be stored one on top of the other on flat horizontal surfaces and fully supported over their total area.
- The topmost panel should be covered with a sheet of polyethylene or cardboard etc.
- NUDEC®PS sheets must not be stored in direct sunlight or under conditions of high humidity and/or temperature as this can have a negative effect of protective film adhesion.

NUDEC®

Pintor Vila Cinca, 24-28
E-08213 - Polinyà (Barcelona) - SPAIN
Tel. (+34) 93.713.27.00
Fax (+34) 93.713.19.36
nudec@nudec.es
www.nudec-plastic.com

IRO
Where Service Is Everything

IROPLASTICS Gesellschaft m.b.H.
Thermoplastische Kunststoffe
A-4843 Ampflwang, Ort 57
t: +43/7675/35 50 0
f: +43/7675/35 50 14
www.iroplastics.com
iroplastics@aon.at

IROPLAST SB

Brief characteristic:

High impact polystyrene with excellent mechanical properties and high cold resistance, good deflection temperature and high stress cracks performance.

Mechanical propertles			
Yield strength	DIN 53455	N/mm²	17,5
Elongation at yield	DIN 53455	%	2,0
Tensile strength at break	DIN 53455	N/mm²	17
Elongation at break	DIN 53455	%	> 30
Modulus in flexure	DIN 53457-B4	N/mm²	1850
Flexural stress at conventional deflection	DIN 53452	N/mm²	39
Impact strength at 23°C	DIN 53453	kJ/m²	> 30
Impact strength at -30°C	DIN 53453	kJ/m²	30
Impact strength notched at 23°C	DIN 53453	kJ/m²	6
Impact strength notched at -30°C	DIN 53453	kJ/m²	5
Indentation hardness (H 358/30)	DIN 53456	N/mm²	80
Thermal propertles			
Vicat softening point VST B 50	DIN 53460	°C	90
ISO/R75 process A	DIN 53461	°C	78
ISO/R75 process B	DIN 53461	°C	89
Continuous working temperature		°C	70
Thermal coefficlent of linear expansion	DIN 53752	10^{-5}/K	8-10
Thermal conductivity	DIN 52612	W/Km	0,17
Specific heat		kJ/kgK	1,2
Electrical propertles			
Dielectric constant	DIN 53483		2,5
Dissipation factor	DIN 53483	10^{-5}	4
Specific volume resistivity	DIN 53482	Ωcm	$>10^{16}$
Surface resistivity	DIN 53482	Ω	$>10^{13}$
Dielectric strength	DIN 53481	kV/mm	155
Other propertles			
Shrinkage		%	0,4-0,7
Water absorption	DIN 53495	%	<0,1
Density	DIN 53479	g/cm^3	1,05

8/96

These are typical values and can`t be construed as product specifications.
The mechanical propertles of this technical information were established with extruded 4 mm thick sheets.
The information contained herein is believed to be reliable to the best of our knowledge. However, all recommendations are made without guarantee of performance or warranty of freedom from legal responsibility.

Iroplastics GmbH Postfach 36 A-4843 Ampflwang Telefon (0043) (0) 7675/35500 Telefax (0043) (0) 7675/355014

Appendix II Initial screening of adhesives. Joining plastics together – what happens over time? **FoU project Dnr 353-3471-2011**

Name	Nr.	Usage – easy?	Percent/solvent	Type	Application method	Look	Bubbles	Color after curing	Visible/RI	Solvent action	Bond breakage/ Bond ability	Other
Paraloid B72	1	Medium easy	40% in acetone	Acrylate, ethyl methacrylate/ methacrylate, EMA/MA, 70/30	Brush	Ok. A bit messy due to low viscosity	Yes, many	Transparent	Visible	Not recognizible	Easy to break	
Paraloid B72	1b	Medium easy	40% in 50/50 Aceton/etanol	Acrylate, ethyl methacrylate/ methacrylate, EMA/MA, 70/30	Brush	Ok. A bit messy due to low viscosity	Some	Transparent	Visible	Not recognizible	Easy to break	
Paraloid B72 in tube	2	Medium easy		Acrylate, ethyl methacrylate/ methacrylate, EMA/MA, 70/30	From tube/nozzle	Ok/poor. A bit messy. Thick bond.	Yes, many	Transparent	Visible	Not recognizible	Medium hard to break. Soft bond.	Thick consistency. Short working-time.
Paraloid B67	3	Medium easy	40% in 2-propanol	Acrylate, isobutyl methacrylate, iBMA	Brush	Ok. A bit messy due to low viscosity.	No	Transparent	Visible	Not recognizible	Easy to break	
Plexisol P550-40	4	Not easy/ medium easy		n-BMA	Brush or toothpick	Ok/poor. A bit messy. Thick bond.	Some/few	Transparent	Visible	Not recognizible	Medium hard to break. Soft bond.	Very thick consistency. Short working time.
Primal AC 35	5	Easy/ medium		Acrylate dispersion, ethyl acrylate/ methylmethacrylate, EA/MMA	Brush	Ok/good. A bit messy due to low viscosity.	No	Transparent	Visible	Not recognizible	Easy to break	
Fynebond	6	Medium/ Not easy		Epoxy 2C	Brush/ needle (capillary)	Ok/good. A bit messy due to low viscosity.	No	Transparent	Visible (but less than for non-epoxies)	Not recognizible	Medium hard to break	Resin crystallized In room temperature

Hxtal Nyl-1	7	Medium/ Not easy		Epoxy 2C	Brush/ Needle (capillary)	Ok/good. A bit messy due to low viscosity.	No	Transparent	Visible (but less Than for non-epoxies)	Not recognizible	Medium hard to break	
Araldite 2020	8	Medium/ Not easy		Epoxy 2C	Brush/ Needle (capillary)	Ok/good. A bit messy due to low viscosity.	No	Transparent	Visible	Not recognizable	Hard to break	
Araldite 2028	9			polyurethane 2C								
Plextol 498	10	Medium easy/ easy		disp, MMA/BA	Brush	Ok	Very few	Transparent	Visible	Not recognizible	Medium hard to break. Soft bond.	
Aquazol 200	11	Medium easy/ easy	40% in deionized water	Poly (2-ethyl-2-oxazoline)	Brush	Ok	Few	Transparent/ Slightly pale yellow	Visible	Not recognizible	Medium hard to break	
Billys Stenlim klar	12	Medium easy		Polyester 2c	Brush/ toothpick	Ok/poor	Some	Yellow	Visible	Not recognizible	Easy to break	
Mowilith 30	13	Medium easy	40% in acetone	PVAc	Brush	Ok. A bit messy due to low viscosity.	Some	Transparent	Visible	Not recognizible	Easy to break. Soft bond.	
Jade 403	14	Easy		disp PVAc, ethene (Horie)	Brush	Ok	Few	Transparent/ slightly pale white	Visible	Not recognizible	Medium hard to break. Soft bond.	
Jade R	15	Easy		disp PVAc,	Brush	Ok	No	Transparent/ slightly pale white	Visible	Not recognizible	Medium hard to break. Soft bond.	

Loctite Super Attack Prec.	16	Medium easy		Cyanoacrylate	From the tube/nozzle	Ok/poor. A bit messy due to low viscosity	Few	Slightly pale white	Visible	Not recognizible	Hard to break	Ca 30 sec. working time
Loctite Super Glue Prof.	17	Easy		Cyanoacrylate 2C	First activator pen. The from the tube/nozzle	Poor. Messy due to low viscosity.	Few	Pale white	Visible	Not recognizible	Medium hard to break.	Ca 15 sec. working time
UHU Allplast	18	Medium easy		akrylester PVC	From the tube/nozzle	Ok. Thick bond.	Some	Transparent	Visible	Not recognizible	Hard to break	
UHU Plus Akrylit	19	Easy		metakrylsyraester 2C	Toothpick	Poor	Few	Yellow/ brown	Visible	Not recognizible	Easy to break	
Karlsons Universal kontakt (polyuretan-baserad)	20			polyurethane based								
Acrifix 116	21	Easy		Acrylate, in solution mix of ethyl methanoate, nitroethane, 2-phenoxyethanol, ethyl acetate and n-butanol	Brush	Ok/good	Some	Transparent	Visible	Not recognizible	Medium hard to break	
Acrifix 192	22	Easy		?, UV-härd	Brush	Ok	Few	Transparent	Visible	Not recognizible	Hard to break	
Bohle UV VerifixLV 740 VIS	23	Medium/ Not easy		? UV-härd	Brush/ Needle (capillary)	Ok. A bit messy due to low viscosity	No	Transparent	Visible	Not recognizible	Easy to break	Still a bit tacky after curing. Attracts dust.

Appendix III

1. Chemical Product and Company Identification

ACRIFIX® 1S 0116

Supplier:

Evonik CYRO LLC
299 Jefferson Road
Parsippany, NJ 07054-0677
+1-973-929-8291

Product Information Number 1-207-490-4242
24 Hour Emergency Number, CHEMTREC 1-800-424-9300

(TM) indicates trademark

Product Use: solvent adhesive for PLEXIGLAS®

2. Composition/Information on Ingredients

This material is classified as hazardous under OSHA regulations.

Ingredients	CAS Reg. No.	Weight %
ethyl formate	109-94-4	15 - 40
nitroethane	79-24-3	15 - 40
2-phenoxyethanol	122-99-6	3 - 7
ethyl acetate	141-78-6	3 - 7
butan-1-ol	71-36-3	1 - 5

NJTSR # 56705700001-6829P

See Section 8, Exposure Controls/Personal Protection

3. Hazards Identification

Emergency Overview

Color: colourless to slightly yellowish
Appearance: liquid
Odor: fruity

Flammable liquid and vapor.
Causes eye and respiratory tract irritation.
May be harmful if swallowed.
Harmful if inhaled.
May cause skin irritation.

Primary Routes of Exposure
Inhalation
Eye contact
Skin contact

Potential Health Effects

Inhalation
- lung damage
- lung oedema
- narcotic effect
- dizziness or suffocation

Harmful if inhaled.
Inhalation of vapor or mist can cause the following:
- irritation of nose and throat

Inhalation of high concentrations may cause the following:

Eye Contact
Causes eye irritation.

Skin Contact
- dermatitis
- defatting

Prolonged or repeated skin contact can cause the following:
May cause skin irritation.

Ingestion
- central nervous system depression
- difficulty breathing
- irritation
- narcotic effect

Material can cause the following:
May be harmful if swallowed.

Chronic Effects
- liver and kidney damage
- defatting and dermatitis

Potential Environmental Effects
See SECTION 12, Ecological Information

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4. First Aid Measures

First Aid Procedures

Inhalation
Remove to fresh air. Give artificial respiration if breathing has stopped. If breathing is difficult, give oxygen. Get immediate medical attention.

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get immediate medical attention.

Skin Contact
Flush skin with plenty of water. Remove contaminated clothing and shoes. Wash clothing before reuse. Obtain medical attention if irritation develops or persists.

Ingestion

Only induce vomiting if directed by a physician. Get immediate medical attention. Never give anything by mouth to an unconscious person.

5. Fire-Fighting Measures

Flash point	< -1 °C < 30 °F
Ignition temperature	440 °C (ethyl formate) 824 °F (ethyl formate) 410 °C (nitroethane) 770 °F (nitroethane)
Lower explosion limit	2.7 %(V) (ethyl formate) 3.4 %(V) (nitroethane)
Upper explosion limit	13.5 %(V) (ethyl formate)
OSHA Flammability Classification	Flammable liquid

Other Flammable Properties

Flammable liquid. Vapors can travel to a source of ignition and flash back. Explosive mixtures may occur at temperatures at or above the flashpoint.

Unusual Hazards

Products or compounds possibly released in case of fire: nitrogen oxides - carbon oxides

Extinguishing Media

Use the following extinguishing media when fighting fires involving this material:
dry chemical - carbon dioxide - alcohol-resistant foam

Fire Fighting Procedures

As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear. Containers can build up pressure if exposed to heat (fire). Cool with water spray.

6. Accidental Release Measures

Procedures

Remove sources of ignition and ventilate area. Absorb spill with inert material and place in a chemical waste container. Obey relevant local, state, provincial and federal laws and regulations.
Do not contaminate any lakes, streams, ponds, groundwater or soil.
Use personal protective equipment. See Material Safety Data Sheet section 8, Exposure Controls/Personal Protection.

7. Handling and Storage

Handling

Avoid contact with eyes, skin and clothing. Keep away from heat. Keep away from sparks, flames and other sources of ignition. Wash thoroughly after handling. Do not taste or swallow. Avoid breathing vapor or mist. Use only with adequate ventilation. The need for grounding and bonding of containers in accordance with OSHA 29 CFR 1910.106 and NFPA 77 should be assessed for all product transfers. Container hazardous when empty. Follow all MSDS/label precautions even after the container is emptied because it may retain product residues. Residual vapors might explode on ignition; do not apply heat, cut, drill, grind or weld on or near this container.

Storage

Keep only in the original container at a temperature not exceeding 30 °C. Keep container tightly closed and store in a well ventilated area.Keep container closed.

Other

Improper disposal or re-use of this container may be dangerous and illegal.

8. Exposure Controls/Personal Protection

Exposure Limit Information

ETHYL FORMATE

(CAS Number 109-94-4)

Occupational Exposure Values :			Remark(s):
ACGIH TLV-TWA	100 ppm	303 mg/m3	
ACGIH TLV-STEL			not established
OSHA PEL-TWA	100 ppm	300 mg/m3	
OSHA PEL-STEL			not established
OEL-TWA (Alberta)	100 ppm	303 mg/m3	
OEL-STEL (Alberta)			not established
OEL-TWA (British Columbia)	100 ppm		
OEL-STEL (British Columbia)			not established
OEL-TWA (Ontario)	100 ppm	300 mg/m3	
OEL-STEL (Ontario)			not established
OEL-TWA (Quebec)	100 ppm	303 mg/m3	
OEL-STEL (Quebec)			not established
OEL-TWA (Mexico)	100 ppm	300 mg/m3	
OEL-STEL (Mexico)	150 ppm	450 mg/m3	

NITROETHANE

(CAS Number 79-24-3)

Occupational Exposure Values :			Remark(s):
ACGIH TLV-TWA	100 ppm	307 mg/m3	
ACGIH TLV-STEL			not established
OSHA PEL-TWA	100 ppm	310 mg/m3	
OSHA PEL-STEL			not established

OEL-TWA (Alberta)	100 ppm	307 mg/m3	
OEL-STEL (Alberta)			not established
OEL-TWA (British Columbia)	100 ppm		
OEL-STEL (British Columbia)			not established
OEL-TWA (Ontario)	100 ppm	306 mg/m3	
OEL-STEL (Ontario)			not established
OEL-TWA (Quebec)	100 ppm	307 mg/m3	
OEL-STEL (Quebec)			not established
OEL-TWA (Mexico)	100 ppm	310 mg/m3	
OEL-STEL (Mexico)	150 ppm	465 mg/m3	

2-PHENOXYETHANOL

(CAS Number 122-99-6)

Occupational Exposure Values : Remark(s):

ACGIH TLV-TWA			not established
ACGIH TLV-STEL			not established
OSHA PEL-TWA			not established
OSHA PEL-STEL			not established
NIOSH REL-TWA			not established
NIOSH REL-STEL			not established
OEL-TWA (North Carolina)			not established
OEL-STEL (North Carolina)			not established
OEL-TWA (Alberta)			not established
OEL-STEL (Alberta)			not established
OEL-TWA (British Columbia)			not established
OEL-STEL (British Columbia)			not established
OEL-TWA (Ontario)	25 ppm	141 mg/m3	Skin designation (substance can be absorbed through intact skin).
OEL-STEL (Ontario)			not established
OEL-TWA (Quebec)			not established
OEL-STEL (Quebec)			not established
OEL-TWA (Mexico)			not established
OEL-STEL (Mexico)			not established

ETHYL ACETATE

(CAS Number 141-78-6)

Occupational Exposure Values : Remark(s):

ACGIH TLV-TWA	400 ppm	1,440 mg/m3	
ACGIH TLV-STEL			not established
OSHA PEL-TWA	400 ppm	1,400 mg/m3	
OSHA PEL-STEL			not established
OEL-TWA (Alberta)	400 ppm	1,440 mg/m3	
OEL-STEL (Alberta)			not established
OEL-TWA (British Columbia)	150 ppm		

OEL-STEL (British Columbia)			not established
OEL-TWA (Ontario)	400 ppm	1,440 mg/m3	
OEL-STEL (Ontario)			not established
OEL-TWA (Quebec)	400 ppm	1,440 mg/m3	
OEL-STEL (Quebec)			not established
OEL-TWA (Mexico)	400 ppm	1,400 mg/m3	
OEL-STEL (Mexico)			not established

1-BUTANOL

(CAS Number 71-36-3)

Carcinogen designation(s) USA: EPA-D

Occupational Exposure Values : Remark(s):

ACGIH TLV-TWA	20 ppm	61 mg/m3	
ACGIH TLV-STEL			not established
OSHA PEL-TWA	100 ppm	300 mg/m3	
OSHA PEL-STEL			not established
OEL-TWA (Alberta)			not established
OEL-CEIL (Alberta)	50 ppm	152 mg/m3	Skin designation (substance can be absorbed through intact skin).
OEL-TWA (British Columbia)	15 ppm		Skin designation (skin absorption can contribute to the overall exposure).
OEL-CEIL (British Columbia)	30 ppm		Skin designation (skin absorption can contribute to the overall exposure).
OEL-TWA (Ontario)	20 ppm		
OEL-STEL (Ontario)			not established
OEL-TWA (Quebec)			not established
OEL-CEIL (Quebec)	50 ppm	152 mg/m3	Skin Designation
OEL-TWA (Mexico)			not established
OEL-CEIL (Mexico)	50 ppm	150 mg/m3	Mexican OEL Skin Designation: absorption through the skin, including mucous membranes and eyes, must be considered.

Engineering Controls (Ventilation)

Use process enclosures, local exhaust ventilation or other engineering controls to control airborne exposure.

Respiratory Protection

A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 or applicable federal/provincial requirements must be followed whenever workplace conditions warrant respirator use. NIOSH's "Respirator Decision Logic" may be useful in determining the suitability of various types of respirators.

Eye Protection

Use safety glasses (ANSI Z87.1 or approved equivalent).

Skin Protection
Use chemically resistant apron or other impervious clothing to avoid prolonged or repeated skin contact.

Hand Protection
butyl rubber gloves
Gloves should be removed and replaced immediately if there is any indication of degradation or chemical breakthrough.
Gloves should be replaced regularly, especially after extended contact with the product.
For each work-place a suitable glove type has to be selected.

Other Protective Equipment
To identify additional Personal Protective Equipment (PPE) requirements, it is recommended that a hazard assessment in accordance with the OSHA PPE Standard (29CFR1910.132) be conducted before using this product. A safety shower and eye wash fountain should be readily available.

9. Physical and Chemical Properties

Appearance	colourless to slightly yellowish
Physical state	liquid
Odor	fruity
Flash point	< -1 °C < 30 °F
pH-value	not applicable
Viscosity (dynamic)	ca. 650 - 900 mPa.s at 20 °C / 68 °F
Specific gravity (water = 1)	0.998 g/cm3 at 20 °C / 68 °F
Vapor density (air = 1)	> 1 at 20 °C / 68 °F
Vapor pressure	ca. 260 hPa (= mbar) at 20 °C / 68 °F (ethyl formate)
Melting temperature	not available
Initial Boiling PointInitial Boiling Point	54 °C / 129 °F at 1,013 hPa (= mbar)
Solubility in water	118 g/l45 g/l at 20 °C / 68 °F (ethyl formate) (nitroethane)
n-Octanol/water partition coefficient	not available
Evaporation rate	not available
Odor threshold	not available
Further information	none

See Section 5, Fire Fighting Measures

10. Stability and Reactivity

Stability
The following applies to the component nitroethane: May explode if heated. Shock and heat sensitive.

Conditions To Avoid
Avoid high temperatures and sources of ignition.

Incompatibility With Other Materials
Reactions with strong oxidizing agents. Reactions with lead, copper and their alloys. Forms shock sensitive compounds with strond alcalis, acids or mixtures of amines and heavy metal oxides.

Hazardous Decomposition Products
None when used as directed.

Hazardous Polymerization
Product will not undergo polymerization.

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11. Toxicological Information

Acute Oral Toxicity

LD50 rat — 1,850 mg/kg
Related to substance: ethyl formate

LD50 rat — 1,083 mg/kg
Related to substance: nitroethane

LD50 rat — 1,260 mg/kg
Related to substance: phenoxyethanol

LD50 rat — > 5,000 mg/kg
Related to substance: ethyl acetate

LD50 rat — 790 mg/kg
Related to substance: n-butanol

Acute Inhalational Toxicity

LC50 rat, 4 h — 12.3 - 24.6 mg/l
Related to substance: ethyl formate

LCLo mouse, 2 h — 19.5 mg/l
Related to substance: nitroethane

Acute Dermal Toxicity

LD50 rabbit — > 2,000 mg/kg
Related to substance: nitroethane

LD50 rabbit — > 5,000 mg/kg
Related to substance: ethyl formate

Irritant Effect on the Skin
If contact with skin is prolonged and/or frequent, irritations cannot be excluded.
Related to substance: product

Irritant Effect on the Eyes
Contact with the eyes may cause irritation.
Related to substance: product

Sensitization
no specific test data available no evidence for hazardous properties (structure-activity-relationships) (analogy)

Mutagenicity
no specific test data available

Carcinogenicity

no specific test data available

Reprotoxicity / teratogenicity
no specific test data available

Further Information on Toxicology
High solvent concentrations will cause irritations of the eyes and respiratory system and may cause headache, dizziness and disorder of the central nervous system. Inhaling of higher concentrations of solvent vapours causes a narcotic effect. On chronic overexposition damages to the liver and kidneys cannot be excluded. Methämoglobin formation cannot be ruled out. Carefully avoid contact with skin and eyes as well as inhalation of product vapours.

12. Ecological Information

Information on Elimination (Persistence and Degradability)
Biodegradability
potentially biodegradable
Related to substance: nitroethane
biodegradable
(main components)
Bioaccumulation

Ecotoxicological Effect

Fish Toxicity

LC50 Pimephales promelas	596 mg/l
Related to substance: nitroethane	

Daphnia Toxicity

EC0 Daphnia magna	120 mg/l
Related to substance: ethyl formate	
EC50 Daphnia magna	859 mg/l
Related to substance: nitroethane	

Algae Toxicity

EC50 Scenedesmus, OECD 201, 72 h	6 mg/l
Related to substance: nitroethane	

Bacteria Toxicity

EC50	100 mg/l
Related to substance: nitroethane	

Further Information on Ecology
Prevent substance from entering soil, natural bodies of water and sewer systems.

13. Disposal Considerations

Procedures
Waste must be disposed of in accordance with federal, state and local regulations. Incineration is the preferred method. Empty containers must be handled with care due to product residue. DO NOT HEAT OR CUT THE EMPTY CONTAINER WITH ELECTRIC OR GAS TORCH. CYRO encourages the recycle, recovery and reuse of materials, where permitted, as an alternate to disposal as a waste.
Contaminated packaging should be emptied optimally and after appropriate professional cleansing may be taken for reuse. Packaging that cannot be cleaned should be disposed of professionally. Uncontaminated packaging may be taken for recycling.

14. Transport Information

US DOT Hazard Classification

Proper Shipping Name	ADHESIVES
Hazard Class	3
ID/UN Number	1133
Packing Group	II

Canadian TDG Classification

Refer to the classification US DOT

Shipment by sea IMDG/GGVSee

UN number	1133
Class	3
EmS	F-E, S-D
Marine pollutant	No
Packaging group	II
Proper Shipping Name	ADHESIVES

Air transport ICAO/IATA

UN number	1133
Class	3
Packing Group	II
Proper Shipping Name	ADHESIVES

15. Regulatory Information

INVENTORY INFORMATION

REACH (EU)	preregistered, registered or exempted
TSCA (USA)	listed or exempted
DSL (CDN)	listed or exempted
AICS (AUS)	listed or exempted
METI (J)	listed or exempted
ECL (KOR)	listed or exempted
PICCS (RP)	listed or exempted
IECSC (CN)	listed or exempted

US FEDERAL REGULATORY INFORMATION

Component / CASRN	TPQ [lbs]	CERCLA RQ [lbs] (40CFR302.4)	SARA 302 List of EHS	SARA 313 (40CFR372)	TSCA 12b
butan-1-ol / 71-36-3	NONE	5000	NO	YES	NO
ethyl acetate / 141-78-6	NONE	5000	NO	NO	reportable one-time

COMPONENT CLASSIFICATION UNDER CLEAN AIR ACT SECTION 112

Component / CASRN	Weight %	HAP	EHAP
NONE			

PRODUCT CLASSIFICATION UNDER SECTION 311/312 OF SARA (40CFR370)

ACUTE, CHRONIC, FIRE, REACTIVE,

US STATE REGULATORY INFORMATION

Component / CASRN	New Jersey RTK	Pennsylvania RTK	Massachusetts RTK	California Proposition 65 Cancer	California Proposition 65 Reproductive
ethyl formate / 109-94-4	YES	YES	YES	NO	NO
nitroethane / 79-24-3	YES	YES	YES	NO	NO
2-phenoxyethanol / 122-99-6	NO	NO	NO	NO	NO
butan-1-ol / 71-36-3	YES	YES	YES	NO	NO
ethyl acetate / 141-78-6	YES	YES	YES	NO	NO
acrylic polymer / trade secret	NO	NO	NO	NO	NO

CANADIAN REGULATION

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulation and the MSDS contains all information required by the Controlled Products Regulations.

This is a controlled product.
WHMIS: B2, D2B, F

Component / CASRN	NPRI
ethyl formate / 109-94-4	NO
nitroethane / 79-24-3	NO
2-phenoxyethanol / 122-99-6	NO
butan-1-ol / 71-36-3	YES
ethyl acetate / 141-78-6	YES

16. Other Information

	Health	Flammability	Physical Hazard
HMIS-Ratings	2	3	3
NFPA-Ratings	2	3	3

HMIS Hazard Ratings	NFPA Hazard Ratings
4 = severe	4 = extreme
3 = serious	3 = high
2 = moderate	2 = moderate
1 = slight	1 = slight
0 = minimal	0 = insignificant
N = no rating for powders	N = no rating for powders
* = chronic health hazard	

none

This MSDS was prepared in accordance with ANSI Z400.1-1998.

Places marked by || have been amended from the last version.

Date of printing : 11/18/2012

SAFETY DATA SHEET

ARALDITE 2020

HUNTSMAN
Enriching lives through innovation

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifier

Product name : ARALDITE 2020

Product code : 00050782

Product description : Not available.

1.2 Relevant identified uses of the substance or mixture and uses advised against

Product use : 2-Component adhesive system

1.3 Details of the supplier of the safety data sheet

Supplier : Huntsman Advanced Materials (Europe)BVBA
Everslaan 45
3078 Everberg / Belgium
Tel.: +41 61 299 20 41
Fax: +41 61 299 20 40

e-mail address of person responsible for this SDS : Global_Product_EHS_AdMat@huntsman.com

1.4 Emergency telephone number

Supplier

Telephone number : EUROPE: +32 35 75 1234
France ORFILA: +33(0)145425959
ASIA: +65 6336-6011
China: +86 20 39377888
Australia: 1800 786 152
New Zealand: 0800 767 437
USA: +1/800/424.9300

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Product definition : Working pack (preparation)

Classification according to Directive 1999/45/EC [DPD]

The product is classified as dangerous according to Directive 1999/45/EC and its amendments.

Classification : Xn; R20/21/22
C; R34
R43
N; R51/53

Human health hazards : Harmful by inhalation, in contact with skin and if swallowed. Causes burns. May cause sensitisation by skin contact.

Environmental hazards : Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

See Section 16 for the full text of the R phrases or H statements declared above.

See Section 11 for more detailed information on health effects and symptoms.

2.2 Label elements

SECTION 2: Hazards identification

Hazard symbol or symbols :

Indication of danger : Corrosive, Dangerous for the environment

Risk phrases : R20/21/22- Harmful by inhalation, in contact with skin and if swallowed.
R34- Causes burns.
R43- May cause sensitisation by skin contact.
R51/53- Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Safety phrases : S26- In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S36/37/39- Wear suitable protective clothing, gloves and eye/face protection.
S45- In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S61- Avoid release to the environment. Refer to special instructions/safety data sheet.

Hazardous ingredients : reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)
butanedioldiglycidyl ether
isophorone diamine
trimethylhexamethylenediamine

Supplemental label elements : Not applicable.

Supplemental label elements : Contains epoxy constituents. See information supplied by the manufacturer.

Special packaging requirements

Containers to be fitted with child-resistant fastenings : Not applicable.

Tactile warning of danger : Not applicable.

2.3 Other hazards

Other hazards which do not result in classification : Not available.

SECTION 3: Composition/information on ingredients

Substance/mixture : Working pack (preparation)

Product/ingredient name	Identifiers	%	Classification 67/548/EEC	Classification Regulation (EC) No. 1272/2008 [CLP]	Type
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	REACH #: 01-2119456619-26 CAS: 25068-38-6	35-50	Xi; R36/38 R43 N; R51/53	Skin Irrit. 2, H315 Eye Irrit. 2, H319 Skin Sens. 1, H317 Aquatic Chronic 2, H411	[1]
butanedioldiglycidyl ether	CAS: 2425-79-8	25-35	Xn; R20/21 Xi; R36/38 R43 R52/53	Acute Tox. 4, H312 Acute Tox. 4, H332 Skin Irrit. 2, H315 Eye Irrit. 2, H319 Skin Sens. 1, H317	[1]
isophorone diamine	CAS: 2855-13-2	7-10	Xn; R21/22 C; R34	Acute Tox. 4, H302 Acute Tox. 4, H312	[1]

SECTION 3: Composition/information on ingredients

			R43 R52/53	Skin Corr. 1B, H314 Eye Dam. 1, H318 Skin Sens. 1, H317 Aquatic Chronic 3, H412	
trimethylhexamethylenediamine	CAS: 25620-58-0	5-7	Xn; R22 C; R34 R43 R52/53	Acute Tox. 4, H302 Skin Corr. 1B, H314 Eye Dam. 1, H318 Skin Sens. 1, H317 Aquatic Chronic 3, H412	[1]
			See section 16 for the full text of the R-phrases declared above	**See Section 16 for the full text of the H statements declared above.**	

There are no additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

Type

[1] Substance classified with a health or environmental hazard
[2] Substance with a workplace exposure limit
[3] Substance meets the criteria for PBT according to Regulation (EC) No. 1907/2006, Annex XIII
[4] Substance meets the criteria for vPvB according to Regulation (EC) No. 1907/2006, Annex XIII

Occupational exposure limits, if available, are listed in Section 8.

SECTION 4: First aid measures

4.1 Description of first aid measures

Eye contact : Get medical attention immediately. Immediately flush eyes with plenty of water, occasionally lifting the upper and lower eyelids. Check for and remove any contact lenses. Continue to rinse for at least 10 minutes. Chemical burns must be treated promptly by a physician.

Inhalation : Get medical attention immediately. Remove victim to fresh air and keep at rest in a position comfortable for breathing. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway. Loosen tight clothing such as a collar, tie, belt or waistband. In case of inhalation of decomposition products in a fire, symptoms may be delayed. The exposed person may need to be kept under medical surveillance for 48 hours.

Skin contact : Get medical attention immediately. Flush contaminated skin with plenty of water. Remove contaminated clothing and shoes. Wash contaminated clothing thoroughly with water before removing it, or wear gloves. Continue to rinse for at least 10 minutes. Chemical burns must be treated promptly by a physician. In the event of any complaints or symptoms, avoid further exposure. Wash clothing before reuse. Clean shoes thoroughly before reuse.

Ingestion : Get medical attention immediately. Wash out mouth with water. Remove dentures if any. Remove victim to fresh air and keep at rest in a position comfortable for breathing. If material has been swallowed and the exposed person is conscious, give small quantities of water to drink. Stop if the exposed person feels sick as vomiting may be dangerous. Do not induce vomiting unless directed to do so by medical personnel. If vomiting occurs, the head should be kept low so that vomit does not enter the lungs. Chemical burns must be treated promptly by a physician. Never give anything by mouth to an unconscious person. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway.

SECTION 4: First aid measures

Loosen tight clothing such as a collar, tie, belt or waistband.

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Wash contaminated clothing thoroughly with water before removing it, or wear gloves.

4.2 Most important symptoms and effects, both acute and delayed

Potential acute health effects

Eye contact : Corrosive to eyes. Causes burns.

Inhalation : Harmful by inhalation. May give off gas, vapor or dust that is very irritating or corrosive to the respiratory system. Exposure to decomposition products may cause a health hazard. Serious effects may be delayed following exposure.

Skin contact : Corrosive to the skin. Causes burns. Harmful in contact with skin. May cause sensitisation by skin contact.

Ingestion : Harmful if swallowed. May cause burns to mouth, throat and stomach.

Over-exposure signs/symptoms

Eye contact : Adverse symptoms may include the following:
pain
watering
redness

Inhalation : No specific data.

Skin contact : Adverse symptoms may include the following:
pain or irritation
redness
blistering may occur

Ingestion : Adverse symptoms may include the following:
stomach pains

4.3 Indication of any immediate medical attention and special treatment needed

Notes to physician : In case of inhalation of decomposition products in a fire, symptoms may be delayed. The exposed person may need to be kept under medical surveillance for 48 hours.

Specific treatments : Symptomatic treatment and supportive therapy as indicated. Following severe exposure the patient should be kept under medical review for at least 48 hours.

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media : Use an extinguishing agent suitable for the surrounding fire.

Unsuitable extinguishing media : None known.

5.2 Special hazards arising from the substance or mixture

Hazards from the substance or mixture : In a fire or if heated, a pressure increase will occur and the container may burst.

Hazardous thermal decomposition products : Decomposition products may include the following materials:
carbon dioxide
carbon monoxide
nitrogen oxides

5.3 Advice for firefighters

SECTION 5: Firefighting measures

Special precautions for fire-fighters : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. This material is toxic to aquatic organisms. Fire water contaminated with this material must be contained and prevented from being discharged to any waterway, sewer or drain.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode. Clothing for fire-fighters (including helmets, protective boots and gloves) conforming to European standard EN 469 will provide a basic level of protection for chemical incidents.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

For non-emergency personnel : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilt material. Do not breathe vapour or mist. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment.

For emergency responders : If specialised clothing is required to deal with the spillage, take note of any information in Section 8 on suitable and unsuitable materials. See also Section 8 for additional information on hygiene measures.

6.2 Environmental precautions : Avoid dispersal of spilt material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air). Water polluting material. May be harmful to the environment if released in large quantities.

6.3 Methods and materials for containment and cleaning up

Small spill : Stop leak if without risk. Move containers from spill area. Dilute with water and mop up if water-soluble. Alternatively, or if water-insoluble, absorb with an inert dry material and place in an appropriate waste disposal container. Dispose of via a licensed waste disposal contractor.

Large spill : Stop leak if without risk. Move containers from spill area. Approach the release from upwind. Prevent entry into sewers, water courses, basements or confined areas. Wash spillages into an effluent treatment plant or proceed as follows. Contain and collect spillage with non-combustible, absorbent material e.g. sand, earth, vermiculite or diatomaceous earth and place in container for disposal according to local regulations. Dispose of via a licensed waste disposal contractor. Contaminated absorbent material may pose the same hazard as the spilt product.

6.4 Reference to other sections : See Section 1 for emergency contact information.
See Section 8 for information on appropriate personal protective equipment.
See Section 13 for additional waste treatment information.

SECTION 7: Handling and storage

The information in this section contains generic advice and guidance. The list of Identified Uses in Section 1 should be consulted for any available use-specific information provided in the Exposure Scenario(s).

7.1 Precautions for safe handling

SECTION 7: Handling and storage

Protective measures : Put on appropriate personal protective equipment (see Section 8). Persons with a history of skin sensitization problems should not be employed in any process in which this product is used. Do not get in eyes or on skin or clothing. Do not breathe vapour or mist. Do not ingest. Avoid release to the environment. Refer to special instructions/safety data sheet. Use only with adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Keep in the original container or an approved alternative made from a compatible material, kept tightly closed when not in use. Empty containers retain product residue and can be hazardous. Do not reuse container.

Advice on general occupational hygiene : Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas. See also Section 8 for additional information on hygiene measures.

7.2 Conditions for safe storage, including any incompatibilities : Store between the following temperatures: 2 to 40°C (35.6 to 104°F). Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabelled containers. Use appropriate containment to avoid environmental contamination.

7.3 Specific end use(s)

Recommendations : Not available.

Industrial sector specific solutions : Not available.

SECTION 8: Exposure controls/personal protection

The information in this section contains generic advice and guidance. The list of Identified Uses in Section 1 should be consulted for any available use-specific information provided in the Exposure Scenario(s).

8.1 Control parameters

Occupational exposure limits

No exposure limit value known.

Recommended monitoring procedures : If this product contains ingredients with exposure limits, personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment. Reference should be made to European Standard EN 689 for methods for the assessment of exposure by inhalation to chemical agents and national guidance documents for methods for the determination of hazardous substances.

Derived effect levels

No DELs available.

Predicted effect concentrations

No PECs available.

8.2 Exposure controls

SECTION 8: Exposure controls/personal protection

Appropriate engineering controls : Use only with adequate ventilation. If user operations generate dust, fumes, gas, vapour or mist, use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits.

Individual protection measures

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Contaminated work clothing should not be allowed out of the workplace. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

Eye/face protection : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.

Skin protection

Hand protection : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Material of gloves for long term application (BTT>480min): : butyl rubber, Ethyl Vinyl Alcohol Laminate (EVAL)

Material of gloves for short term/splash application (10min<BTT<480min): : nitrile rubber

(BTT = Break Through Time)

Use gloves approved to relevant standards e.g. EN 374 (Europe), F739 (US). Suitability and durability of a glove is dependent on usage, e.g. frequency and duration of contact, chemical resistance of glove material and dexterity. Always seek advice from glove suppliers. Additional information can be found for instance at www.gisbau.de.

Body protection : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Other skin protection : Appropriate footwear and any additional skin protection measures should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Respiratory protection : In case of inadequate ventilation wear respiratory protection. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Environmental exposure controls : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

Appearance

Physical state : Liquid.

Colour : Not available.

Odour : Not available.

Odour threshold : Not available.

pH : Not available.

Melting point/freezing point : Not available.

SECTION 9: Physical and chemical properties

Initial boiling point and boiling range	: Not available.
Flash point	: Closed cup: >120°C [DIN 51758 EN 22719 (Pensky-Martens Closed Cup)]
Evaporation rate	: Not available.
Flammability (solid, gas)	: Not available.
Burning time	: Not applicable.
Burning rate	: Not applicable.
Upper/lower flammability or explosive limits	: Not available.
Vapour pressure	: Not available.
Vapour density	: Not available.
Relative density	: Not available.
Solubility(ies)	
Water solubility	:
Partition coefficient: n-octanol/water	: Not available.
Auto-ignition temperature	: Not available.
Decomposition temperature	: Not available.
Viscosity	: Not available.
Explosive properties	: Not available.
Oxidising properties	: Not available.

9.2 Other information

Density	: 1.1 g/cm^3 [20°C (68°F)]

SECTION 10: Stability and reactivity

10.1 Reactivity	: No specific test data related to reactivity available for this product or its ingredients.
10.2 Chemical stability	: The product is stable.
10.3 Possibility of hazardous reactions	: Under normal conditions of storage and use, hazardous reactions will not occur.
10.4 Conditions to avoid	: No specific data.
10.5 Incompatible materials	: No specific data.
10.6 Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity

Product/ingredient name	Endpoint	Species	Result	Exposure
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	LC0 Inhalation Vapour	Rat - Male	0.00001 ppm	5 hours
	LD50 Dermal	Rat - Male, Female	>2000 mg/kg	-
	LD50 Oral	Rat - Female	>2000 mg/kg	-
butanedioldiglycidyl ether	LD50 Dermal	Rat - Male, Female	>2150 mg/kg	-
	LD50 Oral	Rat - Male, Female	1163 mg/kg	-

Irritation/Corrosion

Conclusion/Summary : Not available.

Sensitiser

Product/ingredient name	Test	Route of exposure	Species	Result
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	OECD 429 Skin Sensitisation: Local Lymph Node Assay	skin	Mouse	Sensitising
butanedioldiglycidyl ether	OECD 406 Skin Sensitization	skin	Guinea pig	Sensitising
isophorone diamine	Data based on tests on similar product	skin	Guinea pig	Sensitising

Conclusion/Summary : Not available.

Mutagenicity

Product/ingredient name	Test	Result
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	-	Positive
	-	Positive
	-	Negative
	-	Negative
butanedioldiglycidyl ether	OECD 471 Bacterial Reverse Mutation Test	Positive
	OECD 473 In vitro Mammalian Chromosomal Aberration Test	Positive
	OECD 474 Mammalian Erythrocyte Micronucleus Test	Negative

Conclusion/Summary : Not available.

Carcinogenicity

Product/ingredient name	Test	Species	Exposure	Result	Route of exposure	Target organs

SECTION 11: Toxicological information

reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	OECD 453 Combined Chronic Toxicity/Carcinogenicity Studies	Rat	2 years; 7 days per week	Negative	Oral	-
	OECD 453 Combined Chronic Toxicity/Carcinogenicity Studies	Rat	2 years; 5 days per week	Negative	Dermal	-
	OECD 453 Combined Chronic Toxicity/Carcinogenicity Studies	Mouse	2 years; 3 days per week	Negative	Dermal	-

Reproductive toxicity

Product/ingredient name	Test	Species	Result/Result type	Target organs
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	OECD 416 Two-Generation Reproduction Toxicity Study	Rat	Oral: 540 mg/kg NOEL :	-

Teratogenicity

Product/ingredient name	Test	Species	Result/Result type
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	OECD 414 Prenatal Developmental Toxicity Study	Rat - Female	>540 mg/kg NOEL :
	-	Rabbit - Female	>300 mg/kg NOEL :
	OECD 414 Prenatal Developmental Toxicity Study	Rabbit - Female	180 mg/kg NOAEL

Information on the likely routes of exposure : Not available.

Potential acute health effects

Inhalation : Harmful by inhalation. May give off gas, vapor or dust that is very irritating or corrosive to the respiratory system. Exposure to decomposition products may cause a health hazard. Serious effects may be delayed following exposure.

Ingestion : Harmful if swallowed. May cause burns to mouth, throat and stomach.

Skin contact : Corrosive to the skin. Causes burns. Harmful in contact with skin. May cause sensitisation by skin contact.

Eye contact : Corrosive to eyes. Causes burns.

Symptoms related to the physical, chemical and toxicological characteristics

Inhalation : No specific data.

Ingestion : Adverse symptoms may include the following:
stomach pains

Skin contact : Adverse symptoms may include the following:
pain or irritation
redness
blistering may occur

Eye contact : Adverse symptoms may include the following:
pain
watering
redness

Delayed and immediate effects and also chronic effects from short and long term exposure

Short term exposure

SECTION 11: Toxicological information

Potential immediate effects : Not available.

Potential delayed effects : Not available.

Long term exposure

Potential immediate effects : Not available.

Potential delayed effects : Not available.

Potential chronic health effects

Product/ingredient name	Test	Result type		Result	Target organs
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	OECD 408 Repeated Dose 90-Day Oral Toxicity Study in Rodents	NOAEL	Sub-chronic NOAEL Oral	50 mg/kg	-
	OECD 411 Subchronic Dermal Toxicity: 90-day Study	NOEL :	Sub-chronic NOEL : Dermal	10 mg/kg	-
	OECD 411 Subchronic Dermal Toxicity: 90-day Study	NOAEL	Sub-chronic NOAEL Dermal	100 mg/kg	-
butanedioldiglycidyl ether	OECD 407 Repeated Dose 28-day Oral Toxicity Study in Rodents	NOAEL	Sub-chronic NOAEL Oral	200 mg/kg	-

Conclusion/Summary : Not available.

General : Once sensitized, a severe allergic reaction may occur when subsequently exposed to very low levels.

Carcinogenicity : No known significant effects or critical hazards.

Mutagenicity : No known significant effects or critical hazards.

Teratogenicity : No known significant effects or critical hazards.

Developmental effects : No known significant effects or critical hazards.

Fertility effects : No known significant effects or critical hazards.

Other information : Not available.

SECTION 12: Ecological information

12.1 Toxicity

Product/ingredient name	Test	Endpoint		Exposure	Species	Result	
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	-	Acute	EC50	72 hours Static	Algae	9.4	mg/L
	OECD 202 *Daphnia* sp. Acute Immobilisation Test	Acute	EC50	48 hours Static	Daphnia	1.7	mg/L
	-	Acute	IC50	3 hours Static	Bacteria	>100	mg/L
	OECD 203 Fish, Acute Toxicity Test	Acute	LC50	96 hours Static	Fish	1.5	mg/L
	OECD 211 Daphnia Magna Reproduction Test	Chronic	NOEC	21 days Semi-static	Daphnia	0.3	mg/L
butanedioldiglycidyl ether	OECD 202 *Daphnia* sp. Acute Immobilisation Test	Acute	EC50	24 hours Static	Daphnia	75	mg/L
	OECD 201 Alga, Growth	Acute	EL50	72 hours	Algae	>160	mg/L

SECTION 12: Ecological information

	Inhibition Test			Static				
	OECD 209 Activated Sludge, Respiration Inhibition Test	Acute	IC50	3 hours Static	Bacteria	>100	mg/L	
	OECD 203 Fish, Acute Toxicity Test	Acute	LC50	96 hours Static	Fish	24	mg/L	

12.2 Persistence and degradability

Product/ingredient name	Test	Period	Result
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	OECD Derived from OECD 301F (Biodegradation Test)	28 days	5 %
butanedioldiglycidyl ether	OECD 301F Ready Biodegradability - Manometric Respirometry Test	28 days	43 %

Conclusion/Summary : reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700): Not readily biodegradable.

Product/ingredient name	Aquatic half-life	Photolysis	Biodegradability
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	Fresh water 4.83 days Fresh water 3.58 days Fresh water 7.1 days	-	Not readily
butanedioldiglycidyl ether	-	-	Not readily

12.3 Bioaccumulative potential

Product/ingredient name	$LogP_{ow}$	BCF	Potential
reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700)	3.242	31	low
butanedioldiglycidyl ether	-0.269	-	low

12.4 Mobility in soil

Soil/water partition coefficient (K_{OC}) : Not available.

Mobility : Not available.

12.5 Results of PBT and vPvB assessment

Not applicable.

12.6 Other adverse effects

: No known significant effects or critical hazards.

12.7 Other ecological information

SECTION 13: Disposal considerations

The information in this section contains generic advice and guidance. The list of Identified Uses in Section 1 should be consulted for any available use-specific information provided in the Exposure Scenario(s).

13.1 Waste treatment methods

Product

Methods of disposal : The generation of waste should be avoided or minimised wherever possible. Significant quantities of waste product residues should not be disposed of via the foul sewer but processed in a suitable effluent treatment plant. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Waste packaging should be recycled. Incineration or landfill should only be considered when recycling is not feasible. This material and its container must be disposed of in a safe way. Care should be taken when handling emptied containers that have not been cleaned or rinsed out. Empty containers or liners may retain some product residues. Avoid dispersal of spilt material and runoff and contact with soil, waterways, drains and sewers.

Hazardous waste : Yes.

European waste catalogue (EWC)

Waste code	Waste designation
07 02 08*	other still bottoms and reaction residues

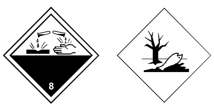
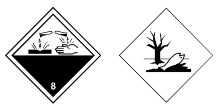
Packaging

Methods of disposal : The generation of waste should be avoided or minimised wherever possible. Waste packaging should be recycled. Incineration or landfill should only be considered when recycling is not feasible.

Special precautions : This material and its container must be disposed of in a safe way. Care should be taken when handling emptied containers that have not been cleaned or rinsed out. Empty containers or liners may retain some product residues. Avoid dispersal of spilt material and runoff and contact with soil, waterways, drains and sewers.

SECTION 14: Transport information

	14.1 UN number	14.2 UN proper shipping name
ADR/RID	UN2289	ISOPHORONEDIAMINE SOLUTION
ADN/ADNR	not available	not available
IMDG	UN2289	ISOPHORONEDIAMINE SOLUTION (BISPHENOL A EPOXY RESIN). Marine pollutant (reaction product: bisphenol A-(epichlorhydrin); epoxy resin (number average molecular weight < 700))
IATA	UN2289	ISOPHORONEDIAMINE SOLUTION

	ADR/RID	ADN/ADNR	IMDG	IATA
14.3 Transport hazard class(es)	8 		8 	8 
14.4 Packing group	III		III	III
14.5 Environmental hazards	Yes.		Yes.	Yes.
14.6 Special precautions for user	Not available.		Not available.	Not available.

SECTION 14: Transport information

Additional information	Hazard identification number 80 Tunnel code E		Emergency schedules (EmS) F-A, S-B	Passenger and Cargo Aircraft Quantity limitation: 5 L Packaging instructions: 818 Cargo Aircraft Only Quantity limitation: 60 L Packaging instructions: 820

14.7 Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code : Not applicable.

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

EU Regulation (EC) No. 1907/2006 (REACH)

Annex XIV - List of substances subject to authorisation

Substances of very high concern

None of the components are listed.

Annex XVII - Restrictions on the manufacture, placing on the market and use of certain dangerous substances, mixtures and articles : Not applicable.

Other EU regulations

Europe inventory : All components are listed or exempted.

Black List Chemicals : Not listed

Priority List Chemicals : Not listed

Integrated pollution prevention and control list (IPPC) - Air : Not listed

Integrated pollution prevention and control list (IPPC) - Water : Not listed

National regulations

References : The provision of Safety Data Sheets comes under Regulation 6 of CHIP (CHIP is the recognised abbreviation for the Chemicals Hazard Information and Packaging Regulations). This is an addition to the Health and Safety at Work Act 1974.

International regulations

Chemical Weapons Convention List Schedule I Chemicals : Not listed

Chemical Weapons Convention List Schedule II Chemicals : Not listed

SECTION 15: Regulatory information

Chemical Weapons Convention List Schedule III Chemicals : Not listed

15.2 Chemical Safety Assessment : This product contains substances for which Chemical Safety Assessments are still required.

SECTION 16: Other information

Indicates information that has changed from previously issued version.

Abbreviations and acronyms :
ATE = Acute Toxicity Estimate
CLP = Classification, Labelling and Packaging Regulation [Regulation (EC) No. 1272/2008]
DNEL = Derived No Effect Level
EUH statement = CLP-specific Hazard statement
PNEC = Predicted No Effect Concentration
RRN = REACH Registration Number

Classification according to Regulation (EC) No. 1272/2008 [CLP/GHS]

Acute Tox. 4, H302
Acute Tox. 4, H312
Acute Tox. 4, H332
Skin Corr. 1B, H314
Eye Dam. 1, H318
Skin Sens. 1, H317
Aquatic Chronic 2, H411

Procedure used to derive the classification according to Regulation (EC) No. 1272/2008 [CLP/GHS]

Classification	Justification
Acute Tox. 4, H302	Expert judgment
Acute Tox. 4, H312	Expert judgment
Acute Tox. 4, H332	On basis of test data
Skin Corr. 1B, H314	Expert judgment
Eye Dam. 1, H318	Expert judgment
Skin Sens. 1, H317	Expert judgment
Aquatic Chronic 2, H411	Expert judgment

Full text of abbreviated H statements :

H302	Harmful if swallowed.
H312	Harmful in contact with skin.
H314	Causes severe skin burns and eye damage.
H315	Causes skin irritation.
H317	May cause an allergic skin reaction.
H318	Causes serious eye damage.
H319	Causes serious eye irritation.
H332	Harmful if inhaled.
H411	Toxic to aquatic life with long lasting effects.
H412	Harmful to aquatic life with long lasting effects.

Full text of classifications [CLP/GHS] :

Acute Tox. 4, H302	ACUTE TOXICITY: ORAL - Category 4
Acute Tox. 4, H312	ACUTE TOXICITY: SKIN - Category 4
Acute Tox. 4, H332	ACUTE TOXICITY: INHALATION - Category 4
Aquatic Chronic 2, H411	AQUATIC TOXICITY (CHRONIC) - Category 2
Aquatic Chronic 3, H412	AQUATIC TOXICITY (CHRONIC) - Category 3
Eye Dam. 1, H318	SERIOUS EYE DAMAGE/ EYE IRRITATION - Category 1
Eye Irrit. 2, H319	SERIOUS EYE DAMAGE/ EYE IRRITATION - Category 2
Skin Corr. 1B, H314	SKIN CORROSION/IRRITATION - Category 1B
Skin Irrit. 2, H315	SKIN CORROSION/IRRITATION - Category 2
Skin Sens. 1, H317	SKIN SENSITIZATION - Category 1

SECTION 16: Other information

Full text of abbreviated R phrases : R22- Harmful if swallowed.
R20/21- Harmful by inhalation and in contact with skin.
R20/21/22- Harmful by inhalation, in contact with skin and if swallowed.
R21/22- Harmful in contact with skin and if swallowed.
R34- Causes burns.
R36/38- Irritating to eyes and skin.
R43- May cause sensitisation by skin contact.
R51/53- Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
R52/53- Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Full text of classifications [DSD/DPD] : C - Corrosive
Xn - Harmful
Xi - Irritant
N - Dangerous for the environment

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Date of previous issue : No previous validation.

Version : 1

Notice to reader

While the information and recommendations in this publication are to the best of our knowledge, information and belief accurate at the date of publication, NOTHING HEREIN IS TO BE CONSTRUED AS A WARRANTY, EXPRESS OR OTHERWISE.

IN ALL CASES, IT IS THE RESPONSIBILITY OF THE USER TO DETERMINE THE APPLICABILITY OF SUCH INFORMATION AND RECOMMENDATIONS AND THE SUITABILITY OF ANY PRODUCT FOR ITS OWN PARTICULAR PURPOSE.

THE PRODUCT MAY PRESENT HAZARDS AND SHOULD BE USED WITH CAUTION. WHILE CERTAIN HAZARDS ARE DESCRIBED IN THIS PUBLICATION, NO GUARANTEE IS MADE THAT THESE ARE THE ONLY HAZARDS THAT EXIST.

Hazards, toxicity and behaviour of the products may differ when used with other materials and are dependent upon the manufacturing circumstances or other processes. Such hazards, toxicity and behaviour should be determined by the user and made known to handlers, processors and end users.

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Material Safety Data Sheet

Product Name:	HXTAL NYL-1 Epoxy Adhesive Part A (Resin)
MSDS Date:	11/10/2010

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name:	HXTAL NYL-1 Part A (Resin)

2. COMPOSITION AND INFORMATION ON INGREDIENTS

Component	CAS#	Concentration
Epoxy resin	30583-72-3	100%
Diglycidyl ether	2238-07-5	130ppm
1-chloro-2,3-epoxy propane	106-89-8	5ppm-10ppm

3. HAZARDS IDENTIFICATION

Physical State	Liquid
Color	Clear, colorless
Odor	odorless
Hazard Summary	May be slightly toxic and may be harmful if swallowed. Irritating to eyes and skin. May cause sensitization by skin contact.

4. FIRST AID MEASURES

Inhalation:	Remove to fresh air.
Skin Contact:	Wash skin with water using soap if available. If persistent irritation occurs, contact a physician.
Eye Contact:	Flush eyes with water. If persistent irritation occurs, contact a physician.
Ingestion:	Do not induce vomiting without medical advice. Immediate medical attention is required. Never give anything by mouth to an unconscious person. Call a physician.

Notes to Physician

Treatment:	Treat symptomatically.

5. FIRE-FIGHTING MEASURES

Suitable extinguishing media:	Foam
	Carbon dioxide (CO_2)
	Dry Chemical
	Sand or earth may be used for small fires only.
Extinguishing media which shall not be used for safety reasons:	Do not use a solid water stream as it may scatter and spread fire.
Specific hazards during fire fighting:	Keep adjacent containers cool by spraying with water.
Special protective equipment for fire-fighters:	Wear self-contained breathing apparatus and protective suit.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions:	Avoid contact with skin, eyes and clothing.
Environmental precautions:	Prevent contamination of soil and water.
	Discharge into the environment must be avoided.
	Do not flush into surface water or sanitary sewer system.

Methods for clean-up:	Absorb liquid with sand, earth or spill control material. Shovel up and place in a labelled, sealable container for subsequent safe disposal. Scrub contaminated surfaces with detergent solution.

7. HANDLING AND STORAGE

Handling

Handling:	Avoid contact with skin, eyes and clothing. Avoid breathing vapors, spray or mist.

Storage

Requirements for storage areas and containers:	Keep containers tightly closed in dry, cool and well ventilated place.

8. EXPOSURE CONTROL / PERSONAL PROTECTION

Engineering measures:	Use with local exhaust ventilation.
Eye protection:	Wear safety glasses with side shields.
Hand protection:	Rubber gloves.
Skin and body protection:	Standard issue work clothes.
Respiratory protection:	In case of insufficient ventilation wear suitable respiratory equipment.

9. PHYSICAL AND CHEMICAL PROPERTIES

Form:	Viscous liquid
Color:	Colorless
Odor:	Odorless
Specific gravity:	1.09
Melting point/range:	10ºC (50º F)
Flash point:	Typical 115º C (239º F)
Relative vapor density:	>1 (Air = 1.0)

Water solubility:	Negligible
Viscosity, dynamic:	1.8-2.5 Pas at 25° C (77° F) ASTM D-445

10. STABILITY AND REACTIVITY

Conditions to avoid:	Caustic soda can induce vigorous polymerization at temperatures around 200° C (392° F)
Materials to avoid:	Caustic sodas Strong oxidizing agents.
Hazardous decomposition products:	Hazardous decomposition products are not expected to form during normal storage.
Hazardous reactions:	Stable under normal conditions. Reacts with strong oxidizing agents. Polymerizes exothermically with amines.

11. TOXICOLOGICAL INFORMATION

Acute oral toxicity:	LD50 rat Low toxicity, LD50 > 2000mg/kg.
Acute dermal toxicity:	LD50 rabbit Low toxicity, LD50 > 2000mg/kg.
Acute inhalation toxicity:	no data available.
Skin irritation:	Expected to be slight irritant.
Eye irritation:	Not expected to be irritating.

12. ECOLOGICAL INFORMATION

Biodegradability:	This section will be updated as ecological reviews are completed.
Toxicity to fish:	This section will be updated as ecological reviews are completed.

13. DISPOSAL CONSIDERATIONS

Observe all Federal, State and Local Environmental regulations.

14. TRANSPORT INFORMATION

DOT Classification:	Not regulated for transport
IATA Classification:	Not regulated for transport

15. REGULATORY INFORMATION

US Toxic Substances Control Act:	On TSCA Inventory
Australia (Industrial Chemical Notification and Assessment Act)	On the inventory or in compliance with the inventory
Canada	All components of this product are on the Canadian DSL list.
Japan	Not listed
Korea	On the inventory or in compliance with the inventory
Phillipines	On the inventory or in compliance with the inventory
China	On the inventory or in compliance with the inventory
Switzerland	On the inventory or in compliance with the inventory
New Zealand	On the inventory or in compliance with the inventory

16. OTHER INFORMATION

	HMIS III
Health:	2
Flammability	1
Reactivity:	0
Personal Protection	0

Material Safety Data Sheet

Product Name: HXTAL NYL-1 Epoxy Adhesive Part B (Hardener)

MSDS Date: 11/10/2010

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name: HXTAL NYL-1 Part B (Hardener)

2. COMPOSITION AND INFORMATION ON INGREDIENTS

Component	CAS#	Concentration
Poly(oxy)(methyl-1,2-ethanediyl), alpha-hydro-omega-(2-aminomethylathoxy)-ether 2-ethyl-2-(hydroxymethyl)-1,3-propanediol(3:1)	39423-51-3	< 92%
1,3-diaza-2,4-cyclopentadiene, glyoxaline	288-32-4	< 10%

3. HAZARDS IDENTIFICATION

Physical State	Liquid
Color	Clear, colorless
Odor	slight ammonia
Hazard Summary	Harmful if swallowed. Severe eye irritant. Severe respiratory irritant. Sever skin irritant

Potential Health Effects

Skin:	Irritating to skin.
	Prolonged skin exposure can be corrosive.
Eyes:	Severe eye irritation.
	Causes itching, burning, redness and tearing.
Ingestion:	Harmful if swallowed.
Inhalation:	May cause respiratory tract irritation.
Aggravated Medical Condition:	Eye disease.
	Asthma.
	Skin disorders and Allergies

Carcinogenicity

California Prop 65: This product contains a chemical known to the State of California to cause cancer. CAS#39423-51-3

Cancer	Reproductive	No significant risk	Max acceptable dose
Yes	No significant risk	No significant risk	No

4. FIRST AID MEASURES

Inhalation:	Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Use oxygen as required, provided a qualified operator is present. Call a physician.
Skin Contact:	Wash off immediately with plenty of water for at least 15 minutes. Take off contaminated clothing and shoes immediately. Wash contaminated clothing before re-use. Call a physician if irritation develops or persists.
Eye Contact:	Rinse immediately with plenty of water, also under the eyelids for at least 15 minutes. Call a physician, preferably an ophthalmologist.
Ingestion:	Do not induce vomiting without medical advice. Immediate medical attention is required. Never give anything by mouth to an unconscious person. Call a physician.

Notes to Physician

Treatment:	Treat symptomatically.

5. FIRE-FIGHTING MEASURES

Suitable extinguishing media:	Alcohol resistant foam
	Carbon dioxide (CO_2)
	Dry Chemical
	Dry Sand
Specific hazards during fire fighting:	Incomplete combustion may form carbon monoxide.
Special protective equipment for fire-fighters:	Wear self-contained breathing apparatus and protective suit.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions:	Wear personal protective equipment
	Immediately evacuate personnel to safe areas.
	Ensure adequate ventilation.
	Do not swallow.
	Avoid breathing vapors, mist or gas.
	Avoid contact with skin, eyes and clothing.
Environmental precautions:	Prevent further leakage or spillage if safe to do so.
	Discharge into the environment must be avoided.
Environmental precautions:	Do not flush into surface water or sanitary sewer system.
	Prevent product from entering drains.
	Collect contaminated fire extinguishing water separately. This must not discharge into drains.
Methods for clean-up:	Ventilate the area.

Methods for clean-up:	Contain and collect spillage with non-combustible absorbent materials, e.g. sand, earth, vermiculite, diatomaceious earth and place in container for disposal according to local regulations (see section 13).

7. HANDLING AND STORAGE

Handling

Handling:	Wear personal protective equipment.
	Use only in well ventilated areas.
	Keep container tightly closed.
	Do not swallow.
	Avoid breathing vapors, mist or gas.
	Avoid contact with skin, eyes and clothing.

Storage

Requirements for storage areas and containers:	Keep containers tightly closed in dry, cool and well ventilated place.
	Containers which are opened must be carefully resealed and kept upright to prevent leakage.
	Keep separate from acids.
	Keep away from direct sunlight.

8. EXPOSURE CONTROL / PERSONAL PROTECTION

Protective Measures:	Ensure that eyewash stations and safety showers are close to the workstation location.
Engineering measures:	Use with local exhaust ventilation.
	Prevent vapor buildup by providing adequate ventilation during and after use.
Eye protection:	Wear appropriate safety eye wear.
	Wear safety glasses with side shields.
Hand protection:	Solvent resistant gloves.

Skin and body protection:	Solvent resistant apron. Long sleeve shirts recommended.
Respiratory protection:	In case of sufficient ventilation wear suitable respiratory equipment.
Hygiene measures:	When using, do not eat or drink or smoke. Wash hands before breaks and immediately after handling the product. Keep work clothes separate. Remove and wash contaminated clothing before re-use. Do not swallow. Avoid breathing vapors, mist or gas. Avoid contact with skin, eyes and clothing.

9. PHYSICAL AND CHEMICAL PROPERTIES

Form:	Liquid, clear
Color:	Colorless
Odor:	Ammoniacal
pH:	12.3
Water solubility:	Soluble
Boiling point/range:	>268° C (200° F)
Flash point:	162.78° C (325° F)
Relative vapor density:	>1 (Air = 1.0)
Vapor pressure:	<1 mm Hg at 40° C
Specific Gravity:	0.9812
Relative Density:	0.98 (Water = 1.0)
Viscosity, dynamic:	>80 CPS at 25° C

10. STABILITY AND REACTIVITY

Materials to avoid:	Strong acids.
Hazardous decomposition products:	In case of fire hazardous decomposition products may be produced such as:
	Carbon monoxide
	Carbon dioxide (CO_2)
Hazardous reactions:	Hazardous polymerization does not occur.
	Stable under recommended storage conditions.

11. TOXICOLOGICAL INFORMATION

Acute oral toxicity:	LD50 rat
	Dose: 220 mg/kg
Acute dermal toxicity:	LD50 rabbit
	Dose: 562 mg/kg
Potential acute health effects	
Ingestion:	Toxic if swallowed. May cause burns to mouth, throat and stomach
Inhalation:	Irritating to Respiratory system.
Eyes:	Corrosive to eyes. Causes burns.
Skin:	Corrosive to the skin. Causes burns.
Potential chronic health effects	
Target organs:	none.
Carcinogenicity:	No known significant effects or critical hazards
Mutagenicity:	No known significant effects or critical hazards

12. ECOLOGICAL INFORMATION

Biodegradability:	Not readily biodegradable
Toxicity to fish:	LC50
	Dose: >100mg/L
	Exposure time: 96h
Additional ecological information:	Should not be released into the environment. Accumulation in aquatic organisms is unlikely.

13. DISPOSAL CONSIDERATIONS

Observe all Federal, State and Local Environmental regulations.

14. TRANSPORT INFORMATION

DOT Classification:

Proper shipping name:	Amines, corrosive liquids, n.o.s.
Class:	8
UN ID#:	UN2735
Packing Group:	III

IATA Classification:

Proper shipping name:	Amines, corrosive liquids, n.o.s.
Class:	8
UN ID#:	UN2735
Packing Group:	III

15. REGULATORY INFORMATION

EU. EINECS:	on the inventory or in compliance with the inventory

US Toxic Substances Control Act:	On TSCA Inventory
Australia (Industrial Chemical Notification and Assessment Act)	On the inventory or in compliance with the inventory
Canada	On the inventory or in compliance with the inventory
Japan	On the inventory or in compliance with the inventory
Korea	On the inventory or in compliance with the inventory
Phillipines	On the inventory or in compliance with the inventory
China	On the inventory or in compliance with the inventory
Switzerland	On the inventory or in compliance with the inventory
New Zealand	On the inventory or in compliance with the inventory

16. OTHER INFORMATION

	HMIS III	**NFPA**
Health:	3	3
Flammability	1	1
Reactivity:	0	0
Personal Protection	0	0

Säkerhetsdatablad enligt (EG) nr 1907/2006 - ISO 11014-1

SDB-nr : 194918
V001.7

Loctite Super Attak Precision

Reviderat den: 06.07.2009
Utskriftsdatum: 19.03.2010

1. NAMNET PÅ ÄMNET/BEREDNINGEN OCH BOLAGET/FÖRETAGET

Handelsnamn:
Loctite Super Attak Precision

Avsedd användning:
Snabblim

Företagsbeteckning:
Henkel Norden AB
Box 120 80
102 22 STOCKHOLM

SE

Tel.: +46 (0) 10 480 7700

E-postadress för den behöriga person som ansvarar för säkerhetsdatabladet:
ua-productsafety.norden@se.henkel.com

Nödupplysningar:
+46 10 480 7500 (kontorstid)

2. FARLIGA EGENSKAPER

R36/37/38 Irriterar ögonen, andningsorganen och huden.
Xi - Irriterande
Produkten är farlig enligt Kemikalieinspektionens föreskrifter om klassificering och märkning av kemiska produkter.
Klistrar ihop hud och ögonlock på någon sekund.
Personer som reagerar allergiskt på akrylat bör undvika hantering med produkten.

3. SAMMANSÄTTNING/INFORMATION OM BESTÅNDSDELAR

Allmän kemisk karaktärisering:
Cyanoakrylatlim
Basämnen i beredningen:
Cyanoakrylat

Angivande av ämnen enligt (EG) nr 1907/2006:

Farliga komponenter CAS-nr.	EINECS ELINCS	Halt	Klassificering
Etylcyanoakrylat 7085-85-0	230-391-5	> 80 - < 100 %	Xi - Irriterande; R36/37/38

För fullständig ordalydelse av R-fraser som anges med koder, se rubrik 16 "Annan information".

Ämnen utan klassificering kan ha arbetsplatsrelaterade hygieniska gränsvärden inom gemenskapen.

4. ÅTGÄRDER VID FÖRSTA HJÄLPEN

Inhalation:
Frisk luft, sök upp läkare vid ihållande besvär.

Hudkontakt:
Vid hudlimmning: drag inte. Utan bänd försiktigt isär-enklast i ljummet vatten med ett trubbigt föremål.
Cyanoakrylater avger värme vid övergång till fast form. Det är ovanligt, men en stor droppe kan avge tillräckligt mycket värme för att orsaka brännskador
Brännskador bör behandlas normalt efter att limmet har tagits bort från skinnet.
Om läppar olyckligtvis limmas ihop ska varmt vatten anbringas på läpparna. Maximal vätning och tryck från saliv inuti munnen ska försöka att erhållas.
Bänd försiktigt isär läppar. Försök inte att dra isär läpparna.

Ögonkontakt:
Täck med varm och fuktig trasa
Cyanoakrylater binder ögonprotein och orsakar tårbildning som underlättar upplösningen av lim.
Håll ögonen täckta med fuktig trasa tills fullständig upplösning av lim skett, ca 1 - 3 dagar.
Tvinga inte upp ögonen. Kontakta läkare om fasta partiklar av cyanoakrylat bakom ögonlocket skaver mot ögat.

Förtäring:
Se till att luftvägarna är fria. Produkten polymeriserar omedelbart i munnen och är därför omöjlig att svälja. Saliven kommer sakta att lösa upp den stelnande produkten (flera timmar).

5. BRANDBEKÄMPNINGSÅTGÄRDER

Lämpliga släckningsmedel:
Skum, släckningspulver, kolsyra.
Vattendimma

Av säkerhetsskäl olämpliga släckningsmedel:

Högtrycksvattenstråle

Särskild skyddsutrustning vid brandbekämpning:
Brandbekämpare måste bära sluten andningsapparat.
Använd personlig skyddsutrustning.

Förbränningsprodukter eller gaser som bildas:
Oxider av kol, oxider av kväve, retande organiska ångor.

6. ÅTGÄRDER VID OAVSIKTLIGA UTSLÄPP

Skyddsåtgärder för personer:
Sörj för tillräcklig ventilation.

Miljöskyddsåtgärder:
Förhindra utsläpp i avloppssystemet.
Får inte släppas ut i ytvatten/grundvatten.

Metod för rengöring och sanering:
Använd inte tygtrasor för att torka upp. Spola med vatten för att färdigställa polymerisationen och skrapa upp från golvet.
Härdat material kan avyttras som ej riskmaterial.
Kontaminerat material tas om hand enligt punkt 13.

7. HANTERING OCH LAGRING

Hantering:
Sörj för god ventilation vid hantering av större mängder
Använd doseringshjälpmedel för att undvika hud- och ögonkontakt.
Öppna och hantera behållare försiktigt.

Lagring:
För optimal hållbarhet förvara i originalbehållare i 2-8°C (35.6-46.4 °F)
Ska lagras svalt, maximal lagringstemperatur 30 °C.
Förvara torrt.
Håll behållare tillsluten och förvara frostfritt.

Förvaras åtskild från livsmedel och konsumtionsvaror (t.ex. kaffe, te, tobak).

8. Begränsning av exponeringen/personligt skydd

Beståndsdelar med arbetsplatsrelaterade gränsvärden som kräver övervakning:
Gäller för
SE
Basis
Hygieniska gränsvärden - HGV

Ingående ämnen	ppm	mg/m^3	Typ	Kategori	Anmärkningar
ETYL-2-CYANOAKRYLAT 7085-85-0	2	10	Nivågränsvärde.		SWO
ETYL-2-CYANOAKRYLAT 7085-85-0	4	20	Korttidsvärde.		SWO
ETYL-2-CYANOAKRYLAT 7085-85-0				Medicinsk kontroll krävs vid hantering av ämnet.	SWO

Anvisningar för utformning av tekniska anläggningar:
Sug upp ångor eller rök direkt vid uppkomst- eller utloppsstället. Använd bordsutsug vid regelbundet arbete.

Handskydd:
För kortvarig kontakt (t. ex. skydd mot stänk) rekommenderas skyddshandskar av nitrilgummi enligt EN 374.
materialtjockhet 0,4 mm
genomsläppningstid > 480 min
Om det är fråga om långvarig och upprepad kontakt bör man vara uppmärksam på att ovan nämnda genomsläppningstider kan vara betydligt kortare än de som anges EN 374. Lämpligheten av skyddshandskar måste alltid kontrolleras när man använder dom i speciella förhållanden (t.ex. mekanisk och termisk belastning, kombatibilitet med produkter, antistatiska egenskaper osv.) Skyddshandskar måste bytas genast när de första tecknen av förslitning och skador visar sig. Följ handsktillverkarnas anvisningar och säkerhetsregler för gällande arbetsförhållanden. Vi rekommenderar att utarbeta en plan för handvård tillsammans med handsktillverkaren och lokala skyddsombud som är lämplig för de lokala arbetsförhållandena.

Ögonskydd:
Skyddsglasögon

Allmänna skydds- och hygieniska åtgärder:
Undvik kontakt med ögonen och huden.
Ät inte, drick inte eller rök inte under hanteringen.
Sörj för god industrihygien

9. Fysikaliska och kemiska egenskaper

Allmänna egenskaper:

Utseende	Flytande Färglös
Lukt:	Irriterande.

Fysikaliska och kemiska egenskaper:

Kokpunkt	> 100 °C (> 212 °F)
Flampunkt	80,0 - 93,4 °C (176 - 200.12 °F)
Ångtryck (25 °C (77 °F))	< 0,5 mbar
Densitet ()	1,05 g/cm3
Löslighet, kvalitativ (lösningsm: Vatten)	Polymeriserar vid kontakt med vatten.
Explosionsgräns	Produkten är inte explosiv.

10. STABILITET OCH REAKTIVITET

Undvik följande villkor:
Stabil under normala förvarings- och användningsförhållanden.

Undvik följande ämnen:
Snabb exotermisk polymerisation sker vid förekomst av vatten, aminer, alkalier och alkoholer.

Farliga sönderdelningsprodukter:
Inga kända.

11. TOXIKOLOGISK INFORMATION

Allmänna uppgifter om toxikologi:
Vid rätt och ändamålsenlig hantering av produkten föreligger enligt vår kännedom inga effekter som kan inverka negativt på hälsan.

Akut oral toxicitet:
Cyanoakrylater anses ha låg toxicitet. Akut oral (råtta) LD50 > 5000mg/kg. Nära omöjlig att svälja eftersom den polymeriserar snabbt imunnen.

Akut inhalativ toxicitet:
Irriterar andningsorganen.
Långvarig exponering för höga koncentrationer av ångor kan leda till kroniska verkningar hos känsliga individer
I torr luft (luftfuktighet <50%) kan ångor irritera ögonen och andningsorganen

Hudirritation:
Irriterande på huden
Kan snabbt limma samman hud och ögon. Anses ha låg toxicitet. Akut dermal LD50 (kanin) > 2000mg/kg
Eftersom polymerisationen sker på ytan av huden anses allergiska reaktioner inte vara möjliga

Ögonirritation:
Irriterar ögonen.
Vätskeformig produkt limmar samman ögonen. I torr atmosfär (RH < 50%) kan ångorna irritera ögonen och ha tårbildande effekt

12. EKOLOGISK INFORMATION

Rörlighet:
Härdade bindemedel är immobila.

<u>Persistens/nedbrytbarhet:</u>
Biologisk slutnedbrytning:
Summan av de organiska komponenterna i produkten uppnår i försök rörande lätt nedbrytbarhet värden under 60% BSB/CSB, alt. under 70% DOC-minskning. Gränsvärdena för 'lätt nedbrytbar/readily degradable' (t.ex. enligt OECD-metoden 301) uppnås inte.
Produkten innehåller polymera komponenter som till stor del är nedbrytbara.

Allmänna uppgifter om ekologi:
Kraven på biologisk och kemisk syreförbrukning (BOD och COD) saknar betydelse.
Låt ej hamna i avloppssystemet/ytvatten/grundvatten.

13. AVFALLSHANTERING

Avfallshantering av produkten:

Polymerisera genom att sakta hälla produkten i vatten (10:1). Kan i vissa fall deponeras som vattenolöslig, ej toxisk, fast kemikalie eller förbrännas under kontrollerade former enligt lagar och förordningar.
Produkt deponeras enligt lokala och nationella lagar och förordningar.
EAK-avfallskoderna är inte produkt- utan till största delen ursprungsrelaterade. Tillverkaren kan därför inte ange någon avfallskod för artiklar / produkter som används inom olika branscher. Dessa avfallskoder lämnas av respektive tillverkare.

Avfallshantering av ej rengjord förpackning:

Efter användning ska tuber, kartonger och flaskor som innehåller rester av produkt hanteras som kemiskt förorenat avfall och undanskaffas enligtlokala och nationella lagar och förordningar.
Avfallshantera produkt/emballage enligt föreskrivna regler.

14. TRANSPORTINFORMATION

Vägtransport ADR:
Inget riskgods

Järnvägstransport RID:
Inget riskgods

Insjötransport ADN:
Inget riskgods

Sjötransport IMDG:
Inget riskgods

Flygfrakt IATA:

Klass:	9
Förpackningsgrupp:	
Packaging-Instruction (passenger)	906
Packaging-Instruction (cargo)	906
UN-nr:	3334
Varningsetikett:	9
Proper shipping name:	Aviation regulated liquid, n.o.s. (Ethyl cyanoacrylate)

15. Föreskrifter - klassificering och märkning

Farosymboler:

Xi - Irriterande

R-fraser:

R36/37/38 Irriterar ögonen, andningsorganen och huden.

S-fraser:
S2 Förvaras oåtkomligt för barn.
S23 Undvik inandning av ånga.
S24/25 Undvik kontakt med huden och ögonen.
S26 Vid kontakt med ögonen, spola genast med mycket vatten och kontakta läkare.

Tilläggsinformation:
Cyanoakrylat. Varning. Kan snabbt klistra samman hud och ögon. Förvaras oåtkomligt för barn.

16. ANNAN INFORMATION

Produktens märkning anges under avsnitt 15. Fullständig ordalydelse av de R-fraser som angetts med koder i säkerhetsdatabladet:
R36/37/38 Irriterar ögonen, andningsorganen och huden.

Övrig information:
"Angivelserna stöder sig på vår nuvarande kännedom och syftar på produkten i levererat tillstånd. De ska beskriva våra produkter med avseende på säkerhetskrav och har därför ej för avsikt att beskriva några produktspecifika egenskaper."

Hänvisning till härdade plaster:
Arbetarskyddsstyrelsens riktlinjer AFS 2005:18 Härdplaster gäller för denna produkt

1. Identification of the Substance/Preparation and Company.

Product Information)

Product Name:&	Paraloid B 67&
Article No.:&	67420&
Application:&	Artists´ and Restoration Material &

Company:)

Company:&	Kremer Pigmente GmbH & Co. KG&
Address:&	Hauptstrasse 41-47, D 88317 Aichstetten&
Tel/Fax:&	Tel. +49 7565 91120, Fax. +49 7565 1606&
Internet:&	www.kremer-pigmente.de, kremer-pigmente@t-online.de&

2. Composition/Information on Ingredients.

Chemical Characterization:&	This product is a preparation.&
Hazardous Ingredients:&	Isobutylmethacrylate 0,6-1,0%& CAS_Nr.: 97-86-9 EINECS-Nr.: 202-613-0 EC-Nr.: & This product does not contain any hazardous components according & to EC Guidelines 67/548/EEC and 99/45/EC.&

3. Hazards Identification.

Hazard designation:&	Not hazardous according to EC Guidelines 67/548/EEC and & 99/45/EC.&

4. First Aid Measures.

After inhalation:&	Take affected person to fresh air and keep calm.&
After skin contact:&	Wash off with plenty of water and soap. Consult a physician if & irritation persists.&
After eye contact:&	Rinse open eye for several minutes under running water. Should & irritation continue, seek medical advice.&
After ingestion:&	If swallowed, give 1-2 glasses of water to drink. Consult a physician. & Never give anything by mouth to an unconscious person.&

5. Fire-Fighting Measures.

Protective equipment:&	Wear self-containing breathing apparatus and protective clothing.&
Special hazards:&	Product is combustible, it burns vigorously with intense heat & development.&
Further information:&	Cool exposed containers with water spray.&

6. Accidental Release Measures.

Personal precautions:&	Provide adequate ventilation. Keep away from sources of ignition.& Wear appropriate protective equipment. Keep spectators away.& Floor may be slippery; use care to avoid falling.&
Environmental precautions:&	Keep spills and cleaning runoff out of municipal sewers and open & bodies of water.&

Methods of & cleaning/absorption:&	Clean-up mechanically. Transfer liquids and solid diking material to & separate suitable containers for recovery or disposal.&

7. Handling and Storage.

Handling:)

Instructions on safe handling:&	Provide adequate ventilation.&
	Monomer vapors may be evolved when material is heated during & processing operations.&
Information on fire and & explosion protection:&	Keep away from sources of ignition - do not smoke. Take & precautionary measures against static discharges.&

Storage:)

Storage conditions: &	Material is combustible. Indoor storage should be limited to & restricted areas, which should be equipped with automatic sprinkling & systems.&
Further information: &	Maximum storage temperature: 49°C (120°C). Minimum storage & temperature: -18°C (0°F).&

8. Exposure Controls/Personal Protection.

Additional information about & design of technical systems:&	Provide adequate ventilation.&
	Facilities storing or utilizing this material should be equipped with & an eyewash facility.&
Components with workplace & control parameters: &	No exposure limits for this product. &
Respiratory protection: &	None required under normal operating conditions.&
	Respiratory protection with filter type N95 (corresp. to NIOSH resp. & DIN standards) recommended for organic vapors. Filter types R95 or & R96 recommended for oil mist.&
Hand protection::&	Gloves made of thick material. &
Eye protection:&	Safety glasses with protective shields (EN 166). &

9. Physical and Chemical Properties.

Form:&	granules &
Color:&	white, cloudy &
Odor:&	acrylic &
Melting temperature:&	nicht bestimmt &
Boiling point:&	nicht anwendbar &
Flash point:&	nicht anwendbar &
Vapor pressure:&	nicht anwendbar &
Solubility in water:&	practically insoluble &
Viscosity:&	nicht anwendbar &

10. Stability and Reactivity.

Thermal decomposition / & Conditions to be avoided:&	No decomposition when used according to specifications.&

Thermal decomposition / & Conditions to be avoided:&	Avoid temperatures above 260°C. The thermal decomposition & depends of time and temperature.&
Products to be avoided:&	There are no known products which are incompatible with this & product.&
Hazardous decomposition & products:&	Thermal decomposition may yield acrylic monomers.&
Further information:&	Product does not polymerize.&

11. Toxicological Information.

Acute toxicity:)

LD50, oral:&	> 5000 mg/kg&
LD50, dermal:&	> 3000 mg/kg&

Primary effects:)

Irritant effect on skin:&	Slight irritant effect (rabbit)&
Irritant effect on eyes:&	Slight irritant effect (rabbit)&

12. Ecological Information.

Further ecological effects:&	No ecological data available.&

Further information:)

Water hazard class:&	1&

13. Disposal Considerations.

Product:&	Must be taken to a special incineration plant after consulting with & the local authorities and after pre-treatment.&

14. Transport Information.

Further information:&	Non-hazardous product according to transportation regulations.&

15. Regulatory Information.

Designation according to EC & guidelines:&	The material is not subject to classification according to EC lists.&

National Regulations (D):)

Local regulations on chemical & accidents:&	Consider solvent concentration; see para. 2 and 10.&
Classification according VbF:&	not necessary&
Water hazard class:&	1, slightly hazardous for water (self-assessment)&

16. Other Information.

This product should be stored, handled and used in accordance with good hygiene practices and in & conformity with any legal regulations.&

This information contained herein is based on the present state of knowledge and is intended to describe our product from the point of view of safety requirements. It should be therefore not be construed as & guaranteeing specific properties.&

Material Safety Data Sheet

1. PRODUCT AND COMPANY IDENTIFICATION

PARALOID (TM) B-72 100% Resin

Revision date: 09/26/2003

Supplier The Dow Chemical Company
100 Independence Mall West
Philadelphia, PA 19106-2399 United States of America

For non-emergency information contact: 215-592-3000

Emergency telephone number

Spill Emergency	215-592-3000
Health Emergency	215-592-3000
Chemtrec	800-424-9300

2. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No.	Concentration
Acrylic polymer(s)	Not Hazardous	99.0 - 100.0%
Individual residual monomers	Not Required	<=0.1%
Toluene	108-88-3	<=0.8%

3. HAZARDS IDENTIFICATION

Emergency Overview

Appearance

Form Granular solid

Colour clear

Odour Acrylic odor

Hazard Summary	**CAUTION!** INHALATION OF DUST CAN CAUSE THE FOLLOWING: IRRITATION OF NOSE, THROAT, AND LUNGS HEADACHE NAUSEA MAY CAUSE EYE/SKIN IRRITATION.

Potential Health Effects

Primary Routes of Entry: Inhalation
Eye contact
Skin contact

Eyes: Monomer vapors from heated product can cause the following:
slight irritation

Skin: Prolonged or repeated skin contact can cause the following:
slight irritation

Inhalation: Inhalation of dust can cause the following:

irritation of nose, throat, and lungs

Inhalation of monomer vapor from heated product can cause the following:

May cause nose, throat, and lung irritation.

headache

nausea

Toluene	ACGIH	Not classifiable as a human carcinogen.
Toluene	US CA65CRT	Developmental toxin.
Toluene	IARC	Classification not possible from current data.
Toluene	IARC	Inadequate data.
Toluene	IARC	Evidence suggests lack of carcinogenicity.

4. FIRST AID MEASURES

Inhalation: Move to fresh air.
Skin contact: Wash with water and soap as a precaution. If skin irritation persists, call a physician.
Eye contact: Flush eyes with water as a precaution. If eye irritation persists, consult a specialist.
Ingestion: Drink 1 or 2 glasses of water. Consult a physician if necessary. Never give anything by mouth to an unconscious person.

5. FIRE-FIGHTING MEASURES

Flash point	not applicable
Ignition temperature	393.0 ℃ (739.40 ℉) estimated
Lower explosion limit	not applicable
Upper explosion limit	not applicable
Suitable extinguishing media:	Use the following extinguishing media when fighting fires involving this material: carbon dioxide (CO_2) dry chemical water spray

Specific hazards during fire fighting: Material as sold is combustible; burns vigorously with intense heat.
Special protective equipment for fire-fighters: Wear self-contained breathing apparatus and protective suit.
Further information: Water mist may be used to cool closed containers.
Remain upwind.
Avoid breathing smoke.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

Appropriate protective equipment must be worn when handling a spill of this material. See SECTION 8, Exposure Controls/Personal Protection, for recommendations.
If exposed to material during clean-up operations, see SECTION 4, First Aid Measures, for actions to follow.

Environmental precautions

CAUTION: Keep spills and cleaning runoff out of municipal sewers and open bodies of water.

Methods for cleaning up

Floor may be slippery; use care to avoid falling.
Eliminate all ignition sources.
Ventilate the area.
Transfer spilled material to suitable containers for recovery or disposal.

7. Handling and storage

Handling

Store in a cool, dry, well ventilated place. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling. Keep container tightly closed. Do not breathe vapours/dust. Static charges can accumulate: use bonding and grounding between transfer equipment and receiving containers and for anyother operations capable of generating static electricity.

Storage

Storage conditions: Material can burn; limit indoor storage to approved areas equipped with automatic sprinklers. Ground all metal containers during storage and handling.

Storage temperature:-18.00 - 49.00 ℃(-0.40 - 120.20 ℉)

Further information:

Monomer vapors can be evolved when material is heated during processing operations. See SECTION 8, for types of ventilation required.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure limit(s)

Exposure limits are listed below, if they exist.

Component	Regulation	Type of listing	Value
Toluene	Rohm and Haas	TWA	50 ppm
	Rohm and Haas	STEL	75 ppm
	Rohm and Haas	Absorbed via skin	
	ACGIH	TWA	50 ppm
	ACGIH	SKIN_DES	
	OSHA/Z2	TWA	200 ppm
	OSHA/Z2	Ceiling	300 ppm
	OSHA/Z2	MAX. CONC	500 ppm
	Z1A	TWA	375 mg/m3 100 ppm
	Z1A	STEL	560 mg/m3 150 ppm

Eye protection: Use safety glasses with side shields (ANSI Z87.1or approved equivalent). Eye protection worn must be compatible with respiratory protection system employed.

Hand protection: Cotton or canvas gloves.

Respiratory protection:A respiratory protection program meeting OSHA 1910.134 and ANSI Z88.2 requirements or equivalent must be followed whenever workplace conditions warrant a respirator's use. None required under normal operating conditions. When dusty conditions are encountered, wear a properly fitted NIOSH approved (or equivalent) half-mask, air-purifying respirator. Air-purifying respirators should be equipped with NIOSH approved (or equivalent) organic vapor cartridges and N95 filters. If oil mist is present, use R95 or P95 filters.

Protective measures: Facilities storing or utilizing this material should be equipped with an eyewash facility.

Engineering measures: Use local exhaust ventilation with a minimum capture velocity of 150 ft/min. (0.75 m/sec.) at the point of dust or mist evolution. Refer to the current edition of "Industrial Ventilation: A Manual of Recommended Practice" published by the American Conference of Governmental Industrial Hygienists for information on the design, installation, use, and maintenance of exhaust systems.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	
Form	Granular solid
Colour	clear
Odour	Acrylic odor
pH	not applicable
Boiling point/range	not applicable
Melting point/range	no data available
Flash point	not applicable
Ignition temperature	393 ℃ (739.40 ℉) estimated
Lower explosion limit	not applicable
Upper explosion limit	not applicable
Vapour pressure	not applicable
Relative vapour density	not applicable
Water solubility	practically insoluble
Density	0.66 g/cm3Bulk density
Viscosity, dynamic	not applicable
Evaporation rate	not applicable
Percent volatility	1 % maximum

NOTE: The physical data presented above are typical values and should not be construed as a specification.

10. STABILITY AND REACTIVITY

Hazardous reactions	None known. This material is considered stable. However, avoid temperatures above 260C/500F. Thermal decomposition is dependent on time and temperature.
Materials to avoid	There are no known materials which are incompatible with this product.
Hazardous decomposition products	Thermal decomposition may yield acrylic monomers.,
polymerization	Product will not undergo polymerization.

11. TOXICOLOGICAL INFORMATION

Acute oral toxicity	LD50rat > 5,000 mg/kg Toxicity data for a compositionally similar material.
Acute dermal toxicity	LD50rabbit > 3,000 mg/kg Toxicity data for a compositionally similar material.
Skin irritation	rabbitslight irritation Toxicity data for a compositionally similar material.
Eye irritation	rabbitslight irritation Toxicity data for a compositionally similar material.

Further information

No data are available for this material. The information shown is based on profiles of compositionally similar materials.

Component:**Toluene**

Acute inhalation toxicity	LC50rat 4 h15.07 mg/l

12. ECOLOGICAL INFORMATION

There is no data available for this product.

Toluene

Ecotoxicity effects

Toxicity to fish	LC50Rainbow trout96 h 24 ppm
Toxicity to fish	LC50Fathead minnow (Pimephales promelas)96 h 26 ppm
Toxicity to fish	LC50Bluegill sunfish96 h 13 ppm
Toxicity to algae	EC50Algae96 h >433 ppm
Toxicity to aquatic invertebrates	EC50Daphnia magna48 h 11.5 ppm

13. DISPOSAL CONSIDERATIONS

Environmental precautions:CAUTION: Keep spills and cleaning runoff out of municipal sewers and open bodies of water.

Disposal

Waste Classification: When a decision is made to discard this material as supplied, it does not meet RCRA's characteristic definition of ignitability, corrosivity, or reactivity, and is not listed in 40 CFR 261.33. The toxicity characteristic (TC), however, has not been evaluated by the Toxicity Characteristic Leaching Procedure (TCLP).

For disposal, incinerate this material at a facility that complies with local, state, and federal regulations.

14. TRANSPORT INFORMATION

DOT

Not regulated for transport

IMO/IMDG

Not regulated (Not dangerous for transport)

15. REGULATORY INFORMATION

Workplace Classification

This product is considered non-hazardous under the OSHA Hazard Communication Standard (29CFR1910.1200).

This product is a'controlled product' under the Canadian Workplace Hazardous Materials Information System (WHMIS).

SARA TITLE III:Section 311/312 Categorizations (40CFR370): This product is not a hazardous chemical under 29CFR 1910.1200, and therefore is not covered by Title III of SARA.

SARA TITLE III:Section 313 Information (40CFR372)

This product does not contain a chemical which is listed in Section 313 at or above de minimis concentrations.

CERCLAInformation(40CFR302.4)

Releases of this material to air, land, or water are not reportable to the National Response Center under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or to state and local emergency planning committees under the Superfund Amendments and Reauthorization Act (SARA) Title III Section 304.

US. Toxic Substances Control Act (TSCA) All components of this product are in compliance with the inventory listing requirements of the U.S. Toxic Substances Control Act (TSCA) Chemical Substance Inventory.

Pennsylvania

Any material listed as "Not Hazardous" in the CAS REG NO. column of SECTION 2, Composition/Information On Ingredients, of this MSDS is a trade secret under the provisions of the Pennsylvania Worker and Community Right-to-Know Act.

California (Proposition 65)

This product contains a component or components known to the state of California to cause birth defects or other reproductive harm:

Components: Toluene 108-88-3

California (Proposition 65)

This product contains trace levels of a component or components known to the state of California to cause cancer and birthdefects or other reproductive harm:

Components: Benzene 71-43-2

16. OTHER INFORMATION

Hazard Rating

	Health	Fire	Reactivity
HMIS	1	1	0

Legend

ACGIH	American Conference of Governmental Industrial Hygienists
BAc	Butyl acetate
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
STEL	Short Term Exposure Limit (STEL):
TLV	Threshold Limit Value
TWA	Time Weighted Average (TWA):
|	Bar denotes a revision from prior MSDS.

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Version:1.1

Print Date: 02/29/2004

75100 - PRIMAL™ AC 350

1. Identification of the Substance/Preparation and of the Company/Undertaking.

Identification of the ProductC

Product Name:&	PRIMAL™ AC 35
Article No.:&	75100 &
Use of the Substance/Preparation:&	Artists´ and Restoration Material

CompanyC

Company:&	Kremer Pigmente GmbH & Co. KG &
Address:&	Hauptstrasse 41-47, D 88317 Aichstetten &
Tel/Fax:&	Tel +49 7565 91120, Fax +49 7565 1606 &
Internet:&	www.kremer-pigmente.de, kremer-pigmente@t-online.de &
Emergency No.:&	+49 7565 91120, Mon-Fri 8:00 - 17:00 &

2. Hazard Identification.

3. Composition/Information on Ingredients.

Chemical Characterization: &	This product is a preparation.&
Hazardous Ingredients: &	Alkohols, C12-14-secondary, ethoxylated (Xi; R36) 1.0-2.5 %& CAS-Nr: 84133-50-6 EINECS-Nr: EC-Nr: & This product does not contain any hazardous components according & to EC Guidelines 67/548/EEC and 99/45/EC.&

4. First Aid Measures.

After inhalation:&	Take affected person to fresh air.&
After skin contact:&	Wash off with plenty of water and soap. Consult a physician if & irritation persists.&
After eye contact:&	Rinse open eye for several minutes under running water. Should & irritation continue, seek medical advice.&
After ingestion:&	Rinse mouth with water and give plenty of water to drink. Consult a & physician. Never give anything by mouth to an unconscious person.&

5. Fire-Fighting Measures.

Suitable extinguishing media:&	Use extinguishing media for surrounding fire.&
Protective equipment:&	Wear self-contained respiratory protective device and protective & clothing.&
Further information:&	Thermal decomposition may yield acrylic monomers.&

6. Accidental Release Measures.

Personal precautions:&	Wear appropriate protective equipment. Keep spectators away.&
Environmental precautions:&	Caution: Keep spills and cleaning runoff out of municipal sewers & and open bodies of water.&
Methods of cleaning/absorption:&	Contain with inert absorbent material (e.g. sand, acid binder, & universal binder, sawdust) and collect in appropriate containers for & disposal.&

7. Handling and Storage.

HandlingC

Instructions on safe handling: &	Avoid contact with eyes, skin and clothing. & Wash hands with soap and water. & Do not swallow or inhale. &
Information on fire and explosion protection:&	Monomer vapors may be evolved when material is heated during & processing operations.&

StorageC

Storage conditions: &	Store in tightly sealed containers in a dry room. & Stir well before use. & Keep from freezing; material may coagulate. & Store between 1-49°C (34-120°F). &

8. Exposure Controls/Personal Protection.

Technical protective measures:&	Adequate ventilation.& Facilities storing or utilizing this material should be equipped with & an eyewash facility.&
Components with workplace & control parameters (Germany):&	---&

Personal protective equipmentC

General protective measures: &	Avoid contact with skin and avoid inhalation of vapour. Do not eat, & drink or smoke while working.&
Respiratory protection: &	A respiratory protection program meeting OSHA 1910.134 and & ANSI Z88.2 requirements must be followed whenever workplace & conditions warrant a respirator´s use.&
Hand protection::&	Protective gloves &
Protective glove material:&	Neoprene. &
Eye protection:&	Safety glasses with protective shields (EN 166). &

9. Physical and Chemical Properties.

Form:&	liquid &
Color:&	milky white &
Odor:&	ammonium-like &
Melting temperature:&	0°C &
Boiling temperature:&	100°C H2O &
Flash point:&	not combustible &
Vapor pressure:&	2266,4808 Pa (20°C) &
Density:&	1.00-1.20 &
Solubility in water:&	dilutable &
pH-Value:&	8.5 - 9.5
Viscosity dynamic:&	300 - 600 mPa.s &

10. Stability and Reactivity.

Thermal & decomposition/Conditions to be & avoided: &	The product is stable. &

Substances to be avoided:&	There are no known products which are incompatible with this & product.&
Hazardous reactions:&	No information available.&

11. Toxicological Information.

Acute toxicityC

LD50, oral:&	> 5000 mg/kg &
LD50, dermal:&	> 5000 mg/kg &

Primary effectsC

Irritant effect on skin:&	Slight irritant effect (rabbit). &
Irritant effect on eyes:&	Non-irritating to eyes (rabbit) &
Further toxicological effects: &	By analogy with a product of similar composition.&

12. Ecological Information.

Further ecological effects: &	No ecological data available.&

Further informationC

Water hazard class: &	1&

13. Disposal Considerations.

Product: &	Coagulate the emulsion by the stepwise addition of ferric chloride & and lime. Remove the clear supernatant and flush to a chemical & sewer. Incinerate liquid and contaminated solids in accordance with & local, state and federal regulations.&
European Waste Code (EWC): &	The waste code must be determined with the regional disposal & service.&

14. Transport Information.

Further information: &	Not classified as a dangerous good under transport regulations.&

15. Regulatory Information.

Technical instructions on air & quality: &	1: 0.05 % &
Water hazard class: &	1, slightly hazardous for water&

Further informationC

EC: This product is in accordance with the requirements of the European Inventory of Existing Chemical & Substances (EINECS).&

TSCA (USA): All components of this product are listed under the U.S. Toxic Substance Control Act & (TSCA) Chemical Inventory.&

16. Other Information.

This product should be stored, handled and used in accordance with good hygiene practices and in & conformity with any legal regulations.&

This information contained herein is based on the present state of knowledge and is intended to describe & our product from the point of view of safety requirements. It should be therefore not be construed as & guaranteeing specific properties.&

Appendix IV Assessment table working properties Joining plastics together - what happens over time? FoU project Dnr 353-3471-2011

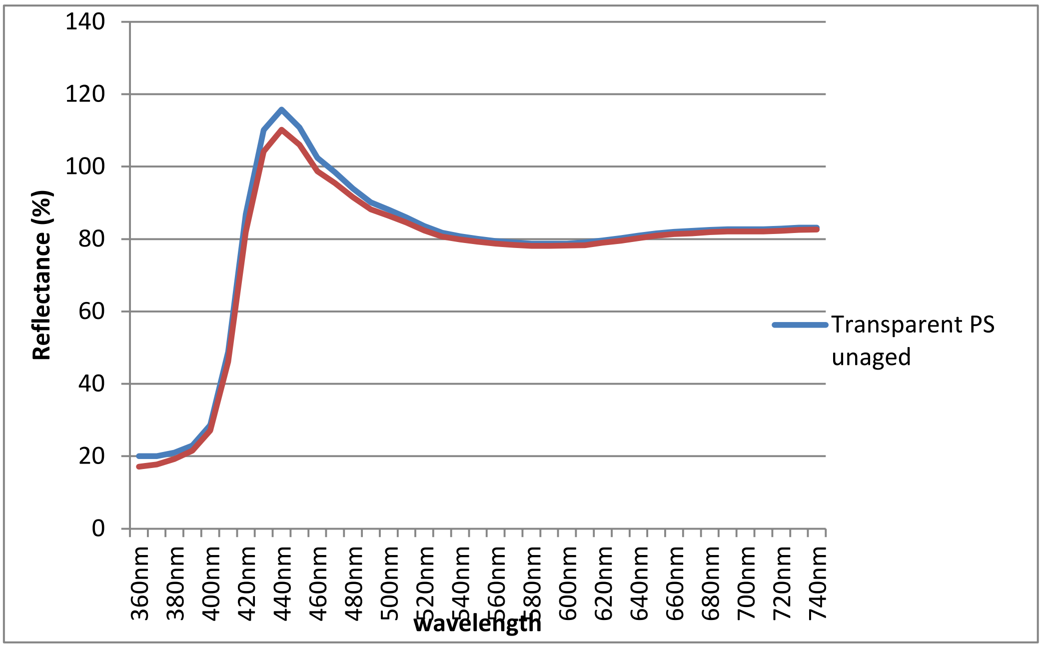
Sample	Application	Usage	Work time	Bubbles, voids	Bubbles%	Shrinkage	Curing	Viscosity	Visibility	Color	Transparency	Gloss	Other	Health aspects	Spill	Accuracy mixing
1 (Paraloid B72 in acetone/ethanol)	Brush	Medium easy	ca 3 min	Many	ca 50%	ca 70%	ca 15 min	Medium	Visible	Transparent	High transparency	Medium/ high gloss	"Stringy"/ flexible when applied	Irritant	Some. Texture and viscosity results in tendency to excess adhesive spill around break edge	Easy, but % accurracy of solution will change over time due to solvent evaporation
2 (Paraloid B67 in 2-propanol)	Brush	Medium easy	ca 3 min	Many (Larger bubbles than Paraloid B72)	ca 50%	ca 70%	ca 15 min	Medium	Visible	Transparent	High transparency	Medium gloss	"Stringy"/ flexible when applied	Irritant	Some. Texture and viscosity results in tendency to excess adhesive spill around break edge	Easy, but % accurracy of solution will change over time due to solvent evaporation
3 (Primal AC35)	Brush	Easy	ca 5 min	Few	ca 15%	ca 40%	ca 20 min	Medium/low	Visible	Pale white/yellow	Low transparency	Low gloss		Slight irritant	Some/little	No mixing
4 (Hxtal Nyl-1)	Brush	Medium/ not easy	ca 10 hours	None	Less than 5%	Less than 10%	ca 48 hours	Low	Visible	Transparent	High transparency	High gloss		Corrosive	Much. Low viscosity results in runny adhesive around break adge	Medium easy. Digital weight necessary
5 (Araldite 2020)	Brush	Medium/ not easy	ca 8 hours	None	Less than 5%	Less than 10%	ca 24 hours	Low	Visible	Transparent	High transparency	High gloss		Corrosive	Much. Low viscosity results in runny adhesive around break adge	Medium easy. Digital weight necessary
6 (Loctite Super Attack Prec.)	From tube/nozzle	Medium	ca 3 min	Few	ca 15%	ca 50%	ca 10 min	Low	Visible	Pale white	Low/not transparent	Low gloss		Irritant	Much. Low viscosity results in runny adhesive around break adge	No mixing
7 (Acrifix 116)	Brush	Easy	ca 5 min	Some	ca 30%	ca 75%	ca 20 min	Medium	Visible	Transparent	Medium transparency	Medium gloss	Thinnest adhesive bond after curing	Irritant	Little	No mixing
8 (Paraloid B72 in ethanol)	Brush	Easy	ca 5 min	Many	ca 50%	ca 50%	ca 20 min	Medium	Visible	Transparent	High transparency	Medium/ high gloss	Less "stringy" than PB72 in acetone/etha nol	Irritant	Some/little	

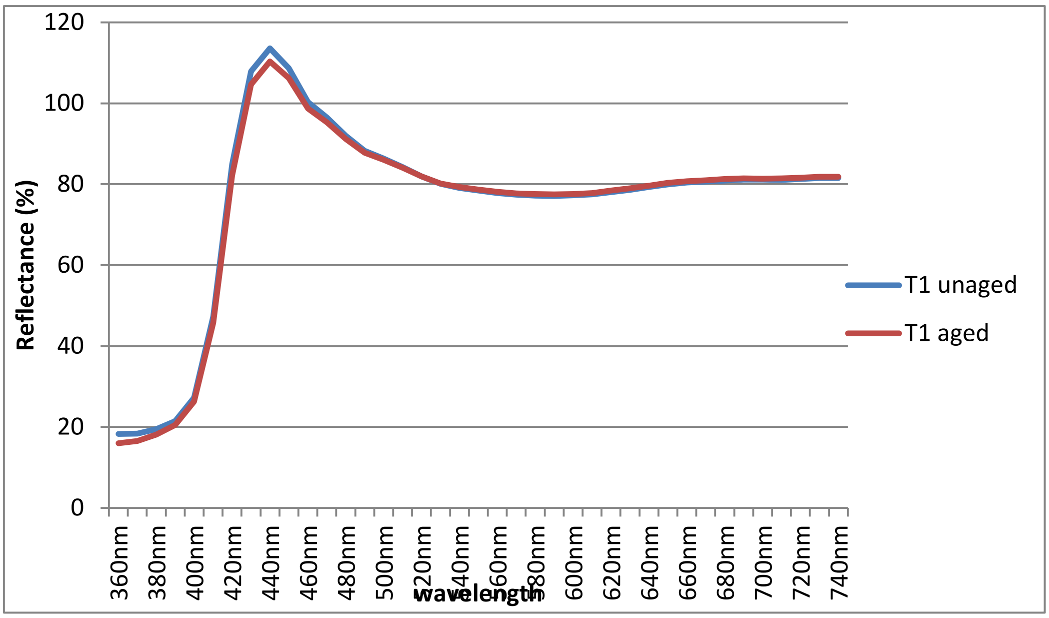
Appendice V Spectrophotometer data Joining plastics together - what happens over time?
FoU project Dnr 353-3471-2011
Used value - SCI (Specular Components Included) The ΔE* calculations used the ΔE*76 standard.
U - Unaged. A - Aged.

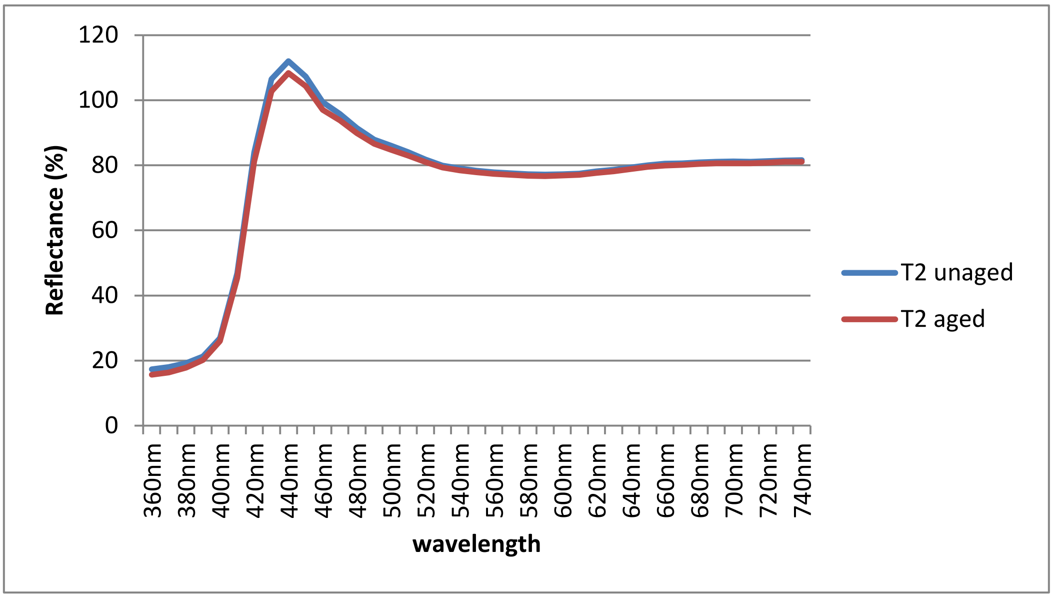
Adhesives on transparent polystyrene					
Data Name	Group Traits	dE*ab(D65	L*(D65)	a*(D65)	b*(D65)
Unaged Transp.polyst.	SCI	0,13	92,28	2,68	-14,52
Unaged Transp.polyst.	SCE	0,18	87,4	3,21	-16,08
1 UTP ref	SCI	0,11	92,86	2,6	-13,49
1 UTP ref	SCE	0,16	87,96	3,12	-14,98
2 T1U	SCI	0,28	91,98	2,76	-14,59
2 T1U	SCE	0,49	87,68	3,1	-15,89
3 T1Uref	SCI	0,35	91,89	2,79	-14,57
3 T1Uref	SCE	0,37	87,56	3,14	-15,86
4 T1Uref2	SCI	1,04	91,16	2,75	-14,47
4 T1Uref2	SCE	0,37	87,1	3,07	-15,72
5 T2U	SCI	0,91	91,49	2,55	-13,88
5 T2U	SCE	1,04	87,32	2,87	-15,05
6 T2Uref	SCI	1,03	91,32	2,55	-13,93
6 T2Uref	SCE	0,97	87,01	2,89	-15,14
7 T2Uref2	SCI	1,43	90,92	2,51	-13,85
7 T2Uref2	SCE	1,19	86,88	2,81	-14,96
8 T3U	SCI	17,55	88,29	1,14	3,36
8 T3U	SCE	16,31	84,99	1,27	3,52
9 T3Uref	SCI	17,11	88,9	1,23	3,42
9 T3Uref	SCE	16,1	84,72	1,42	3,47
10 T3Uref2	SCI	17,01	88,39	1,14	3,51
10 T3Uref2	SCE	15,99	85,15	1,22	3,44
11 T4U	SCI	0,42	91,83	2,69	-14,22
11 T4U	SCE	0,34	87,29	3,2	-15,68
12 T4Uref	SCI	1	91,31	2,64	-13,99
12 T4Uref	SCE	0,82	86,71	3,13	-15,4
13 T4Uref2	SCI	0,82	91,49	2,59	-14,04
13 T4Uref2	SCE	0,82	86,97	2,94	-15,31
14 T5U	SCI	1,49	90,99	2,56	-13,57
14 T5U	SCE	1,48	86,51	2,9	-14,77
15 T5Uref	SCI	1,18	91,29	2,56	-13,69
15 T5Uref	SCE	1,14	86,56	3,05	-15,12
16 T5Uref2	SCI	0,91	91,55	2,56	-13,81
16 T5Uref2	SCE	0,91	86,81	3,05	-15,24
17 T6U	SCI	9,87	87,1	-0,22	-6,51
17 T6U	SCE	10,1	87,06	-0,18	-6,52
18 T6Uref	SCI	9,85	86,87	-0,19	-6,68
18 T6Uref	SCE	9,94	86,83	-0,17	-6,69
19 T6Uref2	SCI	9,78	86,13	-0,16	-7,32
19 T6Uref2	SCE	9,26	85,51	-0,19	-7,59

20 T7U	SCI	4,9	88,52	1,94	-11,3
20 T7U	SCE	5,23	83,63	2,29	-12,35
21 T7Uref	SCI	4,18	89,49	1,94	-11,34
21 T7Uref	SCE	4,68	84,42	2,31	-12,4
22 T7Uref2	SCI	3,18	90,83	1,95	-11,67
22 T7Uref2	SCE	3,61	86,17	2,3	-12,7
23 ATP	SCI	3,09	92,47	1,97	-11,45
23 ATP	SCE	3,49	87,63	2,37	-12,66
24 ATP ref	SCI	2,95	92,47	2,04	-11,57
24 ATP ref	SCE	3,36	87,6	2,46	-12,77
25 T1A	SCI	2,48	92,36	2,12	-12,03
25 T1A	SCE	3,15	88,12	2,43	-13,1
26 T1Aref	SCI	2,5	92,42	2,17	-12
26 T1Aref	SCE	3,15	88,12	2,47	-13,09
27 T1Aref2	SCI	2,53	92,53	2,14	-11,98
27 T1Aref2	SCE	3,23	88,27	2,45	-13,06
28 T2A	SCI	2,78	91,66	2,12	-11,77
28 T2A	SCE	3,3	87,54	2,42	-12,84
29 T2Aref	SCI	2,91	91,32	2,09	-11,73
29 T2Aref	SCE	3,31	87,13	2,38	-12,83
30 T2Aref2	SCI	2,68	92,12	2,1	-11,82
30 T2Aref2	SCE	3,25	87,78	2,4	-12,92
31 T3A	SCI	19,42	89,38	5,04	5,04
31 T3A	SCE	18,16	85,37	5,28	5
32 T3Aref	SCI	18,55	89,32	4,95	5,14
32 T3Aref	SCE	18,01	85,23	5,16	6,01
33 T3Aref2	SCI	19,1	89,73	4,65	5,55
33 T3Aref2	SCE	18,53	85,65	4,87	5,01
34 T4A	SCI	3,52	91,73	1,89	-11,04
34 T4A	SCE	4,1	87,22	2,18	-12,05
35 T4Aref	SCI	3,95	91,14	1,85	-10,72
35 T4Aref	SCE	4,49	86,74	2,14	-11,7
36 T4Aref2	SCI	3,66	91,72	1,85	-10,91
36 T4Aref2	SCE	4,25	87,24	2,13	-11,91
37 T5A	SCI	7,33	91,27	0,96	-7,37
37 T5A	SCE	8,12	86,67	1,2	-8,18
38 T5Aref	SCI	6,86	91,87	1,03	-7,79
38 T5Aref	SCE	7,66	87,23	1,31	-8,61
39 T5Aref2	SCI	7,25	91,71	0,93	-7,42
39 T5Aref2	SCE	8,07	87,15	1,16	-8,22
40 T6A	SCI	22,25	85,3	-3,09	5,91
40 T6A	SCE	23,16	84,09	-3,17	6,01
41 T6Aref	SCI	23,09	85,99	-3,23	6,99
41 T6Aref	SCE	24	84,96	-3,29	6,96
42 T6Aref2	SCI	22,54	85,1	-3,12	6,15
42 T6Aref2	SCE	23,51	83,73	-3,21	6,32
43 T7A	SCI	5,08	91,02	1,5	-9,64
43 T7A	SCE	5,7	86,3	1,82	-10,57
44 T7Aref	SCI	5,6	90,35	1,49	-9,29
44 T7Aref	SCE	6,26	85,65	1,76	-10,14

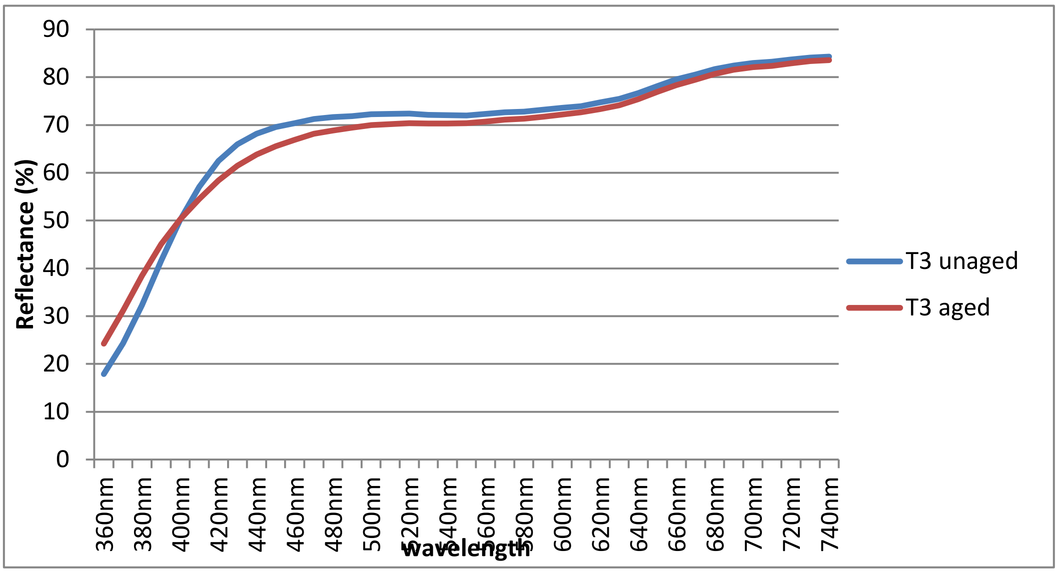
45 T7Aref2	SCI	5,57	90,13	1,5	-9,41
T8U	SCI	1,1	90,8	2,76	-14,43
T8U	SCE	0,44	89,6	3,06	-15,42
T8Uref	SCI	0,65	92	2,81	-14,09
T8Uref	SCE	0,43	88,56	3,03	-14,89
T8Uref2	SCI	1,5	91,11	2,69	-13,31
T8Uref2	SCE	0,45	88,11	2,85	-13,84
T8A	SCI	3,86	91,2	2,03	-10,47
T8A	SCE	2,05	89	2,39	-11,11
T8Aref	SCI	3,1	91,98	1,96	-9,55
T8Aref	SCE	4,22	88	2,21	-10,02
T8Aref2	SCI	3,11	92,5	2,13	-10,07
T8Aref2	SCE	2,42	89,01	2,41	-10,54



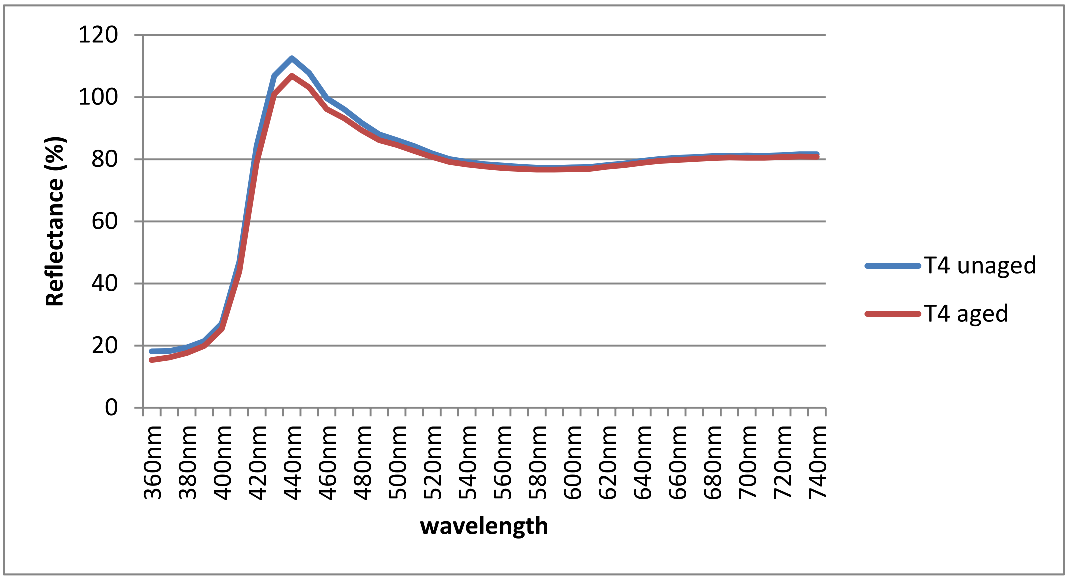




Reflectance (%)
120
100
80
60
40
20
0
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
T2 unaged
T2 aged



Reflectance (%)
90
80
70
60
50
40
30
20
10
0
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
T3 unaged
T3 aged



Reflectance (%)
120
100
80
60
40
20
0
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
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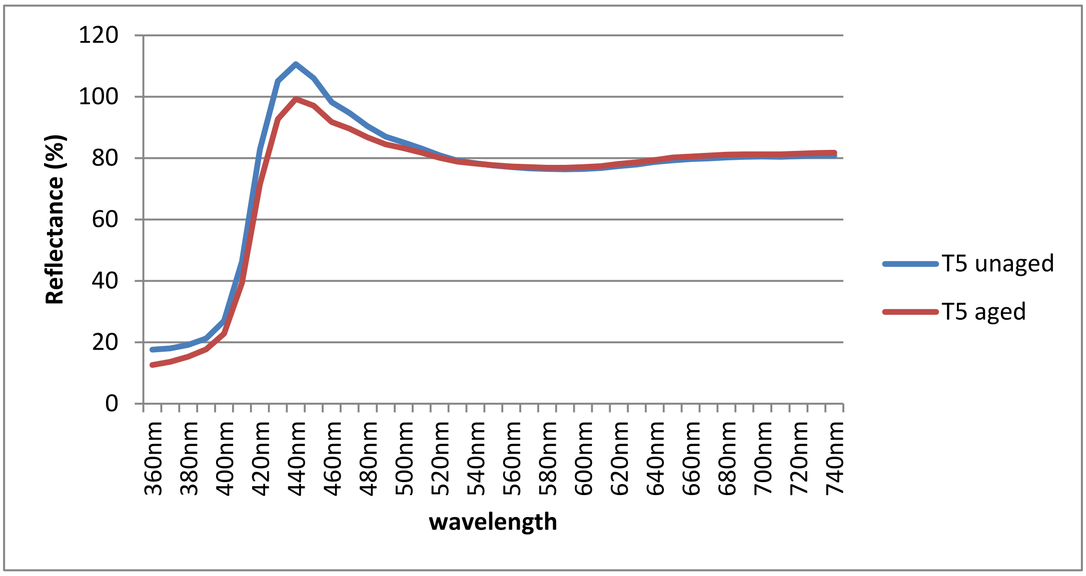
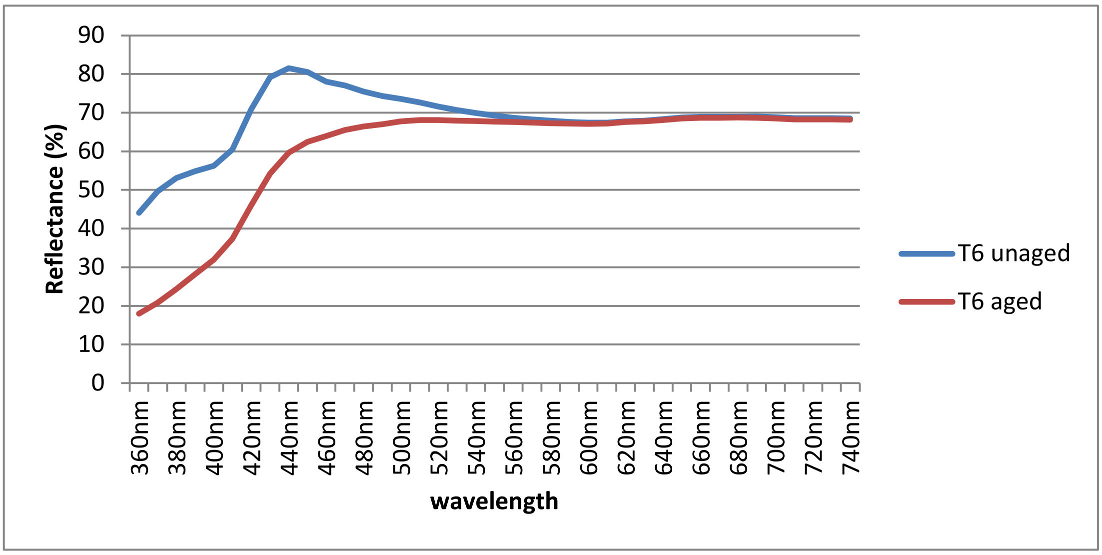
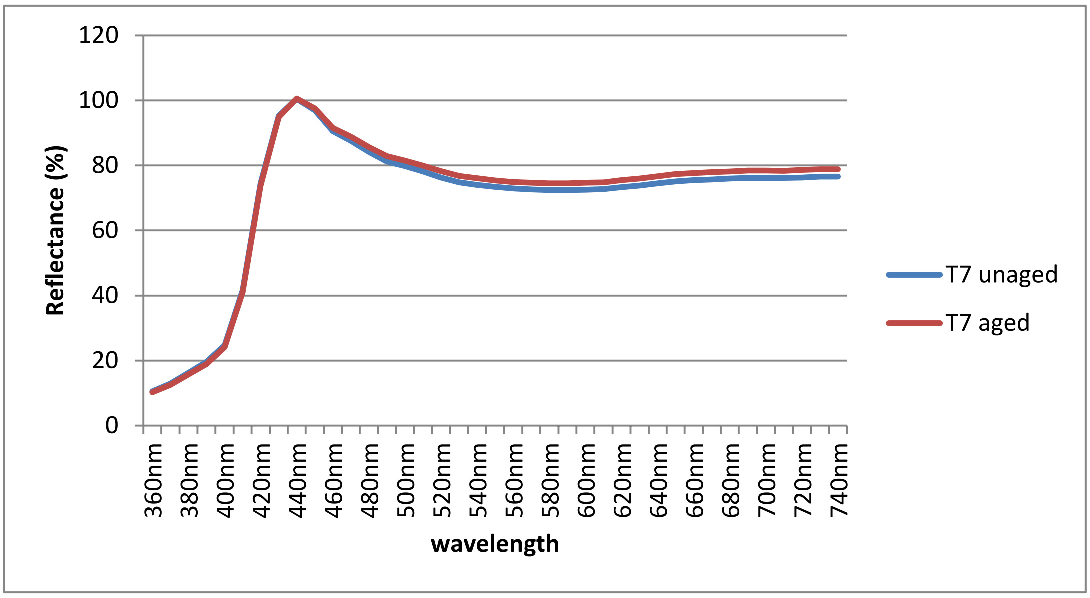
660nm
680nm
700nm
720nm
740nm
wavelength
T4 unaged
T4 aged



Reflectance (%)
120
100
80
60
40
20
0
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
T5 unaged
T5 aged



Reflectance (%)
90
80
70
60
50
40
30
20
10
0
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
T6 unaged
T6 aged



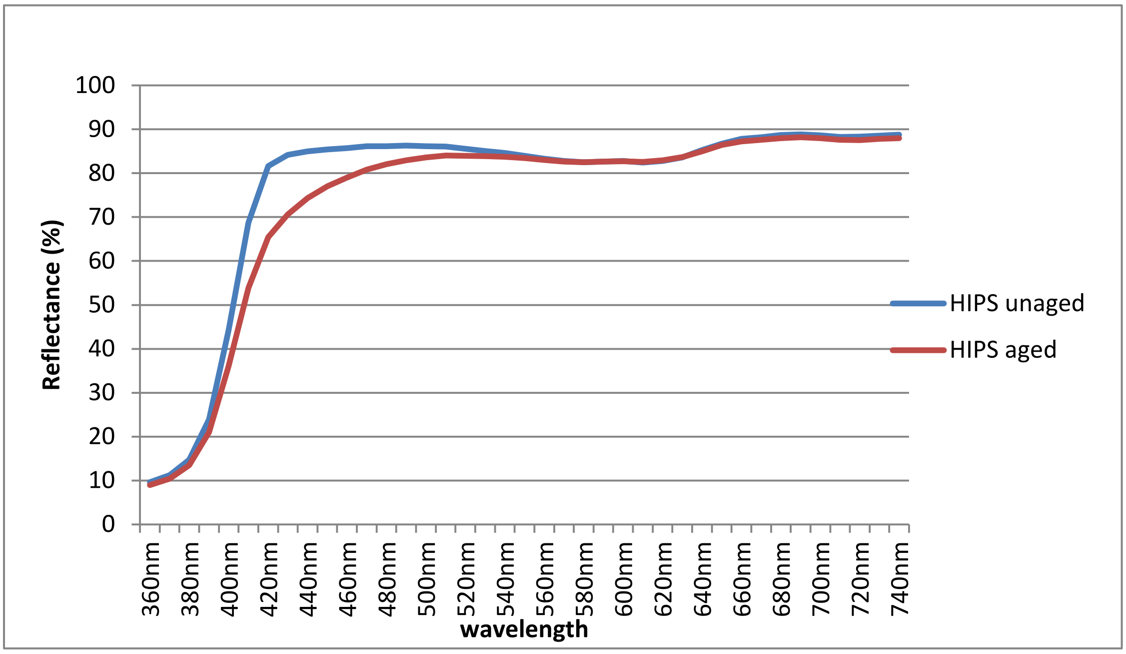
Reflectance (%)
120
100
80
60
40
20
0
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
T7 unaged
T7 aged

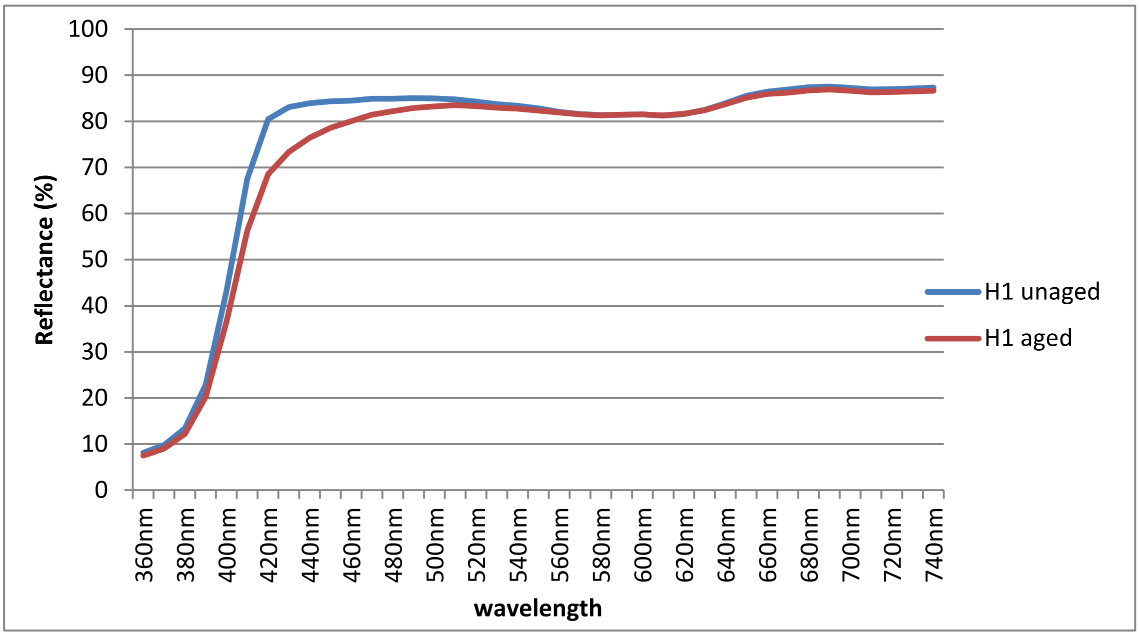
Used value - SCI (Specular Components Included) The ΔE* calculations used the ΔE*76 standard.
U - Unaged. A - Aged.

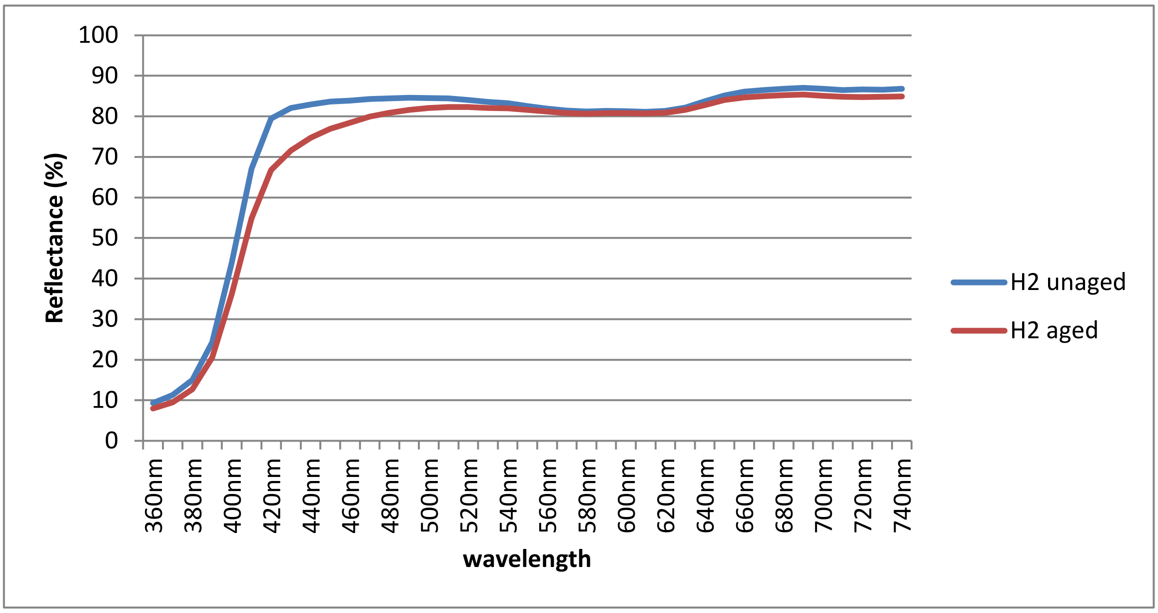
Adhesives on HIPS					
Data Name	Group Traits	dE*ab(D65	L*(D65)	a*(D65)	b*(D65)
Unaged HIPS	SCI	0,04	93,41	-1,2	-0,31
Unaged HIPS	SCE	0,05	90,85	-1,19	-0,03
1 U HIPS ref	SCI	0,05	93,55	-1,26	-0,17
1 U HIPS ref	SCE	0,04	90,99	-1,23	0,14
2 H1U	SCI	0,66	92,79	-1,22	-0,29
2 H1U	SCE	0,09	90,88	-1,18	-0,12
3 H1Uref	SCI	0,62	92,82	-1,23	-0,32
3 H1Uref	SCE	0,12	90,83	-1,19	-0,13
4 H1Uref2	SCI	0,52	92,93	-1,22	-0,29
4 H1Uref2	SCE	0,08	90,96	-1,19	-0,09
5 H2U	SCI	1,03	92,49	-1,31	0,06
5 H2U	SCE	1,09	91,97	-1,22	0,2
6 H2Uref	SCI	1,08	92,43	-1,31	0,05
6 H2Uref	SCE	0,99	91,87	-1,22	0,18
7 H2Uref2	SCI	1,04	92,47	-1,31	0,05
7 H2Uref2	SCE	0,92	91,8	-1,23	0,18
8 H3U	SCI	3,87	92,24	-2,39	2,84
8 H3U	SCE	3,57	90,33	-2,38	3,28
9 H3Uref	SCI	3,87	92,21	-2,43	3,34
9 H3Uref	SCE	3,75	90,32	-2,43	3,46
10 H3ref2	SCI	3,9	92,37	-2,38	3,26
10 H3ref2	SCE	3,63	90,47	-2,37	3,37
11 H4U	SCI	3,93	89,54	-1,18	0,15
11 H4U	SCE	3,67	87,26	-1,15	0,36
12 H4Uref	SCI	3,13	90,34	-1,19	0,08
12 H4Uref	SCE	2,84	88,08	-1,15	0,29
13 H4Uref2	SCI	3,39	90,07	-1,19	0,04
13 H4Uref2	SCE	3,11	87,81	-1,15	0,24
14 H5U	SCI	5,65	87,83	-1,06	0,23
14 H5U	SCE	5,56	85,37	-1,02	0,44
15 H5Uref	SCI	6,23	87,24	-1,03	0,23
15 H5Uref	SCE	6,14	84,78	-1	0,43
16 H5Uref2	SCI	6,71	86,76	-1,02	0,27
16 H5Uref2	SCE	6,64	84,29	-0,98	0,47
17 H6U	SCI	0,21	93,64	-1,24	-0,37
17 H6U	SCE	0,77	91,66	-1,2	-0,19
18 H6Uref	SCI	0,22	93,65	-1,25	-0,37
18 H6Uref	SCE	0,82	91,71	-1,21	-0,19
19 H6Uref2	SCI	0,21	93,64	-1,25	-0,39
19 H6Uref2	SCE	0,8	91,68	-1,2	-0,22

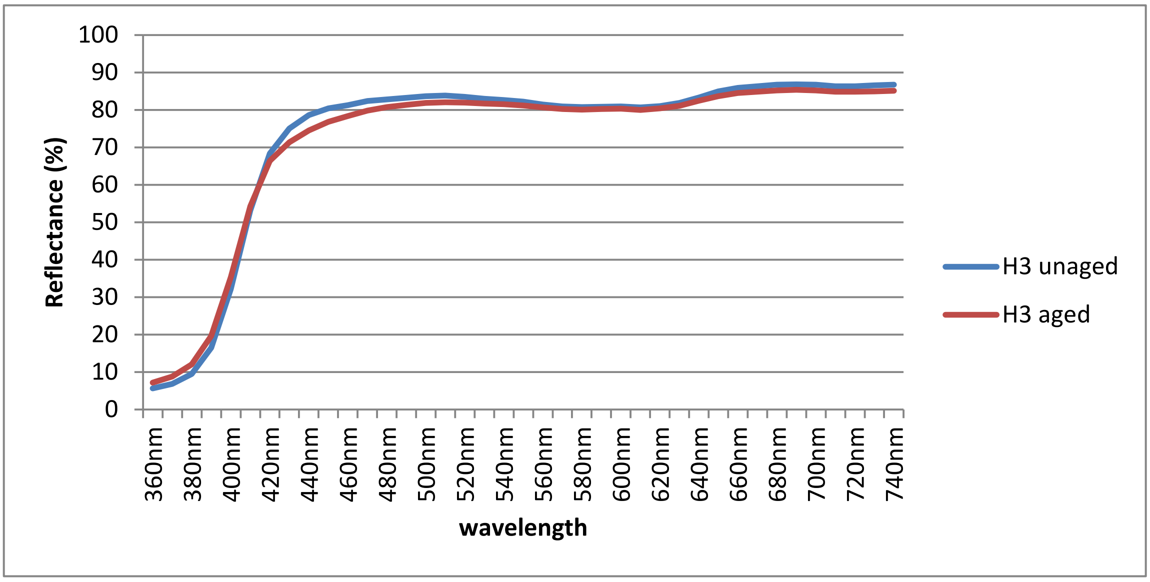
20 H7U	SCI	2,13	91,92	-1,64	1,11
20 H7U	SCE	1,45	90,65	-1,58	1,33
21 H7Uref	SCI	1,78	92,39	-1,64	1,06
21 H7Uref	SCE	1,38	91,11	-1,58	1,27
22 H7Uref2	SCI	2,09	91,92	-1,62	1,07
22 H7Uref2	SCE	1,4	90,6	-1,56	1,28
23 A HIPS	SCI	6,28	92,94	-2,76	5,76
23 A HIPS	SCE	6,59	90,37	-2,8	6,33
24 A HIPSref	SCI	5,66	92,95	-2,65	5,14
24 A HIPSref	SCE	5,93	90,41	-2,69	5,68
25 H1A	SCI	4,51	92,66	-2,4	3,97
25 H1A	SCE	4,53	90,68	-2,4	4,32
26 H1Aref	SCI	4,49	92,68	-2,4	3,96
26 H1Aref	SCE	4,51	90,71	-2,38	4,31
27 H1Aref2	SCI	4,48	92,61	-2,39	3,93
27 H1Aref2	SCE	4,47	90,62	-2,39	4,26
28 H2A	SCI	5,23	92,55	-2,54	4,67
28 H2A	SCE	5,28	90,47	-2,55	5,04
29 H2Aref	SCI	5,29	91,56	-2,45	4,47
29 H2Aref	SCE	4,77	90,87	-2,38	4,58
30 H2Aref2	SCI	5,34	91,61	-2,42	4,56
30 H2Aref2	SCE	4,83	91,16	-2,34	4,65
31 H3A	SCI	5,12	91,93	-2,54	4,24
31 H3A	SCE	4,96	89,99	-2,54	4,64
32 H3Aref	SCI	5,17	91,97	-2,54	4,46
32 H3Aref	SCE	5,02	90,01	-2,55	4,71
33 H3Aref2	SCI	5,09	92,2	-2,55	4,44
33 H3Aref2	SCE	4,96	90,27	-2,55	4,69
34 H4A	SCI	8,26	84,66	-1,31	1,58
34 H4A	SCE	8,96	82,15	-1,3	1,85
35 H4Aref	SCI	9,42	84,22	-1,3	1,59
35 H4Aref	SCE	9,42	81,68	-1,29	1,88
36 H4Aref2	SCI	8,91	84,77	-1,35	1,71
36 H4Aref2	SCE	8,9	82,24	-1,35	2
37 H5A	SCI	7,05	89,94	-2,3	5,7
37 H5A	SCE	7,13	87,55	-2,3	6,15
38 H5Aref	SCI	7,18	89,81	-2,31	5,78
38 H5Aref	SCE	7,26	87,42	-2,32	6,23
39 H5Aref2	SCI	6,11	90,97	-2,34	5,17
39 H5Aref2	SCE	6,17	88,62	-2,36	5,57
40 H6A	SCI	7,67	93,08	-3,04	7,13
40 H6A	SCE	7,81	91,2	-3,05	7,54
41 H6Aref	SCI	7,81	93,03	-3,07	7,26
41 H6Aref	SCE	7,95	91,12	-3,08	7,68
42 H6Aref2	SCI	7,57	93,08	-3,02	7,03
42 H6Aref2	SCE	7,72	91,16	-3,03	7,45
43 H7A	SCI	1,66	93,13	-1,38	1,31
43 H7A	SCE	1,85	91,93	-1,33	1,49
44 H7Aref	SCI	2,04	92,26	-1,37	1,34
44 H7Aref	SCE	1,59	90,97	-1,32	1,54

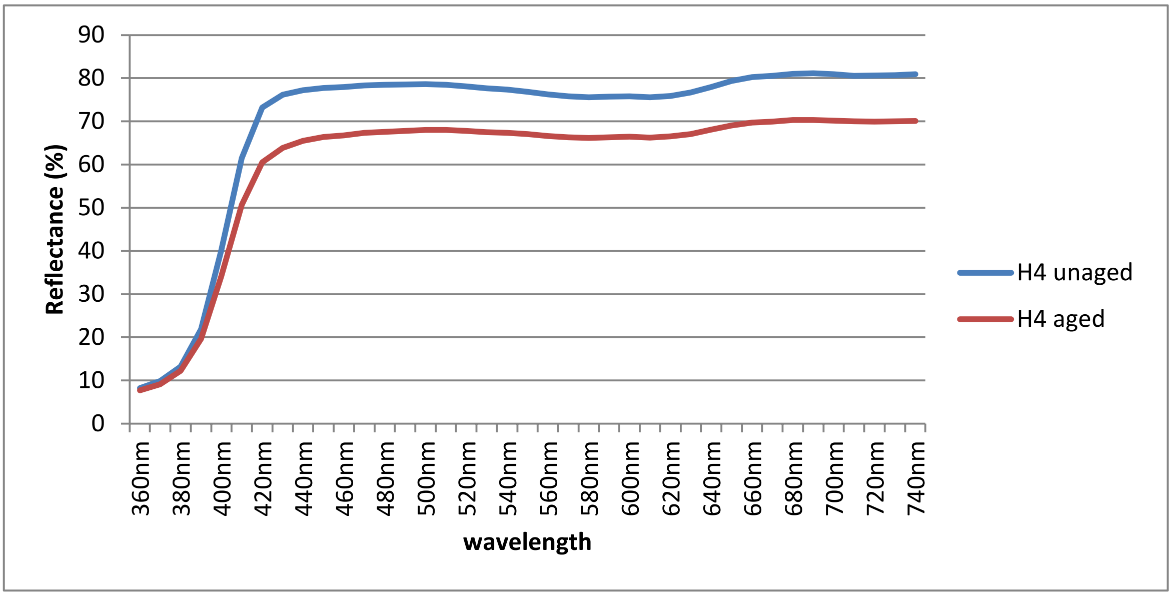
45 H7Aref2	SCI	1,97	92,36	-1,36	1,33
45 H7Aref2	SCE	1,57	91,1	-1,31	1,52
H8U	SCI	0,75	91,65	-0,73	0,56
H8U	SCE	0,1	90,68	-0,65	1,2
H8Uref	SCI	0,65	91,1	-1,15	-0,29
H8Uref	SCE	0,1	90,73	-1,06	0,07
H8Uref2	SCI	0,32	91,99	-1,12	0,04
H8Uref2	SCE	0,15	89,86	-1,02	0,39
H8A	SCI	4,48	90,65	-1,54	3,62
H8A	SCE	4,93	90	-1,5	4,29
H8Aref	SCI	4,55	91,99	-1,61	3,92
H8Aref	SCE	4,51	91,51	-1,54	4,26
H8Aref2	SCI	4,88	92,2	-1,64	4,04
H8Aref2	SCE	4,65	90,1	-1,58	4,45

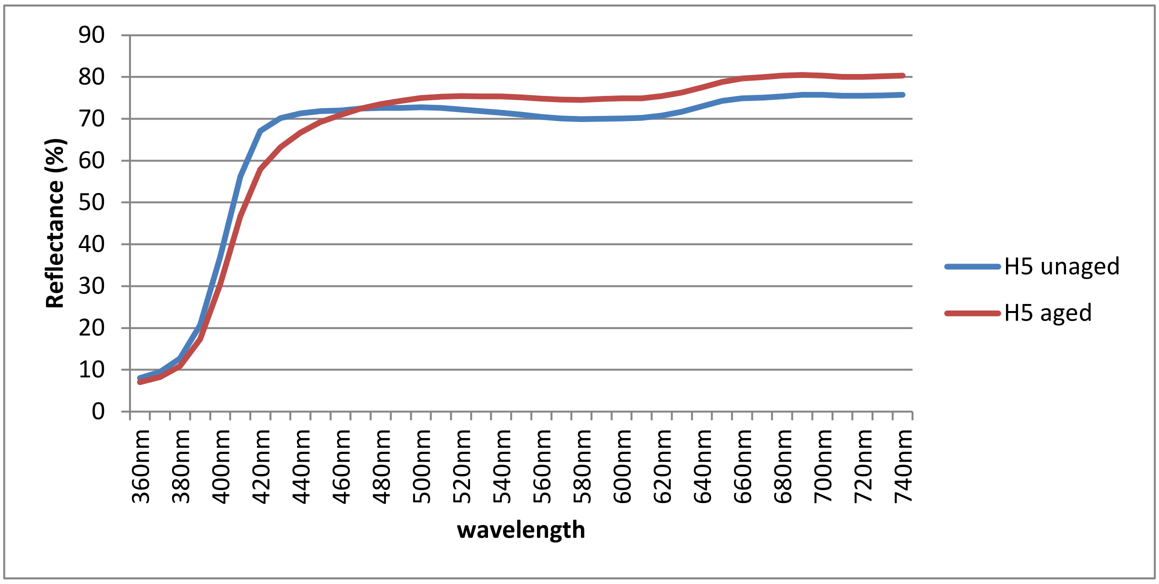




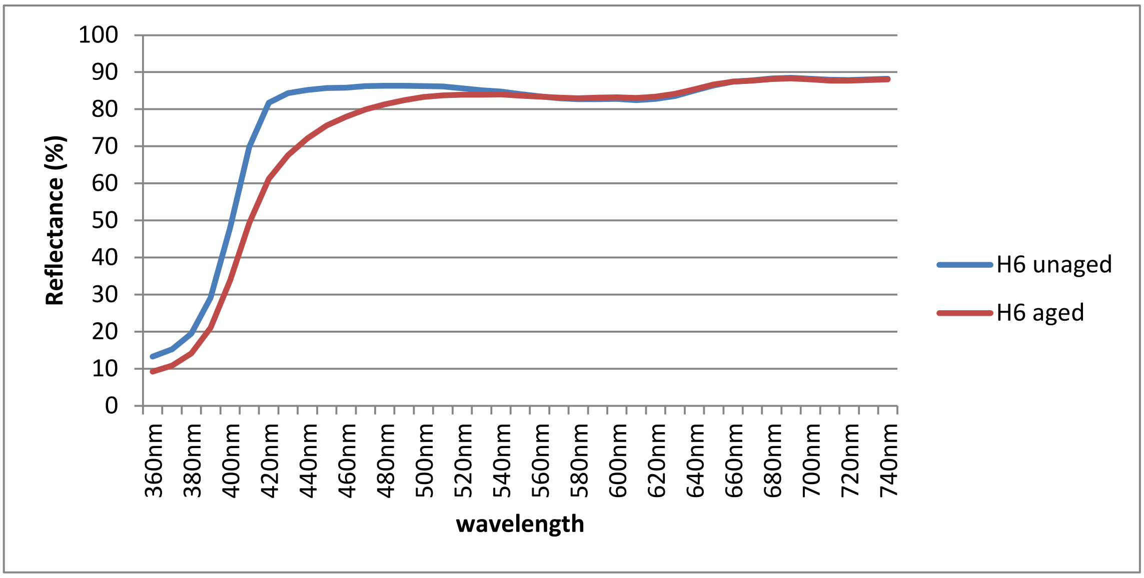

100
90
80
70
60
50
40
30
20
10
0
Reflectance (%)
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
H2 unaged
H2 aged


100
90
80
70
60
50
40
30
20
10
0
Reflectance (%)
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
H3 unaged
H3 aged

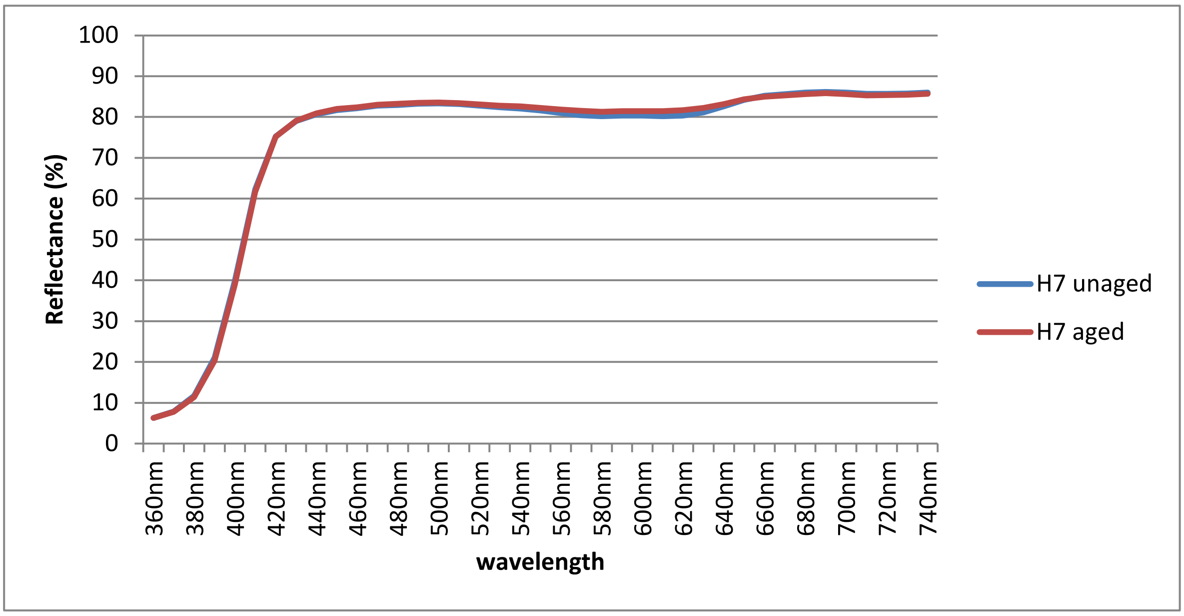

90
80
70
60
50
40
30
20
10
0
Reflectance (%)
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
H4 unaged
H4 aged



90
80
70
60
50
40
30
20
10
0
Reflectance (%)
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
H5 unaged
H5 aged



100
90
80
70
60
50
40
30
20
10
0
Reflectance (%)
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
H6 unaged
H6 aged



100
90
80
70
60
50
40
30
20
10
0
Reflectance (%)
360nm
380nm
400nm
420nm
440nm
460nm
480nm
500nm
520nm
540nm
560nm
580nm
600nm
620nm
640nm
660nm
680nm
700nm
720nm
740nm
wavelength
H7 unaged
H7 aged

Used value - SCI (Specular Components Included) The ΔE* calculations used the ΔE*76 standard.
U - Unaged. A - Aged.

Adhesives on glass plate					
Data Name	Group Traits	dE*ab(D65	L*(D65)	a*(D65)	b*(D65)
1U	SCI	21,4	72,05	-0,02	-10,07
1U	SCE	18,01	71,09	0,08	-9,37
1Uref	SCI	24,32	69,44	0,04	-7,34
1Uref	SCE	20,92	68,62	0,11	-7,51
1Uref2	SCI	24,57	68,98	-0,01	-8,2
1Uref2	SCE	21,22	67,99	0,07	-8,42
2U	SCI	19,87	73,67	0,02	-8,93
2U	SCE	17,04	72,19	0,12	-9,19
2Uref	SCI	18,69	74,85	0,04	-9,09
2Uref	SCE	15,89	73,38	0,15	-9,32
2Uref2	SCI	17,51	76,01	0,06	-9,31
2Uref2	SCE	14,82	74,41	0,18	-9,67
3U	SCI	30,18	68,76	-1,45	4,33
3U	SCE	27,78	68,04	-1,43	3,96
3Uref	SCI	27,52	73,62	-1,54	5,86
3Uref	SCE	26,82	71,17	-1,54	5,54
3Uref2	SCI	28,62	71,3	-1,47	5
3Uref2	SCE	26,73	70,38	-1,45	4,77
4U	SCI	2,25	92,51	1,2	-11,63
4U	SCE	2,98	88,83	1,39	-12,51
4Uref	SCI	2,08	93,05	1,19	-11,83
4Uref	SCE	2,99	89,31	1,38	-12,74
4Uref2	SCI	2,07	92,61	1,22	-11,82
4Uref2	SCE	2,87	89,07	1,42	-12,75
5U	SCI	3,75	91,81	0,85	-10,22
5U	SCE	4,32	87,87	1,03	-11,02
5Uref	SCI	2,94	92,06	1,03	-11,01
5Uref	SCE	3,47	88,04	1,23	-11,89
5Uref2	SCI	3,45	92,12	0,84	-10,49
5Uref2	SCE	4,05	88,16	1,03	-11,33
6U	SCI	30,04	63,84	-0,87	-6,58
6U	SCE	26,36	63,29	-0,79	-6,47
6Uref	SCI	29,75	64,06	-0,85	-6,76
6Uref	SCE	26,06	63,5	-0,76	-6,81
6Uref2	SCI	29,31	64,56	-0,9	-6,44
6Uref2	SCE	25,61	64,04	-0,81	-6,62
7U	SCI	6,88	92,15	-0,1	-7,07
7U	SCE	7,87	88,26	0,07	-7,56
7Uref	SCI	8,12	90,52	-0,26	-6,13
7Uref	SCE	8,96	86,73	-0,1	-6,55

7Uref2	SCI	8,76	89,21	-0,22	-5,92
7Uref2	SCE	9,39	85,43	-0,08	-6,36
1A	SCI	32,15	61,81	0,27	-5,37
1A	SCE	29,62	60,02	0,4	-5,49
1Aref	SCI	34,46	59,56	0,19	-4,87
1Aref	SCE	31,24	58,49	0,28	-4,96
1Aref2	SCI	30,84	63,05	0,33	-5,8
1Aref2	SCE	28,73	60,82	0,46	-5,88
2A	SCI	31,96	62,22	0,34	-4,6
2A	SCE	29,81	60,07	0,44	-4,74
2Aref	SCI	30,88	63,19	0,37	-5,13
2Aref	SCE	28,43	61,35	0,48	-5,24
2Aref2	SCI	28,26	65,76	0,37	-5,7
2Aref2	SCE	26,28	63,41	0,53	-5,89
3A	SCI	48,2	55,98	2,06	10,09
3A	SCE	49,04	51,92	2,01	11
3Aref	SCI	45,63	54,4	0,75	11,09
3Aref	SCE	43,36	53,25	0,73	11
3Aref2	SCI	46,66	54,71	1,09	13,45
3Aref2	SCE	44,78	53,02	1,04	13,06
4A	SCI	5,53	88,59	1,37	-10,09
4A	SCE	5,23	84,89	1,56	-10,9
4Aref	SCI	5,22	88,91	1,36	-10,19
4Aref	SCE	5,11	84,95	1,57	-11,01
4Aref2	SCI	5,5	88,67	1,34	-10,04
4Aref2	SCE	5,28	84,89	1,54	-10,84
5A	SCI	9,8	87,09	0,95	-5,62
5A	SCE	10,19	82,78	1,16	-6,29
5Aref	SCI	9,43	87,43	0,97	-5,83
5Aref	SCE	9,86	83,04	1,17	-6,52
5Aref2	SCI	9,73	87,38	0,92	-5,52
5Aref2	SCE	10,2	82,99	1,12	-6,16
5Aref3	SCI	9,67	87,19	0,96	-5,71
5Aref3	SCE	10,12	82,79	1,16	-6,36
6A	SCI	46,91	49,99	-1,69	6,32
6A	SCE	43,58	49,54	-1,61	5,13
6Aref	SCI	49,34	47,82	-1,56	5,19
6Aref	SCE	45,96	47,43	-1,5	6,27
6Aref2	SCI	49,13	47,82	-1,58	5,79
6Aref2	SCE	45,75	47,39	-1,51	5,74
7A	SCI	6,94	89,37	0,44	-7,12
7A	SCE	7,5	85,25	0,65	-8,28
7Aref	SCI	7,59	89,27	0,23	-7,77
7Aref	SCE	8,16	85,39	0,41	-7,57
7Aref2	SCI	6,91	90,18	0,25	-7,45
7Aref2	SCE	7,62	86,17	0,45	-7,91
8U	SCI	14,02	79,17	1,88	-10,45
8U	SCE	11,87	76,77	2,07	-11,09
8Uref	SCI	15,38	77,85	1,93	-10,08
8Uref	SCE	12,51	76,29	2,05	-10,53

8Uref2	SCI	11,07	81,96	1,94	-11,56
8Uref2	SCE	8,58	79,89	2,12	-12,18
8A	SCI	17,69	76,62	1,41	-6,46
8A	SCE	15,21	75,26	1,56	-6,65
8Aref	SCI	19,73	74,72	1,28	-5,75
8Aref	SCE	17,53	72,96	1,44	-5,96
8Aref2	SCI	15,78	78,64	1,49	-6,62
8Aref2	SCE	14,2	76,28	1,69	-6,93

Appendix VI

Key Word		**Product Name**	
Test File Name	Polystyrene Pull to break	**Method File Name**	Polystyrene Pull to Break
Report Date	2012-11-01	**Test Date**	2012-04-11
Test Type	Tensile	**Speed**	100mm/min
Shape	Plate	**No of Batches:**	56
Qty/Batch:	10		

Example abbreviations:

T1.1 – T8.10 = Transparent polystyrene without adhesive. Initial breaking of plastic.

H1.1 – H8.10 = HIPS without adhesive. Initial breaking of plastic.

T1.1U = Transparent polystyrene with adhesive number 1 (Paraloid B72), unaged. Number 1 out of 10 samples with this adhesive and plastic.

H1.1U = HIPS with adhesive number 1 (Paraloid B72), unaged. Number 1 out of 10 samples with this adhesive and plastic.

T2.6A = Transparent polystyrene with adhesive number 2 (Paraloid B67), aged. Number 6 out of 10 samples with this adhesive and plastic.

H2.6A = HIPS with adhesive number 2 (Paraloid B67), aged. Number 6 out of 10 samples with this adhesive and plastic.

Name	Break_Force	Max_Force	YP(%)_Force	EASL1_Stroke
Parameters	Sensitivity 2	Calc. at Entire Area	0,1 %	Force 1 N
Unit	N	N	N	mm
T1.1	994,763	994,763	-.-	0,16207
T1.2	1026,44	1026,44	-.-	0,19935
T1.3	757,960	757,960	-.-	0,14478
T1.4	1228,26	1228,26	-.-	0,13053
T1.5	1203,05	1203,05	-.-	0,13807
T1.6	1085,82	1085,82	-.-	0,14733
T1.7	1140,80	1140,80	-.-	0,14715
T1.8	956,966	956,966	-.-	0,13298
T1.9	1097,63	1097,63	-.-	0,11520
T1.10	1018,27	1018,27	-.-	0,12769
Average	1051,00	1051,00	-.-	0,14452
Standard Deviation	135,623	135,623	-.-	0,02320
Maximum	1228,26	1228,26	-.-	0,19935
Minimum	757,960	757,960	-.-	0,11520
Median	1056,13	1056,13	-.-	0,14143
T2.1	766,381	766,381	-.-	0,12623
T2.2	927,661	927,661	-.-	0,10882
T2.3	1116,37	1116,48	-.-	0,10664
T2.4	1031,45	1031,45	-.-	0,11819
T2.5	1113,83	1113,83	-.-	0,11691
T2.6	1045,81	1045,81	-.-	0,12750
T2.7	1017,62	1017,62	-.-	0,15608
T2.8	1036,53	1036,53	-.-	0,11943
T2.9	1026,38	1026,38	-.-	0,13345
T2.10	777,950	777,950	-.-	0,10389

Average	985,998	986,009	−.−	0,12171
Standard Deviation	124,313	124,326	−.−	0,01536
Maximum	1116,37	1116,48	−.−	0,15608
Minimum	766,381	766,381	−.−	0,10389
Median	1028,92	1028,92	−.−	0,11881
T3.1	909,222	909,222	−.−	0,09898
T3.2	855,360	855,360	−.−	0,10052
T3.3 962,784	962,784	−.−	0,13008	
T3.4	911,856	911,856	−.−	0,10798
T3.5	1027,84	1027,84	−.−	0,10772
T3.6	868,622	868,622	−.−	0,13688
T3.7	849,128	849,128	−.−	0,13585
T3.8	909,252	909,252	−.−	0,13897
T3.9	873,370	873,370	−.−	0,13503
T3.10	952,466	952,466	−.−	0,14765
Average	911,990	911,990	−.−	0,12397
Standard Deviation	55,9619	55,9619	−.−	0,01810
Maximum	1027,84	1027,84	−.−	0,14765
Minimum	849,128	849,128	−.−	0,09898
Median	909,237	909,237	−.−	0,13256
T4.1	726,972	726,972	−.−	0,13819
T4.2	1214,53	1214,53	−.−	0,15327
T4.3	914,655	914,655	−.−	0,15077
T4.4	783,246	783,246	−.−	0,13742
T4.5	861,775	861,775	−.−	0,14969
T4.6	1109,17	1109,17	−.−	0,13488
T4.7	1217,92	1217,92	−.−	0,17256
T4.8	1035,69	1035,69	−.−	0,20595
T4.9	823,209	823,209	−.−	0,13871
T4.10	949,478	949,478	−.−	0,17283
Average	963,664	963,664	−.−	0,15543
Standard Deviation	174,873	174,873	−.−	0,02244
Maximum	1217,92	1217,92	−.−	0,20595
Minimum	726,972	726,972	−.−	0,13488
Median	932,067	932,067	−.−	0,15023
T5.1	996,420	996,420	−.−	0,14193
T5.2	917,417	917,417	−.−	0,12038
T5.3	1024,17	1024,17	−.−	0,15168
T5.4	981,369	981,369	−.−	0,15601
T5.5	876,783	876,783	−.−	0,13330
T5.6	873,830	873,830	−.−	0,19013
T5.7	1055,42	1055,42	−.−	0,19748
T5.8	915,806	915,806	−.−	0,17208
T5.9	954,742	954,742	−.−	0,16781
T5.10	1086,60	1086,60	−.−	0,16215
Average	968,256	968,256	−.−	0,15930
Standard Deviation	73,4062	73,4062	−.−	0,02407
Maximum	1086,60	1086,60	−.−	0,19748
Minimum	873,830	873,830	−.−	0,12038
Median	968,056	968,056	−.−	0,15908
T6.1	949,947	949,947	−.−	0,13705
T6.2	891,339	891,339	−.−	0,15926
T6.3	900,426	900,426	−.−	0,16231

T6.4	836,752	836,752	–.–	0,16329
T6.5	1010,91	1010,91	–.–	0,17915
T6.6	1078,38	1078,38	–.–	0,14860
T6.7	1025,45	1025,45	–.–	0,14756
T6.8	871,964	871,964	–.–	0,14098
T6.9	982,733	982,733	–.–	0,13888
T6.10	898,933	898,933	–.–	0,15666
Average	944,683	944,683	–.–	0,15337
Standard Deviation	77,5272	77,5272	–.–	0,01323
Maximum	1078,38	1078,38	–.–	0,17915
Minimum	836,752	836,752	–.–	0,13705
Median	925,187	925,187	–.–	0,15263
T7.1	887,423	887,423	–.–	0,16939
T7.2	1084,15	1084,15	–.–	0,15774
T7.3	972,643	972,643	–.–	0,14199
T7.4	931,870	931,870	–.–	0,13613
T7.5	962,645	962,645	–.–	0,15717
T7.6	901,157	901,157	–.–	0,16728
T7.7	883,584	883,584	–.–	0,14734
T7.8 981,574	981,574	–.–	0,13284	
T7.9	872,690	872,690	–.–	0,16316
T7.10	1143,80	1143,80	–.–	0,16690
Average	962,154	962,154	–.–	0,15399
Standard Deviation	89,9168	89,9168	–.–	0,01351
Maximum	1143,80	1143,80	–.–	0,16939
Minimum	872,690	872,690	–.–	0,13284
Median	947,258	947,258	–.–	0,15746
H1.1	767,668	767,668	–.–	0,20028
H1.2	774,997	774,997	–.–	0,16941
H1.3	792,786	792,786	–.–	0,16196
H1.4	822,029	822,029	–.–	0,20439
H1.5	772,959	772,959	–.–	0,16146
H1.6	871,449	871,449	–.–	0,15682
H1.7	919,719	919,719	–.–	0,15115
H1.8	755,898	755,898	–.–	0,14866
H1.9	832,106	832,106	–.–	0,20763
H1.10	941,051	941,051	–.–	0,19414
Average	825,066	825,066	–.–	0,17559
Standard Deviation	65,7982	65,7982	–.–	0,02335
Maximum	941,051	941,051	–.–	0,20763
Minimum	755,898	755,898	–.–	0,14866
Median	807,408	807,408	–.–	0,16569
H2.1	866,164	866,164	–.–	0,18156
H2.2	906,531	906,531	–.–	0,17419
H2.3	935,758	935,758	–.–	0,14285
H2.4	887,219	887,219	–.–	0,17372
H2.5	726,897	726,897	–.–	0,13315
H2.6	848,579	848,579	–.–	0,18762
H2.7	783,739	783,739	–.–	0,14920
H2.8	902,351	902,351	–.–	0,16757
H2.9	806,430	806,430	–.–	0,18154
H2.10	732,149	732,149	–.–	0,17176
Average	839,582	839,582	–.–	0,16632

Standard Deviation	73,9264	73,9264	−.−	0,01829
Maximum	935,758	935,758	−.−	0,18762
Minimum	726,897	726,897	−.−	0,13315
Median	857,372	857,372	−.−	0,17274
H3.1	732,503	732,503	−.−	0,19632
H3.2	925,301	925,301	−.−	0,16827
H3.3	527,701	527,701	−.−	0,16721
H3.4	714,308	714,308	−.−	0,14378
H3.5	721,223	721,223	−.−	0,17677
H3.6	681,648	681,648	−.−	0,13045
H3.7	752,967	752,967	−.−	0,15331
H3.8	892,655	892,655	−.−	0,11851
H3.9	749,771	749,771	−.−	0,16971
H3.10	801,477	801,477	−.−	0,14816
Average	749,955	749,955	−.−	0,15725
Standard Deviation	110,673	110,673	−.−	0,02305
Maximum	925,301	925,301	−.−	0,19632
Minimum	527,701	527,701	−.−	0,11851
Median	741,137	741,137	−.−	0,16026
H4.1	865,192	865,192	−.−	0,11766
H4.2	764,154	764,154	−.−	0,12841
H4.3	834,301	834,301	−.−	0,10881
H4.4	868,588	868,588	−.−	0,18072
H4.5	724,192	724,192	−.−	0,14910
H4.6	702,815	702,815	−.−	0,16241
H4.7	676,891	676,891	−.−	0,12327
H4.8	790,825	790,825	−.−	0,12291
H4.9	705,409	705,409	−.−	0,12424
H4.10	729,399	729,399	−.−	0,13011
Average	766,177	766,177	−.−	0,13476
Standard Deviation	70,1897	70,1897	−.−	0,02234
Maximum868,588	868,588	−.−	0,18072	
Minimum	676,891	676,891	−.−	0,10881
Median	746,777	746,777	−.−	0,12633
H5.1	803,588	803,588	−.−	0,15058
H5.2	900,432	900,432	−.−	0,11615
H5.3	890,409	890,409	−.−	0,12322
H5.4	875,917	875,917	−.−	0,17677
H5.5	891,816	891,816	−.−	0,13385
H5.6	683,854	683,854	−.−	0,14845
H5.7	756,448	756,448	−.−	0,15114
H5.8	808,927	808,927	−.−	0,12320
H5.9	728,664	728,664	−.−	0,13057
H5.10	879,617	879,617	−.−	0,15247
Average	821,967	821,967	−.−	0,14064
Standard Deviation	77,8426	77,8426	−.−	0,01847
Maximum	900,432	900,432	−.−	0,17677
Minimum	683,854	683,854	−.−	0,11615
Median	842,422	842,422	−.−	0,14115
H6.1	779,355	779,355	−.−	0,12184
H6.2	821,500	821,500	−.−	0,13276
H6.3	769,922	769,922	−.−	0,14417
H6.4	821,203	821,203	−.−	0,13544

H6.5	748,633	748,633	−.−	0,14285
H6.6	859,815	859,815	−.−	0,17185
H6.7	935,981	935,981	−.−	0,13714
H6.8	881,435	881,435	−.−	0,14235
H6.9	874,421	874,421	−.−	0,12664
H6.10	773,784	773,784	−.−	0,15960
Average	826,605	826,605	−.−	0,14146
Standard Deviation	60,3040	60,3040	−.−	0,01490
Maximum	935,981	935,981	−.−	0,17185
Minimum	748,633	748,633	−.−	0,12184
Median	821,352	821,352	−.−	0,13975
H7.1	774,668	774,668	−.−	0,15272
H7.2	688,925	688,925	−.−	0,14133
H7.3	762,363	762,363	−.−	0,15462
H7.4	783,815	783,815	−.−	0,13736
H7.5	733,895	733,895	−.−	0,14257
H7.6	888,596	888,596	−.−	0,14490
H7.7	883,972	883,972	−.−	0,13484
H7.8	775,296	775,296	−.−	0,16222
H7.9	862,157	862,157	−.−	0,15199
H7.10	871,716	871,716	−.−	0,16987
Average	802,540	802,540	−.−	0,14924
Standard Deviation	69,5068	69,5068	−.−	0,01114
Maximum	888,596	888,596	−.−	0,16987
Minimum	688,925	688,925	−.−	0,13484
Median	779,556	779,556	−.−	0,14845
T1.1.U	327,967	327,967	−.−	0,09458
T1.2.U	333,231	333,231	−.−	0,08950
T1.3.U	308,483	308,483	−.−	0,10578
T1.4.U	426,057	426,057	−.−	0,08827
T1.5.U	373,491	373,491	−.−	0,08278
Average	353,846	353,846	−.−	0,09218
Standard Deviation	46,7784	46,7784	−.−	0,00868
Maximum	426,057	426,057	−.−	0,10578
Minimum	308,483	308,483	−.−	0,08278
Median	333,231	333,231	−.−	0,08950
T2.1.U.	107,807	107,807	−.−	0,08597
T2.2.U	101,887	101,887	−.−	0,08969
T2.3.U	82,1018	82,1018	−.−	0,08763
T2.4.U	145,321	145,321	−.−	0,10009
T2.5.U	77,2397	77,2397	−.−	0,08552
Average	102,871	102,871	−.−	0,08978
Standard Deviation	26,9984	26,9984	−.−	0,00599
Maximum145,321	145,321	−.−	0,10009	
Minimum	77,2397	77,2397	−.−	0,08552
Median	101,887	101,887	−.−	0,08763
T3.1.U	189,438	189,438	−.−	0,10067
T3.2.U	160,554	160,554	−.−	0,09473
T3.3.U	160,953	160,953	−.−	0,08078
T3.4.U	152,969	152,969	−.−	0,11277
T3.5.U	186,124	186,124	−.−	0,09424
Average	170,008	170,008	−.−	0,09664
Standard Deviation	16,5752	16,5752	−.−	0,01159

Maximum	189,438	189,438	-.-	0,11277
Minimum	152,969	152,969	-.-	0,08078
Median	160,953	160,953	-.-	0,09473
T4.1.U	136,369	136,369	-.-	0,10818
T4.2.U	371,505	371,505	-.-	0,10472
T4.3.U	293,407	293,407	-.-	0,09996
T4.4.U	233,254	233,254	-.-	0,10076
T4.5.U	319,411	319,411	-.-	0,10450
Average	270,789	270,789	-.-	0,10362
Standard Deviation	90,1346	90,1346	-.-	0,00333
Maximum	371,505	371,505	-.-	0,10818
Minimum	136,369	136,369	-.-	0,09996
Median	293,407	293,407	-.-	0,10450
T5.1.U	451,832	451,832	-.-	0,10908
T5.2.U	345,186	345,186	-.-	0,10989
T5.3.U	264,567	264,567	-.-	0,10173
T5.4.U	394,748	394,748	-.-	0,10223
T5.5.U	310,974	310,974	-.-	0,11210
Average	353,461	353,461	-.-	0,10701
Standard Deviation	72,7276	72,7276	-.-	0,00472
Maximum	451,832	451,832	-.-	0,11210
Minimum	264,567	264,567	-.-	0,10173
Median	345,186	345,186	-.-	0,10908
T6.1.U	912,830	912,830	-.-	0,14950
T6.2.U	632,143	632,143	-.-	0,13964
T6.3.U	643,756	643,756	-.-	0,14301
T6.4.U	979,050	979,050	-.-	0,14555
T6.5.U	567,355	567,355	-.-	0,13426
Average	747,027	747,027	-.-	0,14239
Standard Deviation	185,385	185,385	-.-	0,00580
Maximum	979,050	979,050	-.-	0,14950
Minimum	567,355	567,355	-.-	0,13426
Median	643,756	643,756	-.-	0,14301
T7.1.U	321,032	321,032	-.-	0,12093
T7.2.U	282,706	282,706	-.-	0,12072
T7.3.U	193,612	193,612	-.-	0,15433
T7.4.U	404,871	404,871	-.-	0,12701
T7.5.U	596,862	596,862	-.-	0,13198
Average	359,817	359,817	-.-	0,13099
Standard Deviation	152,721	152,721	-.-	0,01386
Maximum	596,862	596,862	-.-	0,15433
Minimum	193,612	193,612	-.-	0,12072
Median	321,032	321,032	-.-	0,12701
H1.1.U	385,461	385,461	-.-	0,09491
H1.2.U	400,769	400,769	-.-	0,11551
H1.3.U	486,083	486,083	-.-	0,10941
H1.4.U	355,600	355,600	-.-	0,10268
H1.5.U	356,696	356,696	-.-	0,13534
Average	396,922	396,922	-.-	0,11157
Standard Deviation	53,4357	53,4357	-.-	0,01534
Maximum	486,083	486,083	-.-	0,13534
Minimum	355,600	355,600	-.-	0,09491
Median	385,461	385,461	-.-	0,10941

H2.1.U	70,7420	70,7420	–.–	0,12786
H2.2.U	56,4702	56,4702	–.–	0,09510
H2.3.U94,0768	94,0768	–.–	0,09619	
H2.4.U	118,564	118,564	–.–	0,10089
H2.5.U	123,582	123,582	–.–	0,08844
Average	92,6870	92,6870	–.–	0,10170
Standard Deviation	29,2374	29,2374	–.–	0,01529
Maximum	123,582	123,582	–.–	0,12786
Minimum	56,4702	56,4702	–.–	0,08844
Median	94,0768	94,0768	–.–	0,09619
H3.1.U	225,695	225,695	–.–	0,08995
H3.2.U	233,785	233,785	–.–	0,09568
H3.3.U	159,866	159,866	–.–	0,12086
H3.4.U	141,322	141,322	–.–	0,11049
H3.5.U	281,248	281,248	–.–	0,08525
Average	208,383	208,383	–.–	0,10045
Standard Deviation	57,2393	57,2393	–.–	0,01484
Maximum	281,248	281,248	–.–	0,12086
Minimum	141,322	141,322	–.–	0,08525
Median	225,695	225,695	–.–	0,09568
H4.1.U	356,472	356,472	–.–	0,14187
H4.2.U	438,194	438,194	–.–	0,11313
H4.3.U	437,684	437,684	–.–	0,11181
H4.4.U	463,956	463,956	–.–	0,09724
H4.5.U	498,018	498,018	–.–	0,10121
Average	438,865	438,865	–.–	0,11305
Standard Deviation	52,2472	52,2472	–.–	0,01748
Maximum	498,018	498,018	–.–	0,14187
Minimum	356,472	356,472	–.–	0,09724
Median	438,194	438,194	–.–	0,11181
H5.1.U	663,134	663,134	–.–	0,13610
H5.2.U	415,262	415,262	–.–	0,09729
H5.3.U	492,342	492,342	–.–	0,11629
H5.4.U	362,345	362,345	–.–	0,11955
H5.5.U	473,553	473,553	–.–	0,12439
Average	481,327	481,327	–.–	0,11872
Standard Deviation	113,751	113,751	–.–	0,01414
Maximum	663,134	663,134	–.–	0,13610
Minimum	362,345	362,345	–.–	0,09729
Median	473,553	473,553	–.–	0,11955
H6.1.U	662,597	662,597	–.–	0,16003
H6.2.U	631,584	631,584	–.–	0,13432
H6.3.U	632,914	632,914	–.–	0,11714
H6.4.U	645,518	645,518	–.–	0,15308
H6.5.U	684,069	684,069	–.–	0,12322
Average	651,336	651,336	–.–	0,13756
Standard Deviation	22,1451	22,1451	–.–	0,01857
Maximum	684,069	684,069	–.–	0,16003
Minimum	631,584	631,584	–.–	0,11714
Median	645,518	645,518	–.–	0,13432
H7.1.U	658,174	658,174	–.–	0,10532
H7.2.U	609,632	609,632	–.–	0,11907
H7.3.U	428,573	428,573	–.–	0,12769

H7.4.U	360,185	360,185	−.−	0,11325
H7.5.U	295,089	295,089	−.−	0,11993
Average	470,331	470,331	−.−	0,11705
Standard Deviation	157,540	157,540	−.−	0,00833
Maximum	658,174	658,174	−.−	0,12769
Minimum	295,089	295,089	−.−	0,10532
Median	428,573	428,573	−.−	0,11907
T1.6.A	380,058	380,058	−.−	0,07332
T1.7.A	302,693	302,693	−.−	0,08809
T1.8.A	447,551	447,551	−.−	0,10284
T1.9.A	85,0868	87,1229	−.−	0,11786
T1.10.A	408,993	408,993	−.−	0,11946
Average	324,876	325,284	−.−	0,10031
Standard Deviation	144,188	143,342	−.−	0,01974
Maximum447,551	447,551	−.−	0,11946	
Minimum	85,0868	87,1229	−.−	0,07332
Median	380,058	380,058	−.−	0,10284
T3.6.A	187,961	187,961	−.−	0,09367
T3.7.A	121,052	121,052	−.−	0,09073
T3.8.A	263,052	263,052	−.−	0,09541
T3.9.A	201,117	201,117	−.−	0,10597
T3.10.A	278,522	278,522	−.−	0,08504
Average	210,341	210,341	−.−	0,09416
Standard Deviation	63,2170	63,2170	−.−	0,00768
Maximum	278,522	278,522	−.−	0,10597
Minimum	121,052	121,052	−.−	0,08504
Median	201,117	201,117	−.−	0,09367
T4.6.A	366,955	366,955	−.−	0,11340
T4.7.A	508,814	508,814	−.−	0,10208
T4.8.A	261,141	261,141	−.−	0,11410
T4.9.A	223,045	223,045	−.−	0,11813
T4.10.A	210,095	210,095	−.−	0,11435
Average	314,010	314,010	−.−	0,11241
Standard Deviation	125,120	125,120	−.−	0,00606
Maximum	508,814	508,814	−.−	0,11813
Minimum	210,095	210,095	−.−	0,10208
Median	261,141	261,141	−.−	0,11410
T5.6.A	91,8341	91,8341	−.−	0,09593
T5.7.A	329,460	329,460	−.−	0,11501
T5.8.A	475,466	475,466	−.−	0,10944
T5.9.A	362,101	362,101	−.−	0,11238
T5.10.A	280,056	280,056	−.−	0,11137
Average	307,783	307,783	−.−	0,10883
Standard Deviation	140,482	140,482	−.−	0,00748
Maximum	475,466	475,466	−.−	0,11501
Minimum	91,8341	91,8341	−.−	0,09593
Median	329,460	329,460	−.−	0,11137
T6.6.A	521,375	521,375	−.−	0,10955
T6.7.A	728,436	728,436	−.−	0,12400
T6.8.A	589,538	589,538	−.−	0,09981
T6.9.A	542,642	542,642	−.−	0,11387
T6.10.A	250,529	250,529	−.−	0,11287
Average	526,504	526,504	−.−	0,11202

Standard Deviation	174,068	174,068	-.-	0,00870
Maximum	728,436	728,436	-.-	0,12400
Minimum	250,529	250,529	-.-	0,09981
Median	542,642	542,642	-.-	0,11287
T7.6.A	545,440	545,440	-.-	0,10470
T7.7.A	492,460	492,460	-.-	0,10020
T7.8.A	320,576	320,576	-.-	0,10886
T7.9.A	457,966	457,966	-.-	0,11047
T7.10.A	693,695	693,695	-.-	0,12306
Average	502,027	502,027	-.-	0,10946
Standard Deviation	135,627	135,627	-.-	0,00858
Maximum	693,695	693,695	-.-	0,12306
Minimum	320,576	320,576	-.-	0,10020
Median	492,460	492,460	-.-	0,10886
H1.6.A	435,542	435,542	-.-	0,10287
H1.7.A	328,938	328,938	-.-	0,12174
H1.8.A	359,570	359,570	-.-	0,15700
H1.9.A	407,521	407,521	-.-	0,13146
H1.10.A	369,673	369,673	-.-	0,11262
Average	380,249	380,249	-.-	0,12514
Standard Deviation	41,7534	41,7534	-.-	0,02073
Maximum	435,542	435,542	-.-	0,15700
Minimum	328,938	328,938	-.-	0,10287
Median	369,673	369,673	-.-	0,12174
H2.6.A	103,019	103,019	-.-	0,13884
H2.7.A	107,705	107,705	-.-	0,13130
H2.8.A190,708	190,708	-.-	0,13480	
H2.9.A	157,447	157,447	-.-	0,12996
H2.10.A	86,3584	86,3584	-.-	0,14375
Average	129,048	129,048	-.-	0,13573
Standard Deviation	43,4853	43,4853	-.-	0,00565
Maximum	190,708	190,708	-.-	0,14375
Minimum	86,3584	86,3584	-.-	0,12996
Median	107,705	107,705	-.-	0,13480
H3.6.A	357,486	357,486	-.-	0,12881
H3.7.A	366,572	366,572	-.-	0,12986
H3.8.A	322,145	322,145	-.-	0,10264
H3.9.A	253,094	253,094	-.-	0,11652
H3.10.A	297,461	297,461	-.-	0,12049
Average	319,352	319,352	-.-	0,11966
Standard Deviation	46,2630	46,2630	-.-	0,01105
Maximum	366,572	366,572	-.-	0,12986
Minimum	253,094	253,094	-.-	0,10264
Median	322,145	322,145	-.-	0,12049
H4.6.A	511,524	511,524	-.-	0,13294
H4.7.A	343,455	343,455	-.-	0,11909
H4.8.A	468,585	468,585	-.-	0,12893
H4.9.A	491,284	491,284	-.-	0,12470
H4.10A	383,150	383,150	-.-	0,14129
Average	439,600	439,600	-.-	0,12939
Standard Deviation	72,6548	72,6548	-.-	0,00840
Maximum	511,524	511,524	-.-	0,14129
Minimum	343,455	343,455	-.-	0,11909

Median	468,585	468,585	−.−	0,12893
H5.6.A	544,027	544,027	−.−	0,12834
H5.7.A	425,948	425,948	−.−	0,11665
H5.8.A	494,806	494,806	−.−	0,13476
H5.9.A	459,480	459,480	−.−	0,12085
H5.10.A	404,771	404,771	−.−	0,13573
Average	465,806	465,806	−.−	0,12727
Standard Deviation	55,4830	55,4830	−.−	0,00841
Maximum	544,027	544,027	−.−	0,13573
Minimum	404,771	404,771	−.−	0,11665
Median	459,480	459,480	−.−	0,12834
H6.6.A	670,446	670,446	−.−	0,14358
H6.7.A	650,554	650,554	−.−	0,12481
H6.8.A	705,800	705,800	−.−	0,13831
H6.9.A	672,267	672,267	−.−	0,14314
H6.10.A	652,366	652,366	−.−	0,15777
Average	670,287	670,287	−.−	0,14152
Standard Deviation	22,2243	22,2243	−.−	0,01184
Maximum	705,800	705,800	−.−	0,15777
Minimum	650,554	650,554	−.−	0,12481
Median	670,446	670,446	−.−	0,14314
H7.6.A	404,431	404,431	−.−	0,07504
H7.7.A	439,776	439,776	−.−	0,11068
H7.8.A	487,539	487,539	−.−	0,11185
H7.9.A	702,146	702,146	−.−	0,11071
H7.10.A	771,252	771,252	−.−	0,11366
Average	561,029	561,029	−.−	0,10439
Standard Deviation	164,874	164,874	−.−	0,01645
Maximum	771,252	771,252	−.−	0,11366
Minimum	404,431	404,431	−.−	0,07504
Median	487,539	487,539	−.−	0,11071
H0.1A	861,994	861,994	−.−	0,19326
H0.2A	709,310	709,310	−.−	0,17321
H0.3A	810,291	810,291	−.−	0,18078
Average	793,865	793,865	−.−	0,18242
Standard Deviation	77,6561	77,6561	−.−	0,01012
Maximum	861,994	861,994	−.−	0,19326
Minimum	709,310	709,310	−.−	0,17321
Median810,291	810,291	−.−	0,18078	
T0.1A	1054,07	1054,07	−.−	0,12641
T0.2A	1010,24	1010,24	−.−	0,15407
T0.3A	1160,62	1160,62	−.−	0,17835
T0.4A	1036,83	1036,83	−.−	0,20854
Average	1065,44	1065,44	−.−	0,16684
Standard Deviation	65,9649	65,9649	−.−	0,03497
Maximum	1160,62	1160,62	−.−	0,20854
Minimum	1010,24	1010,24	−.−	0,12641
Median	1045,45	1045,45	−.−	0,16621
T8.1	950,386	950,386	−.−	0,16012
T8.2	961,326	961,326	−.−	0,15734
T8.3	1138,00	1138,00	−.−	0,15836
T8.4	907,141	907,141	893,799	0,18887
T8.5	1162,37	1162,37	−.−	0,16718

T8.6	1173,26	1173,26	−.−	0,16662
T8.7	877,427	877,427	−.−	0,18338
T8.8	1077,58	1077,58	−.−	0,18161
T8.9	916,570	916,570	−.−	0,16683
T8.10	899,199	899,199	−.−	0,20665
Average	1006,33	1006,33	893,799	0,17370
Standard Deviation	118,214	118,214	−.−	0,01598
Maximum	1173,26	1173,26	893,799	0,20665
Minimum	877,427	877,427	893,799	0,15734
Median	955,856	955,856	893,799	0,16701
H8.1	618,631	618,631	−.−	0,17610
H8.2	574,889	574,889	−.−	0,22026
H8.3	643,484	643,484	−.−	0,14997
H8.4	476,772	476,772	−.−	0,15474
H8.5	612,528	612,528	−.−	0,18641
H8.6	614,816	614,816	−.−	0,17982
H8.7	610,204	610,204	−.−	0,11942
H8.8	653,833	653,833	−.−	0,16312
H8.9	610,466	610,466	−.−	0,14106
H8.10	576,317	576,317	−.−	0,12271
Average	599,194	599,194	−.−	0,16136
Standard Deviation	49,5493	49,5493	−.−	0,03073
Maximum	653,833	653,833	−.−	0,22026
Minimum	476,772	476,772	−.−	0,11942
Median	611,497	611,497	−.−	0,15893
T8.1U	439,118	439,118	−.−	0,07794
T8.2U	376,808	376,808	−.−	0,10024
T8.3U	308,894	308,894	−.−	0,10826
T8.4U	402,864	402,864	−.−	0,08685
T8.5U	392,691	392,691	−.−	0,07133
Average	384,075	384,075	−.−	0,08892
Standard Deviation	47,8591	47,8591	−.−	0,01530
Maximum	439,118	439,118	−.−	0,10826
Minimum	308,894	308,894	−.−	0,07133
Median	392,691	392,691	−.−	0,08685
H8.1U	259,846	259,846	−.−	0,08397
H8.2U	224,482	224,482	−.−	0,08952
H8.3U	350,982	350,982	−.−	0,10491
H8.4U	256,653	256,653	−.−	0,08888
H8.5U	286,239	286,239	−.−	0,10405
Average	275,640	275,640	−.−	0,09427
Standard Deviation	47,4759	47,4759	−.−	0,00957
Maximum	350,982	350,982	−.−	0,10491
Minimum	224,482	224,482	−.−	0,08397
Median	259,846	259,846	−.−	0,08952
T8.6A	477,974	477,974	−.−	0,10354
T8.7A	415,176	415,176	−.−	0,09481
T8.8A	−.−	414,410	−.−	0,10726
T8.9A	403,676	403,676	−.−	0,11562
T8.10A	369,004	369,004	−.−	0,10938
Average416,458	416,048	−.−	0,10612	
Standard Deviation	39,3736	39,3843	−.−	0,00769
Maximum	477,974	477,974	−.−	0,11562

Minimum	369,004	369,004	-.-	0,09481
Median	409,426	414,410	-.-	0,10726
H8.6A	305,889	305,889	-.-	0,10840
H8.7A	232,514	232,514	-.-	0,11783
H8.8A	342,913	342,913	-.-	0,09202
H8.9A	401,568	401,568	-.-	0,10390
H8.10A	430,104	430,104	-.-	0,12755
Average	342,598	342,598	-.-	0,10994
Standard Deviation	78,4234	78,4234	-.-	0,01353
Maximum	430,104	430,104	-.-	0,12755
Minimum	232,514	232,514	-.-	0,09202
Median	342,913	342,913	-.-	0,10840
TotalAverage	638,053	637,365	893,799	0,13277
TotalStandard Devia	299,747	299,995	-.-	0,02954
TotalMaximum	1228,26	1228,26	893,799	0,22026
TotalMinimum	56,4702	56,4702	893,799	0,07133
TotalMedian	684,069	683,962	893,799	0,13049

Specifications for SEM investigation Series1 and Series2:

All SEM images were taken with the following settings:

Signal A = BSD
Iprobe = 1,0 nA
EHT = 20,00 kV
WD = 15-17mm

All SEM images were taken with gold sputtered samples except for samples from Series 1 unaged due to temporary problems with the sputtering machine.

Series 2 images included in this appendix are generally in magnifications x100 and x1000 with a few exceptions in x18, x50 or x250.
Series 1 images in this appendix are in magnifications x18 and x100

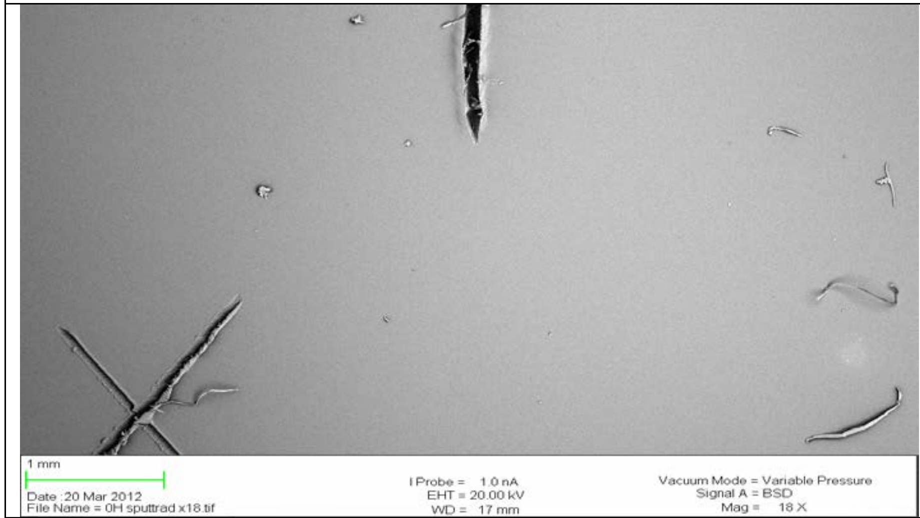
Abbreviations sample names on SEM images:
T = Transparent polystyrene
H = HIPS

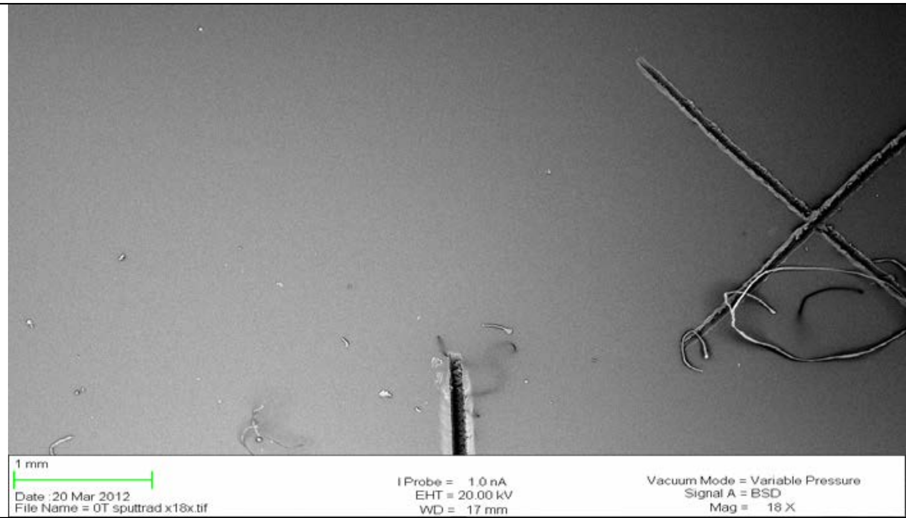
Number	Adhesive
1	40% Paraloid B72 in 50/50 acetone/ethanol
2	40% Paraloid B67 in 2-propanol
3	Primal AC 35
4	Hxtal Nyl-1
5	Araldite 2020
6	Loctite Super Attack Precision
7	Acrifix 116
8	40% Paraloid B72 in ethanol

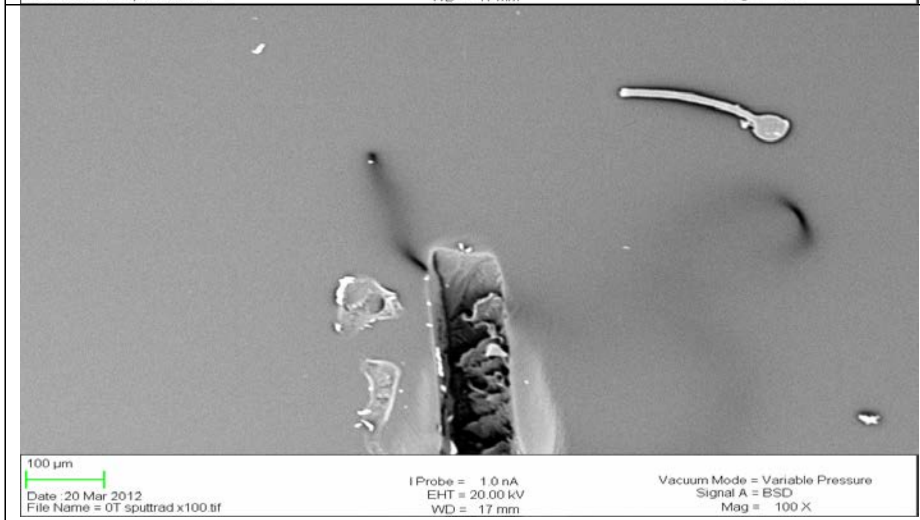
Letter ”U” or no letter after sample number = Unaged sample
Letter ”A” or ”aged” after sample number = Aged sample

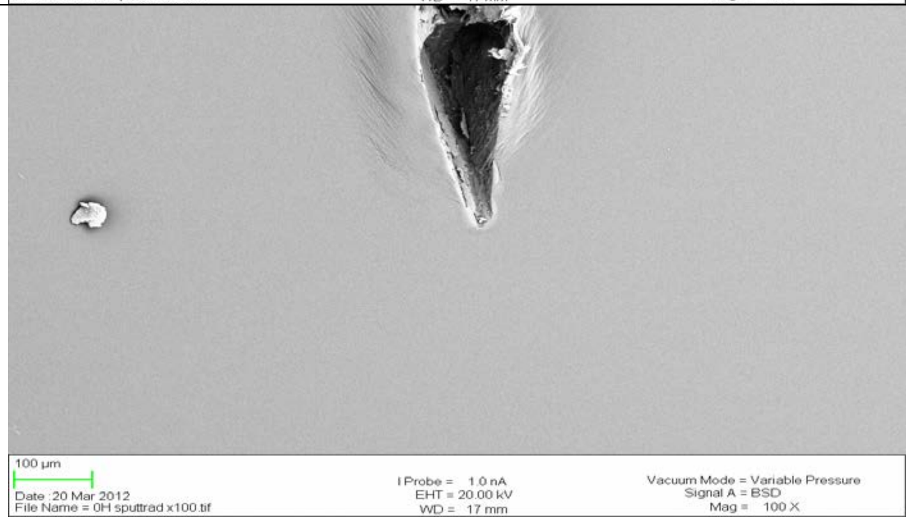
0T and 0H are samples of plastics without adhesives. In samples 0Tx18 and 0Hx18 in Series2 the area marked ”X” on one side of the visible scalpel cut is area covered with masking tape for 24h for testing whether or not the masking tape left any residue on plastic which could lead to misinterpretations. No residues were observed.

SEM images Series2 Unaged

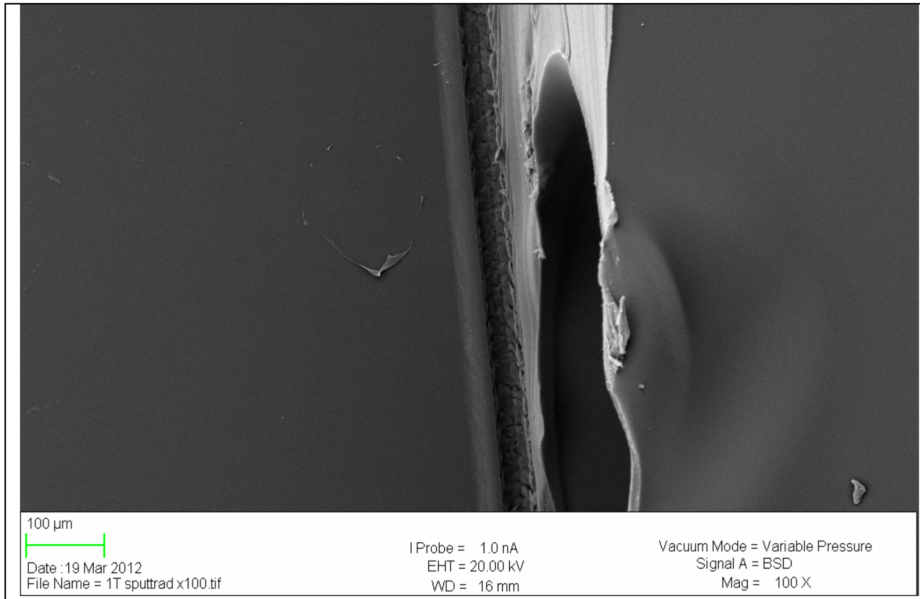


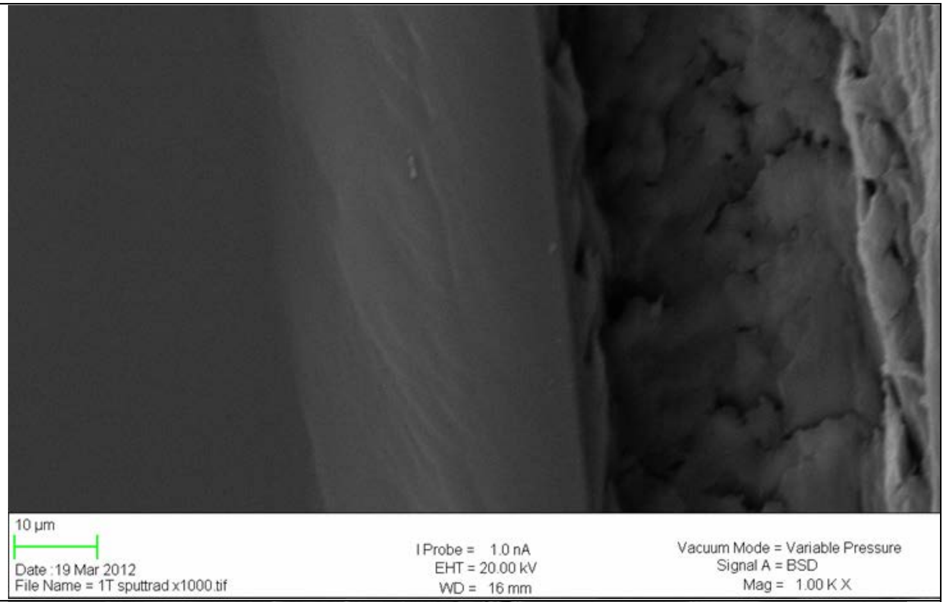


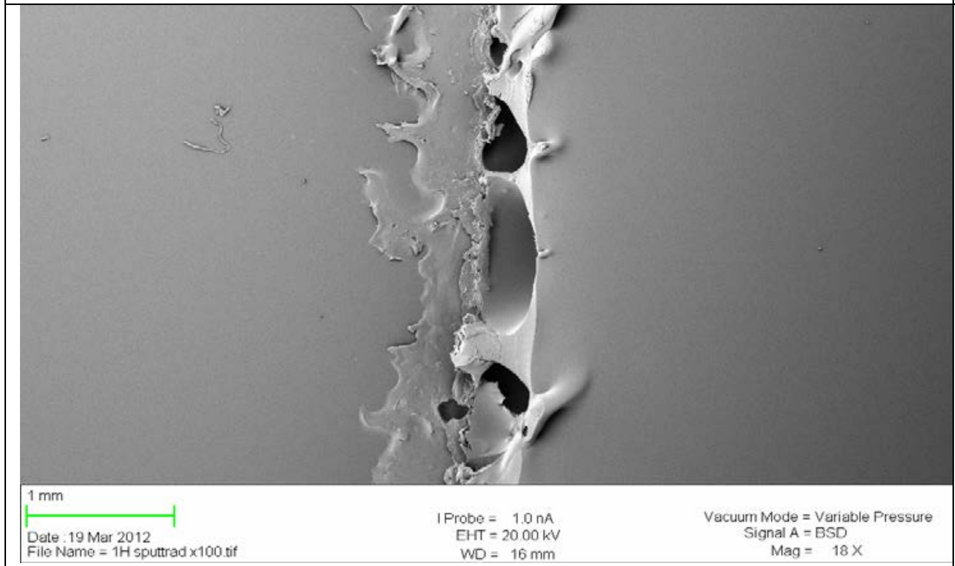


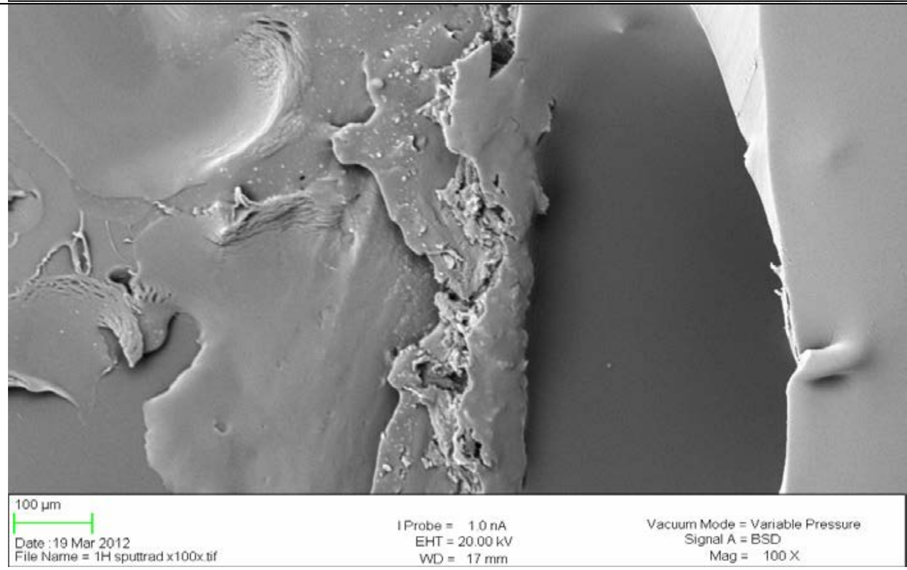


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

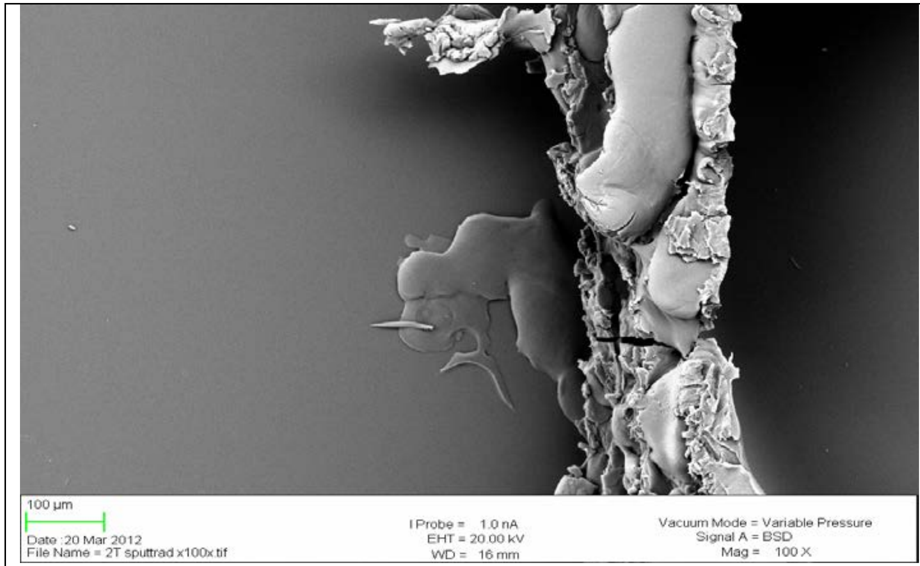


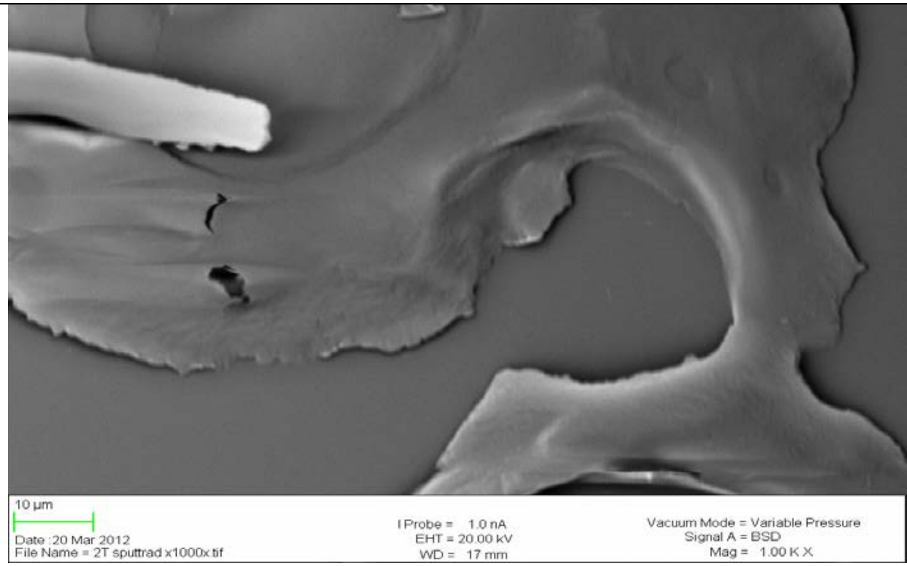


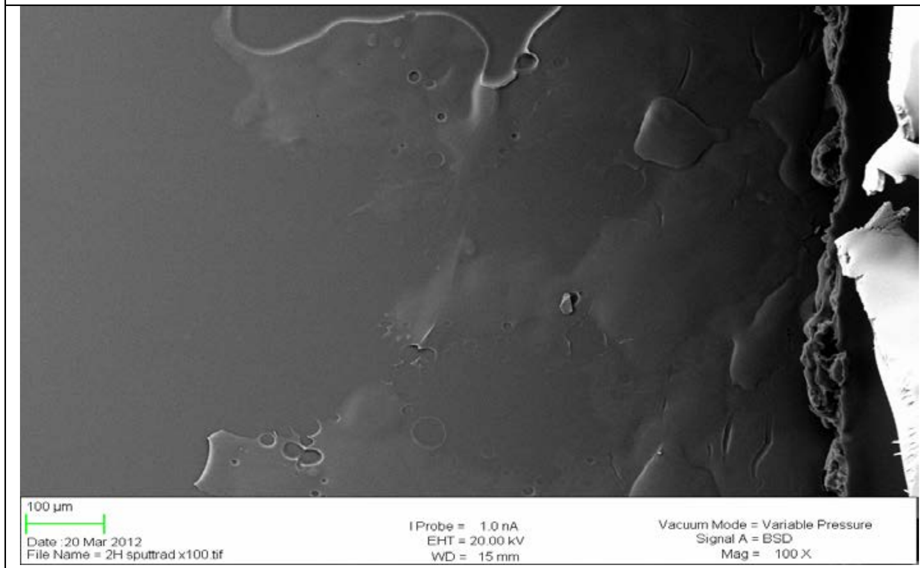


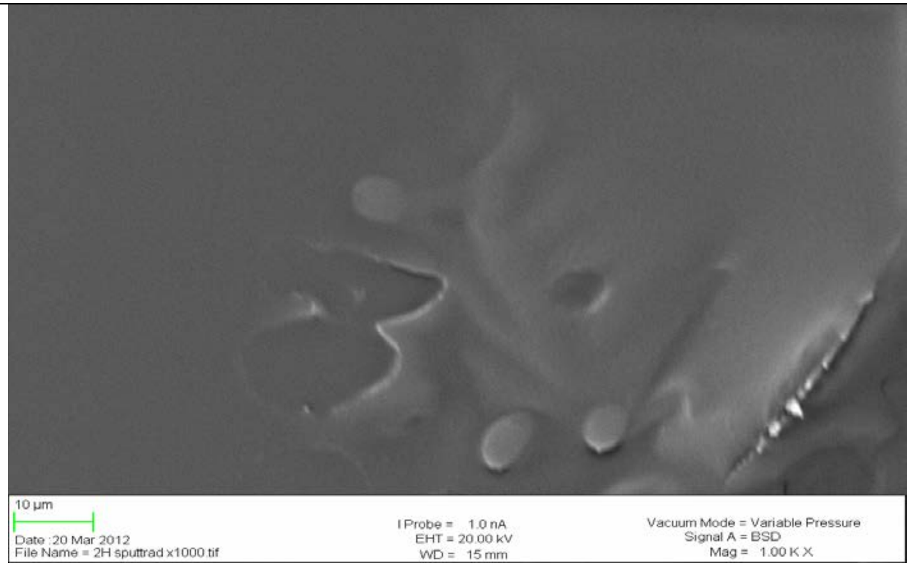


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

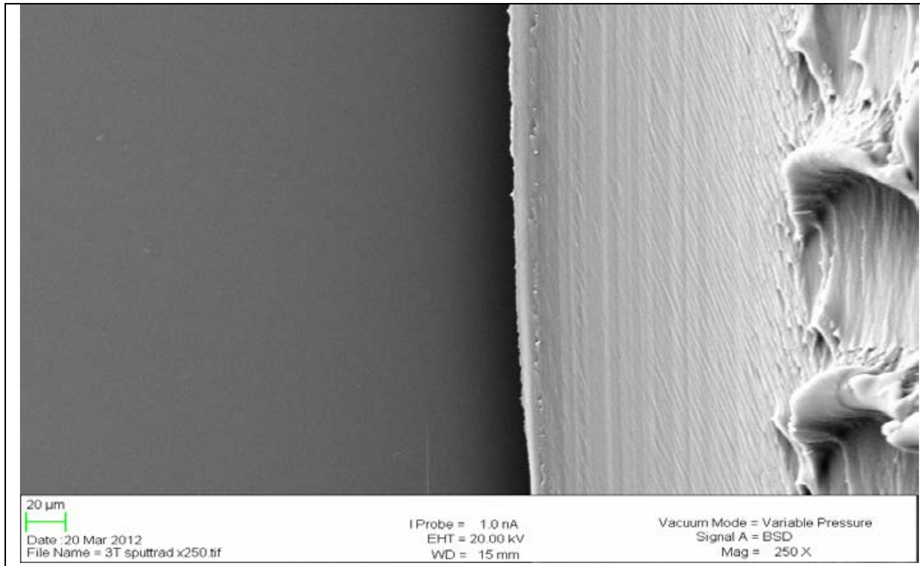


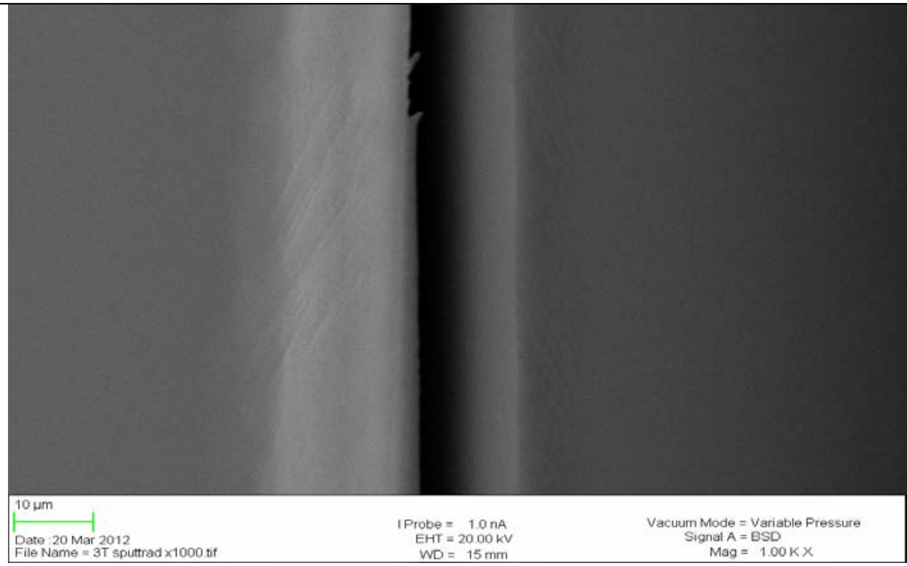


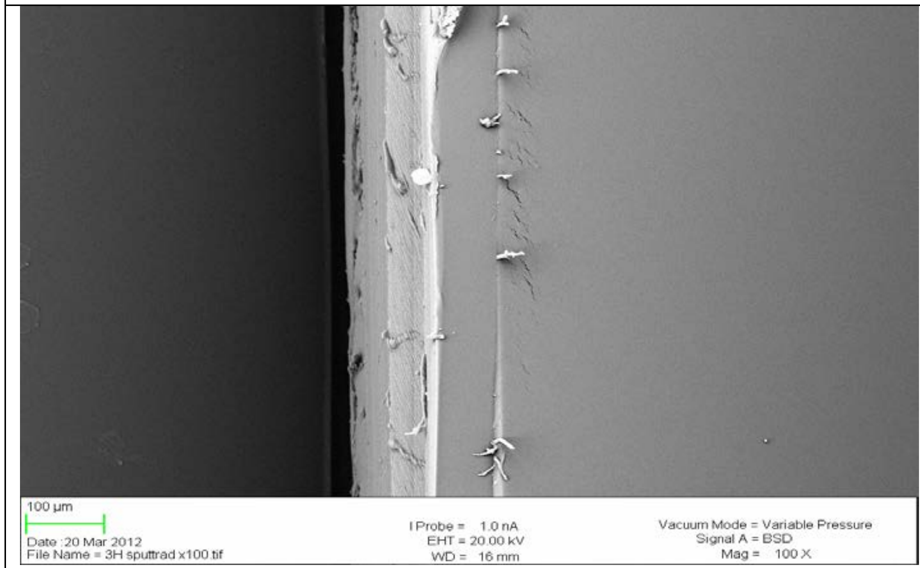


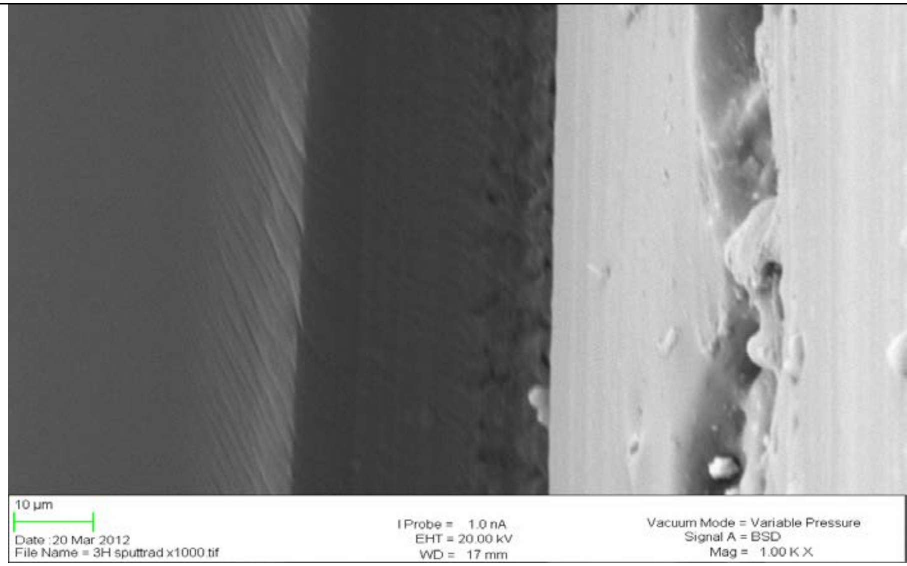


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

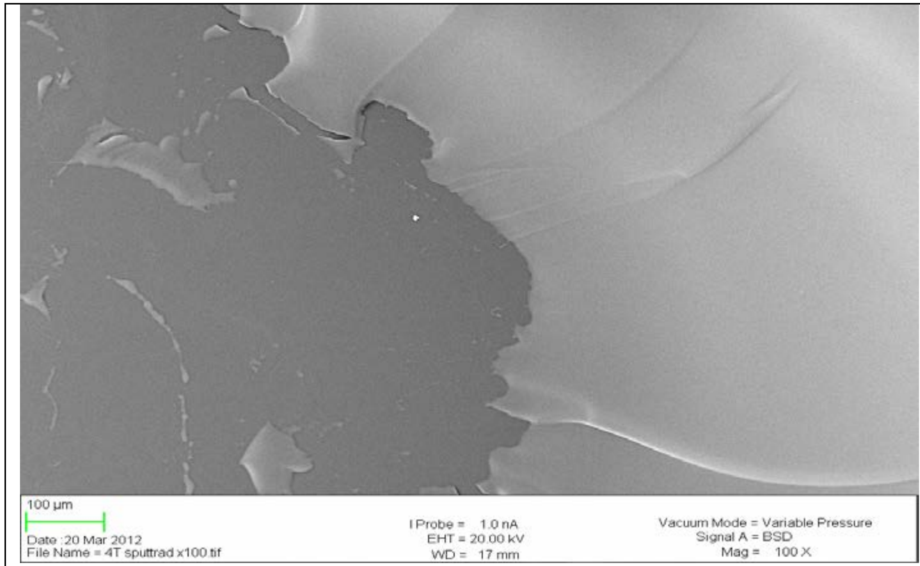


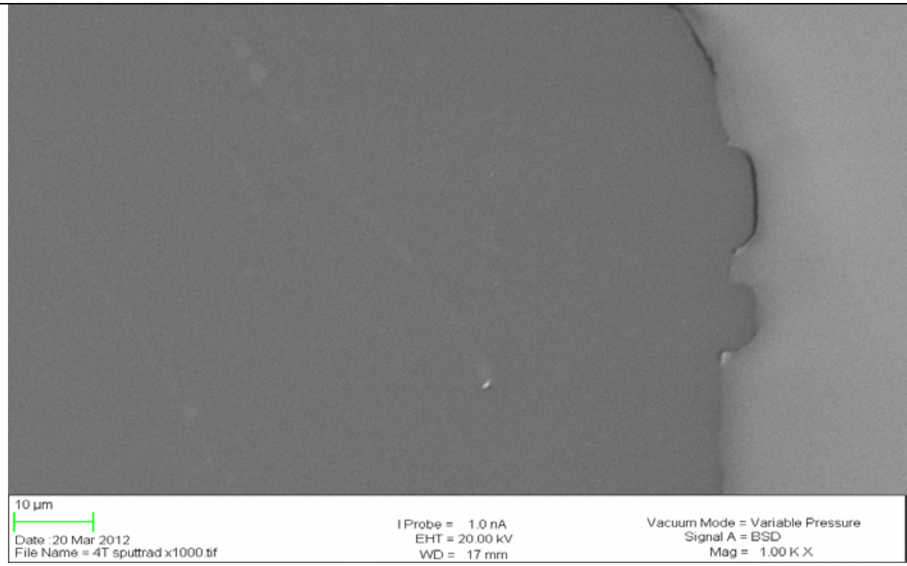


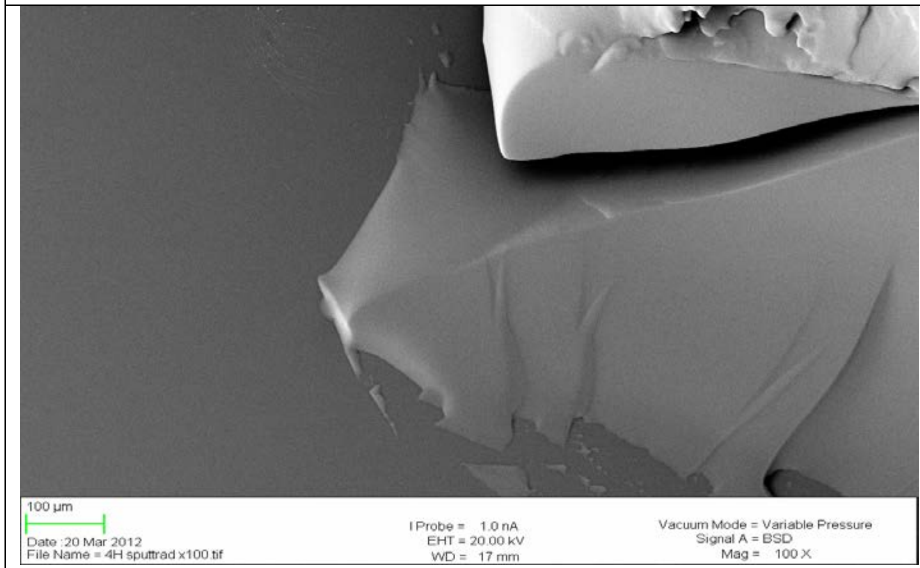


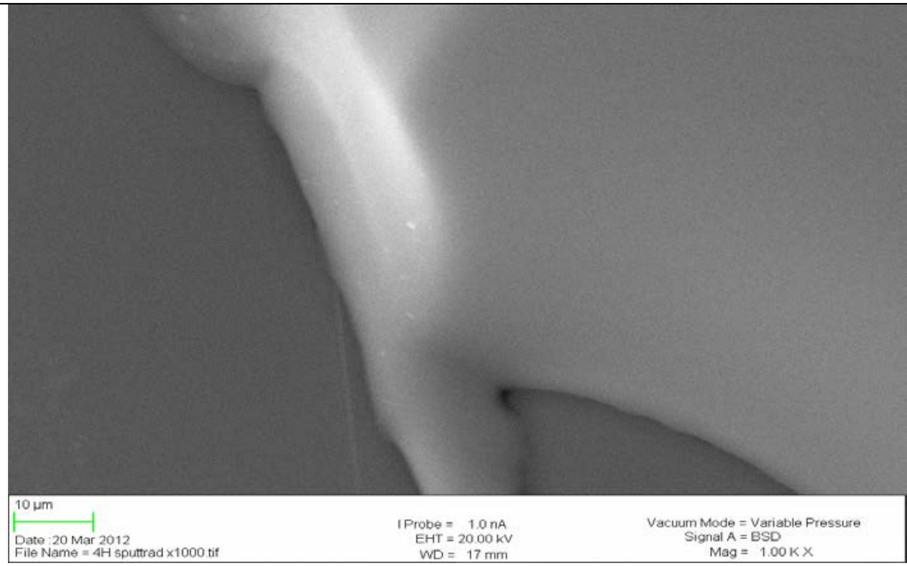


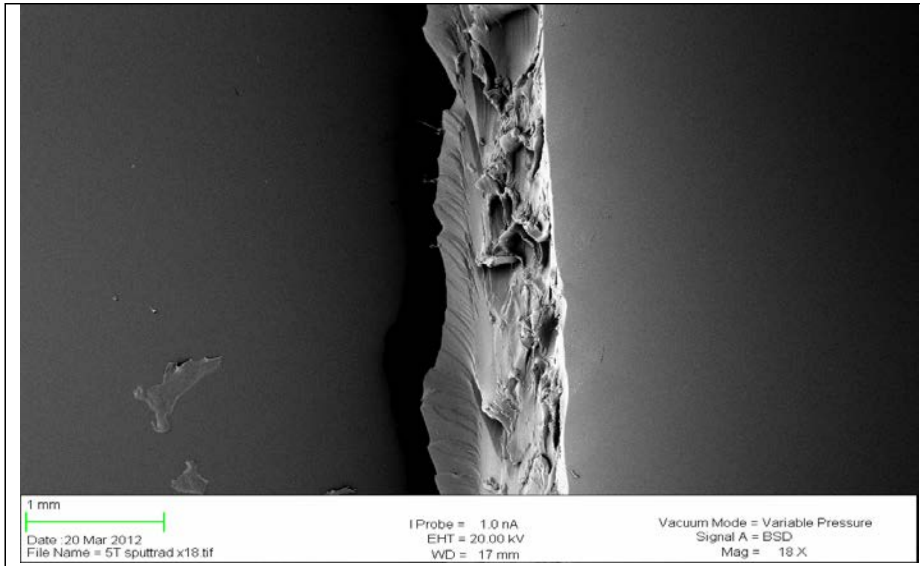
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011







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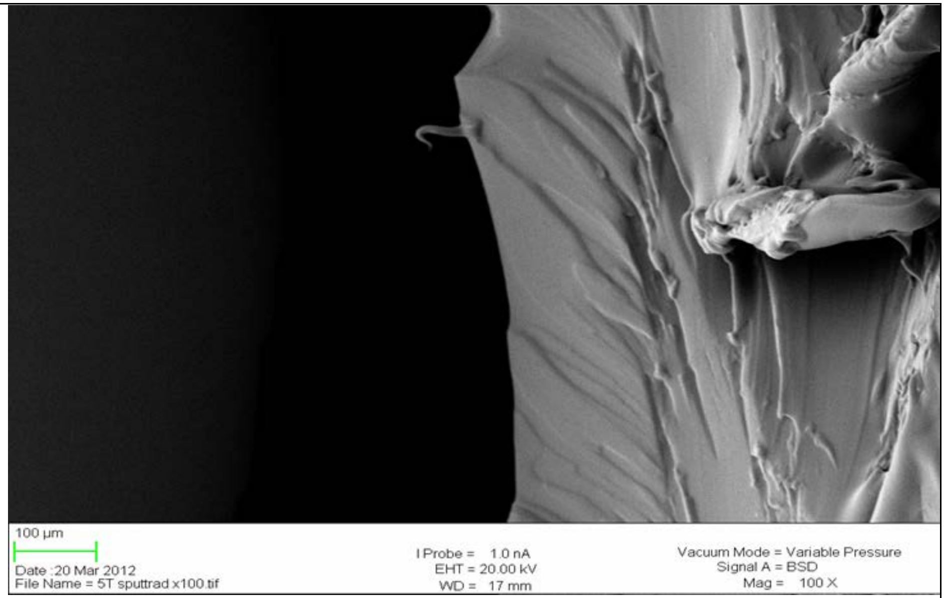
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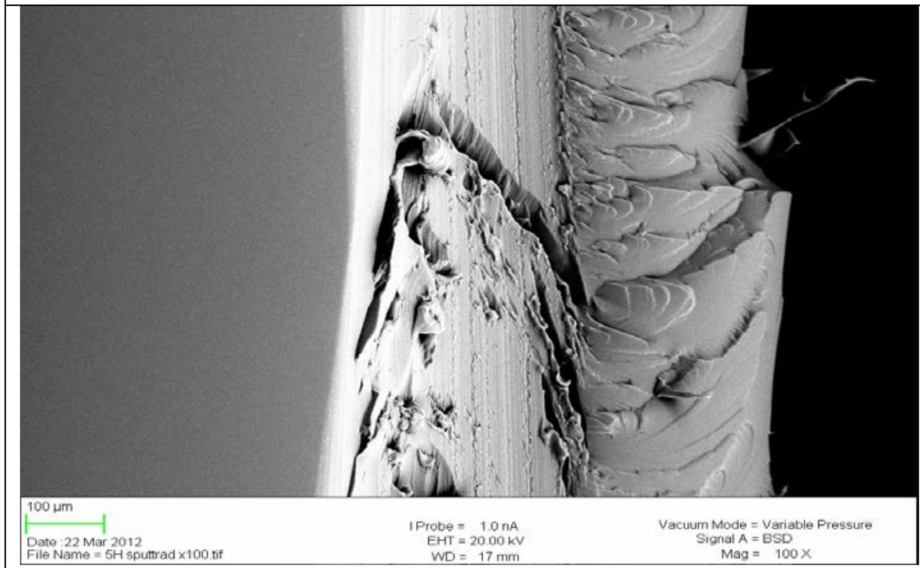
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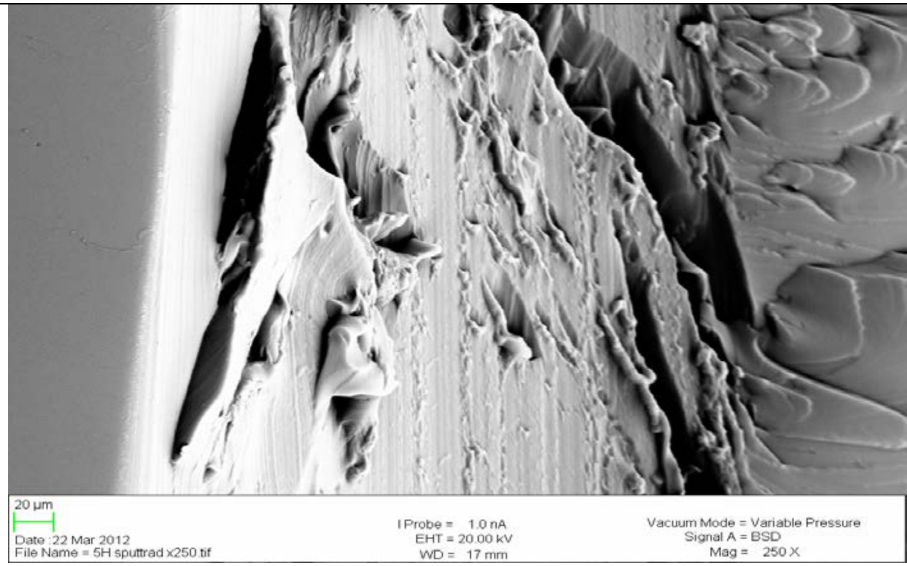
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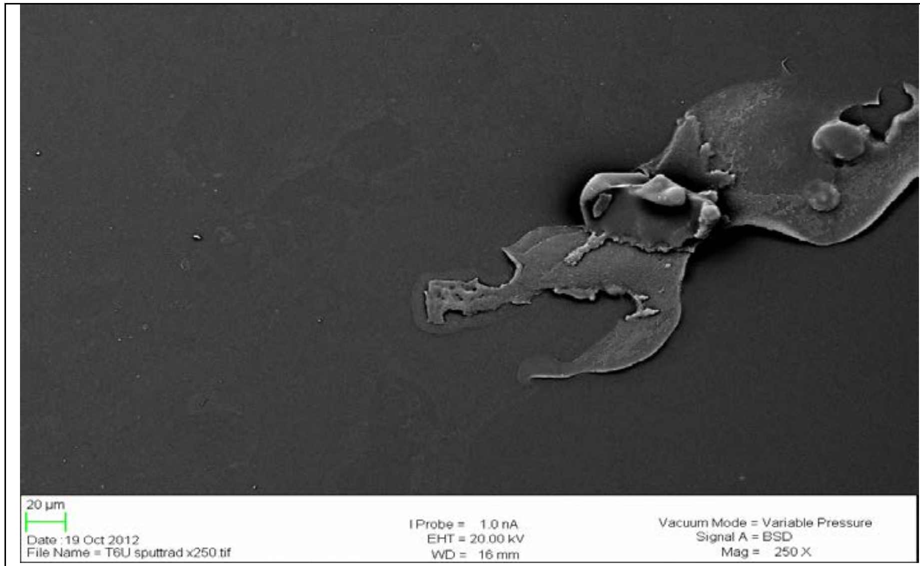
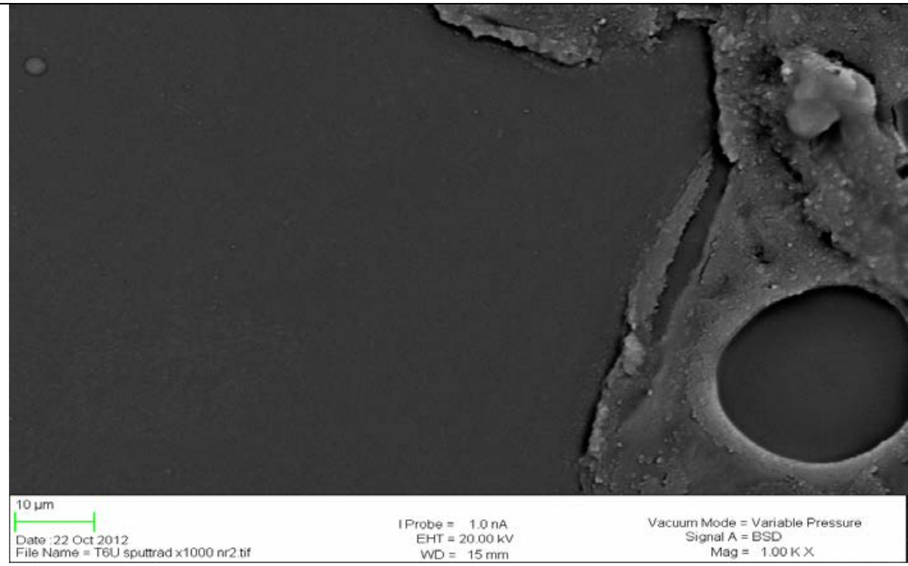
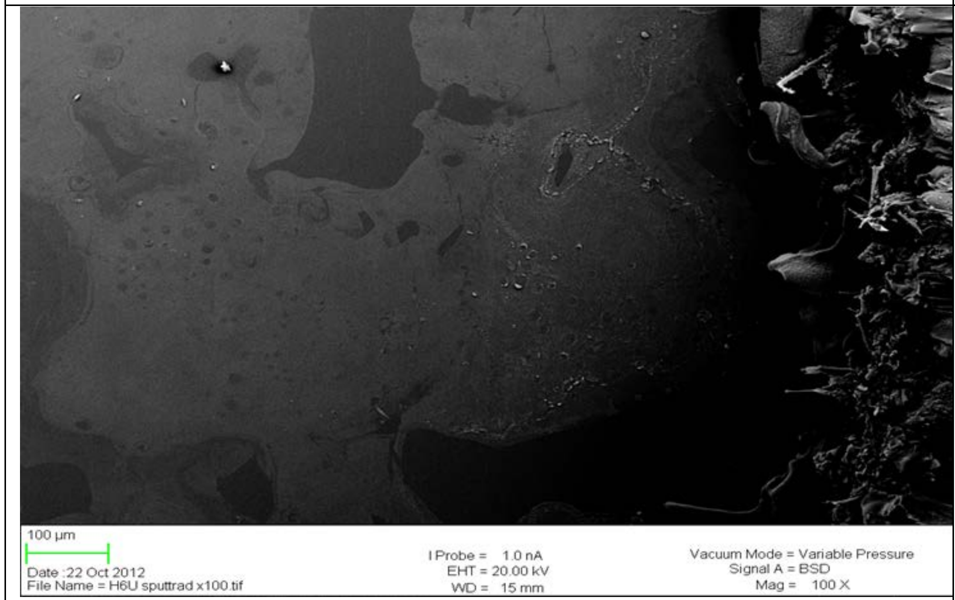
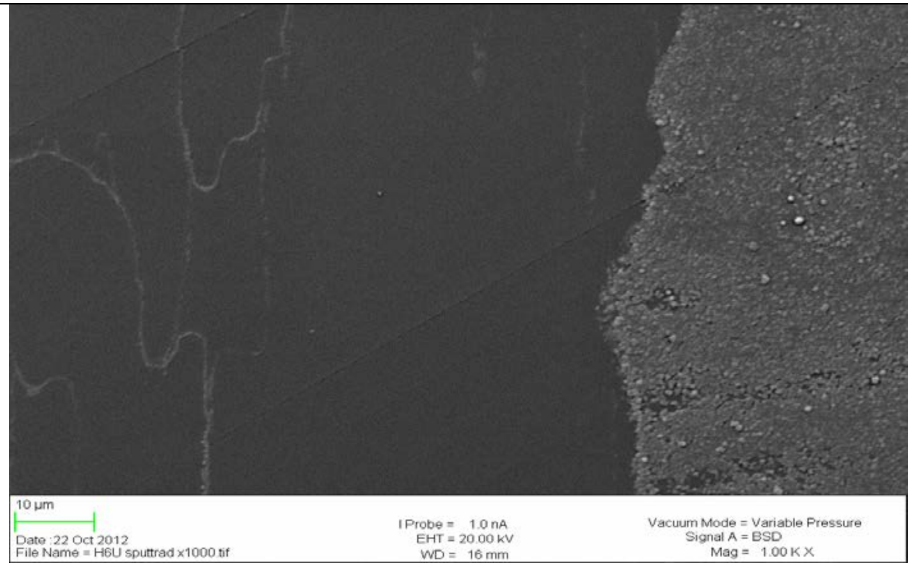
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

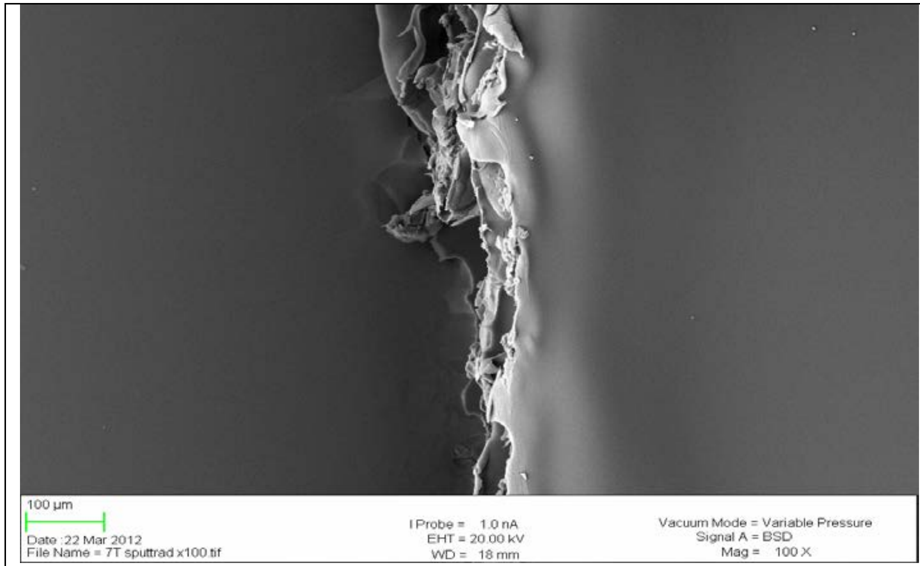


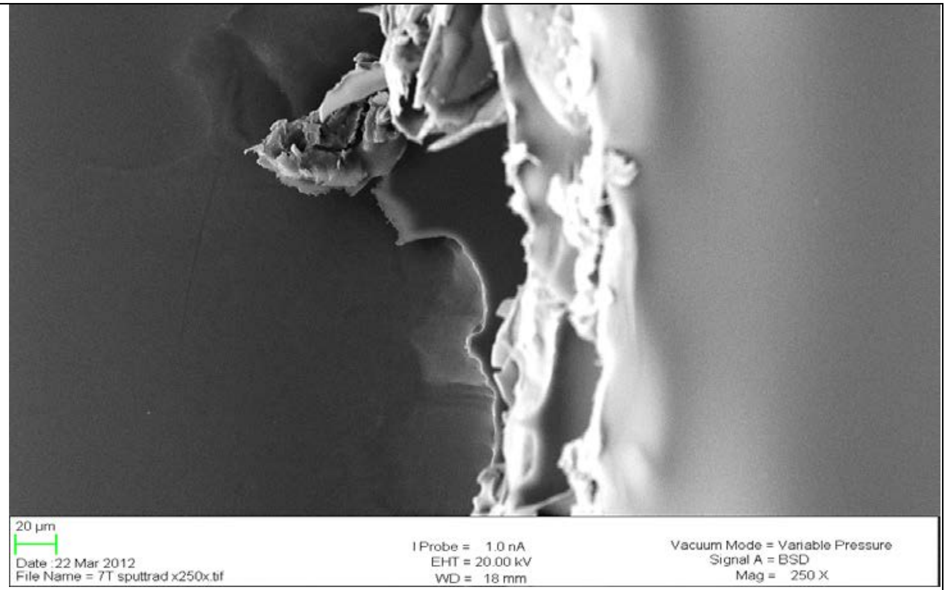


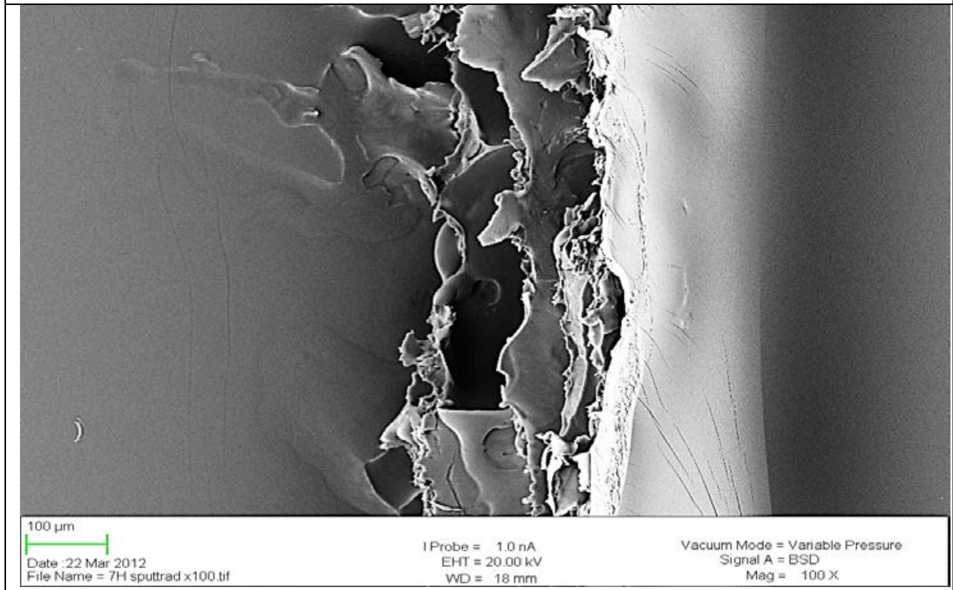


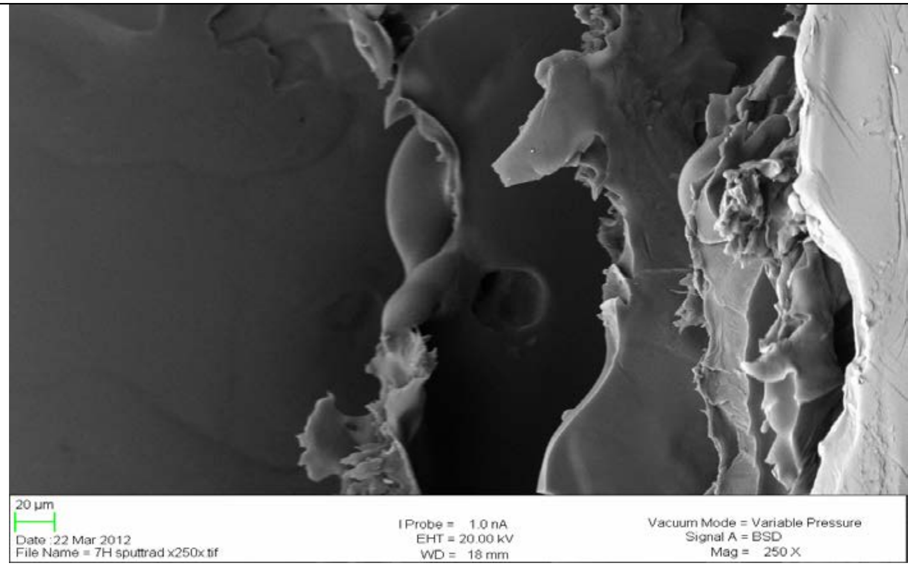


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

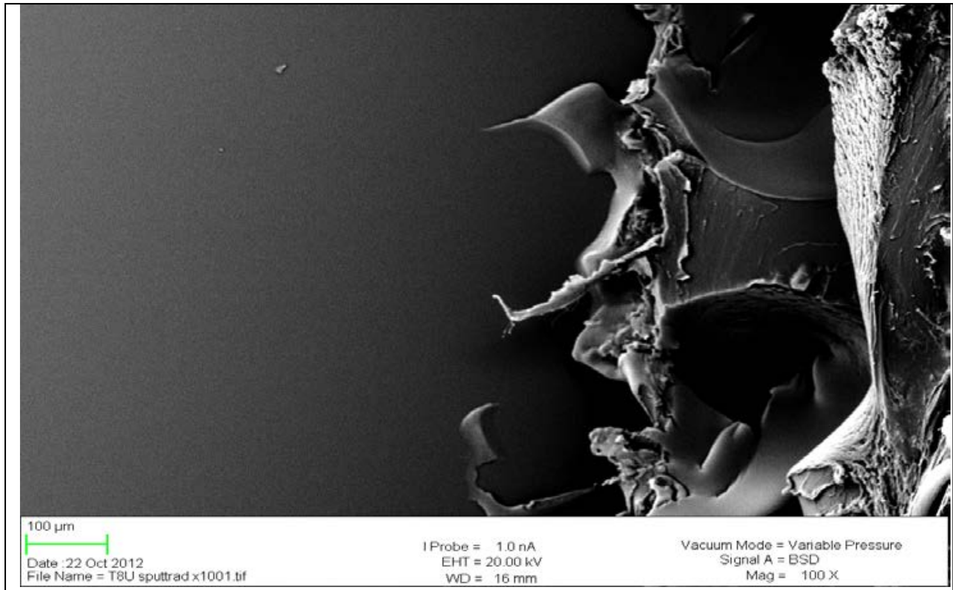


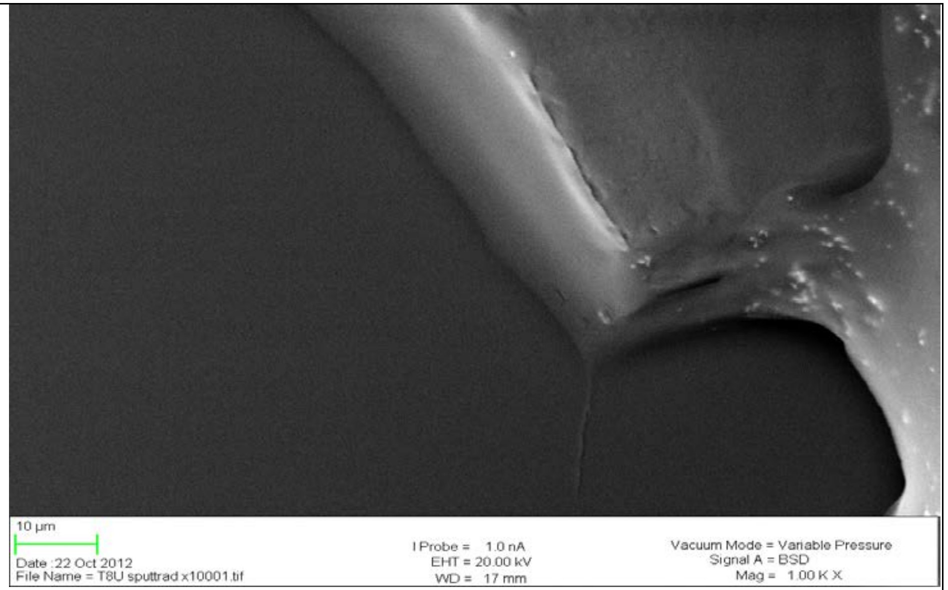


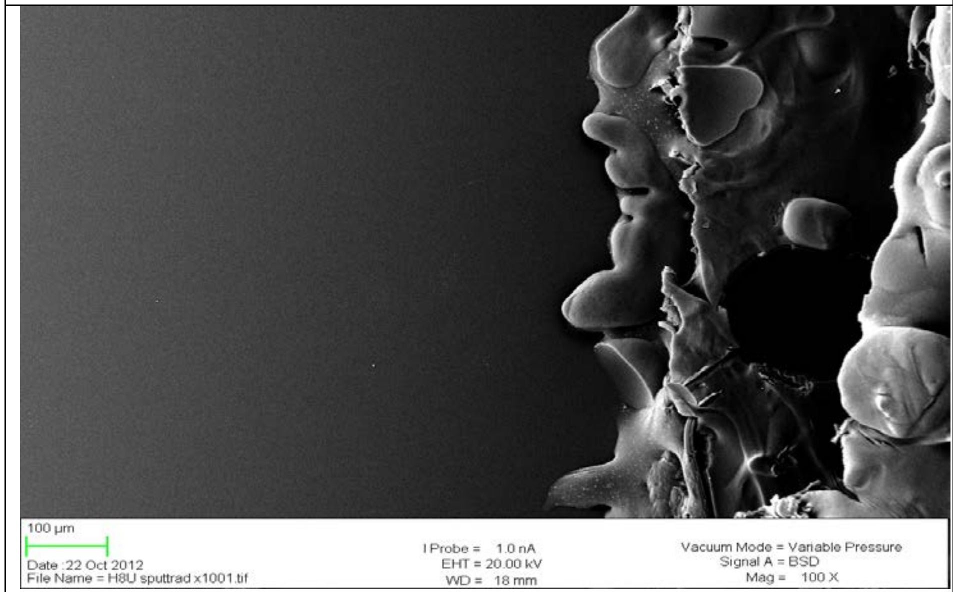


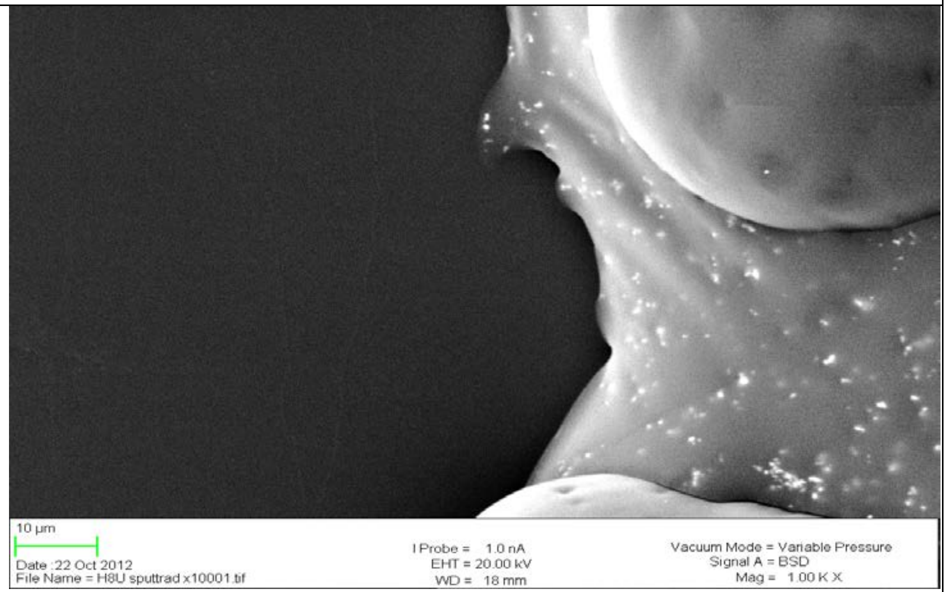


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

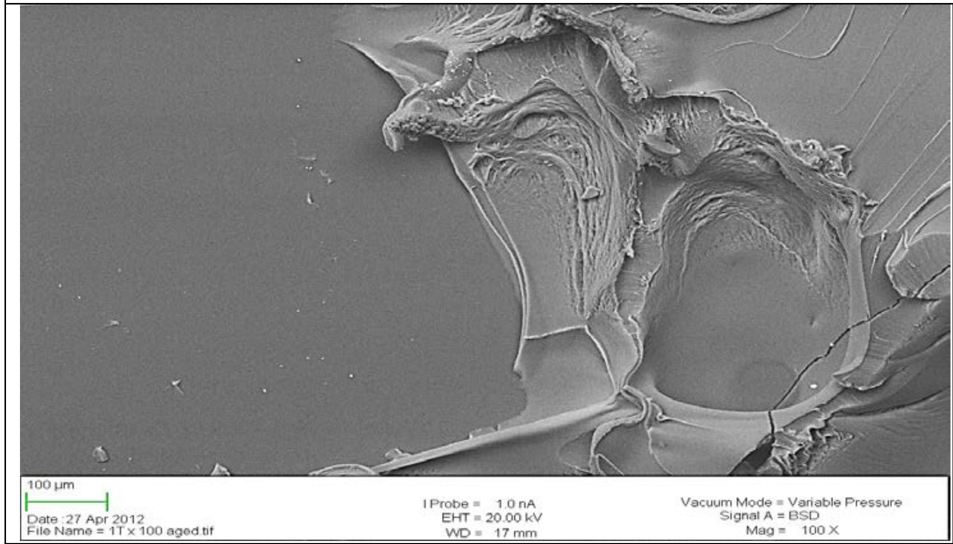


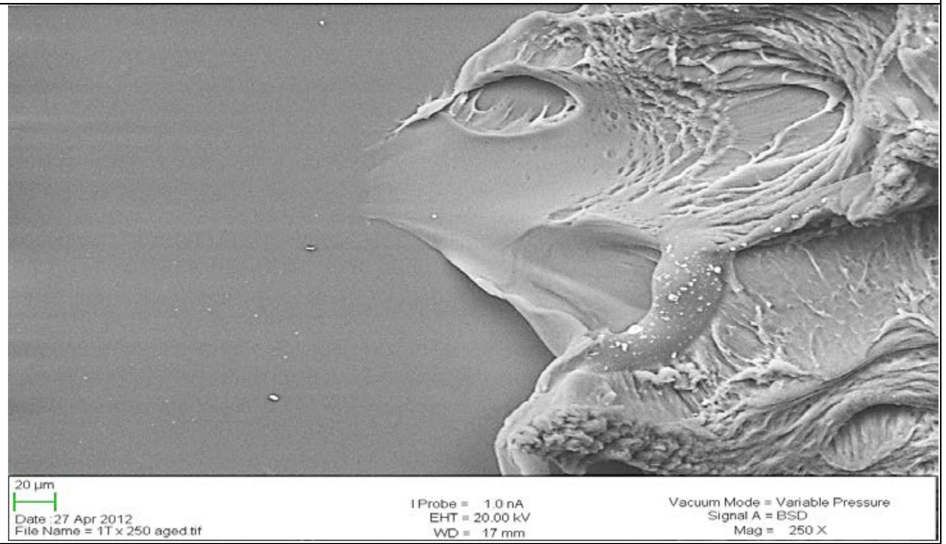


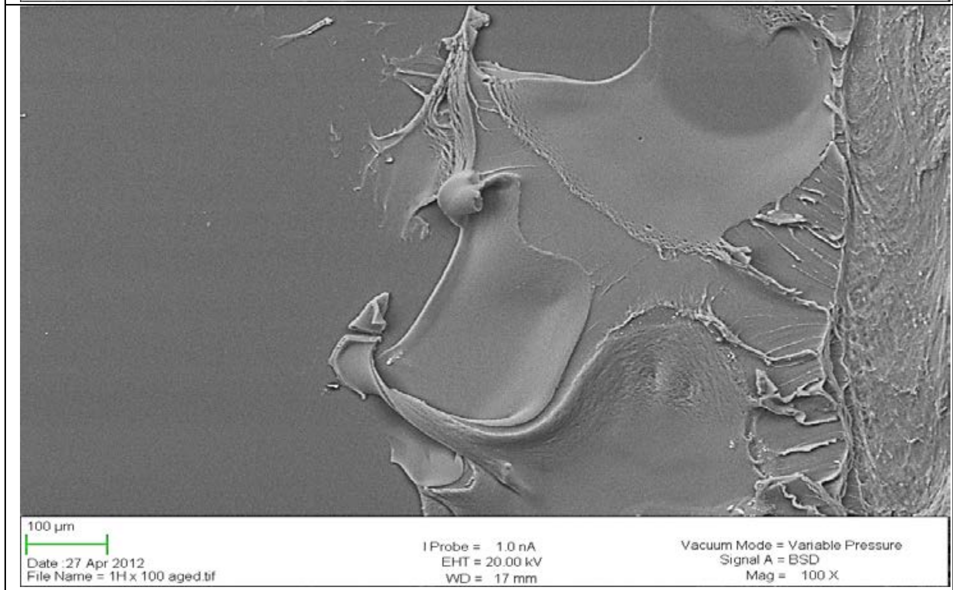


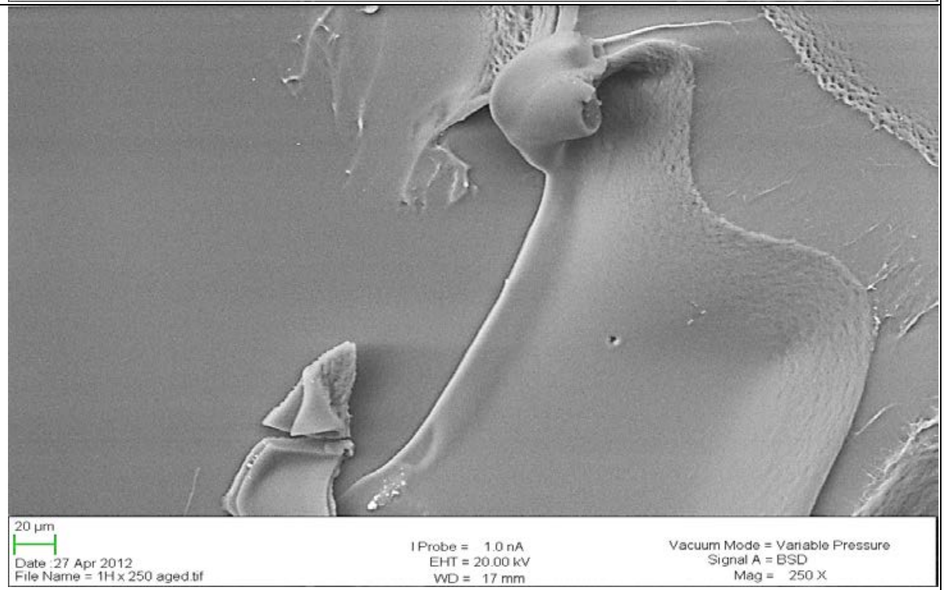


SEM Series 2 Aged

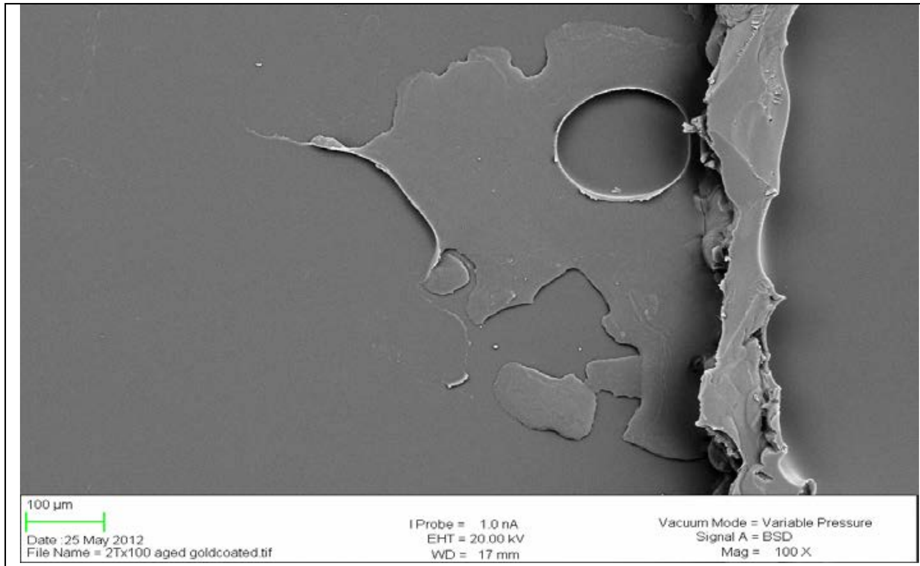


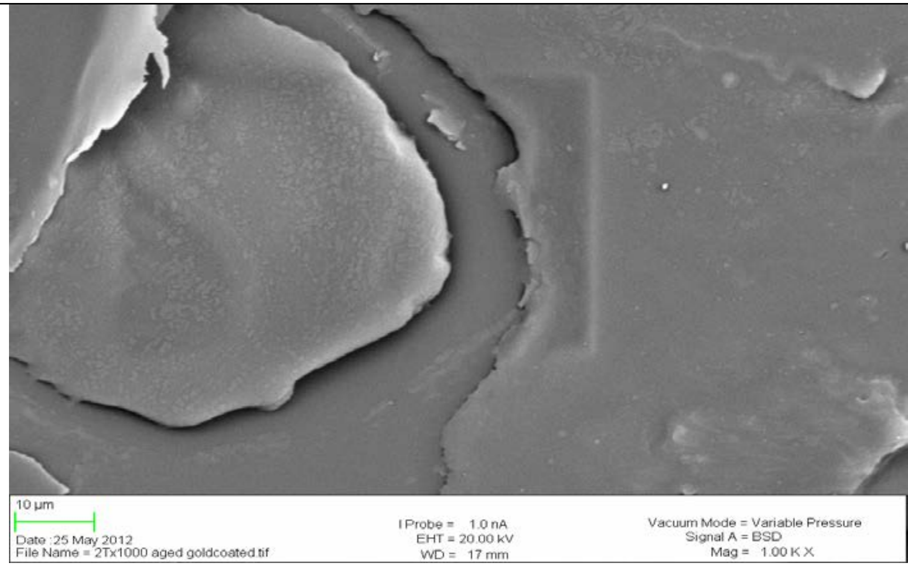


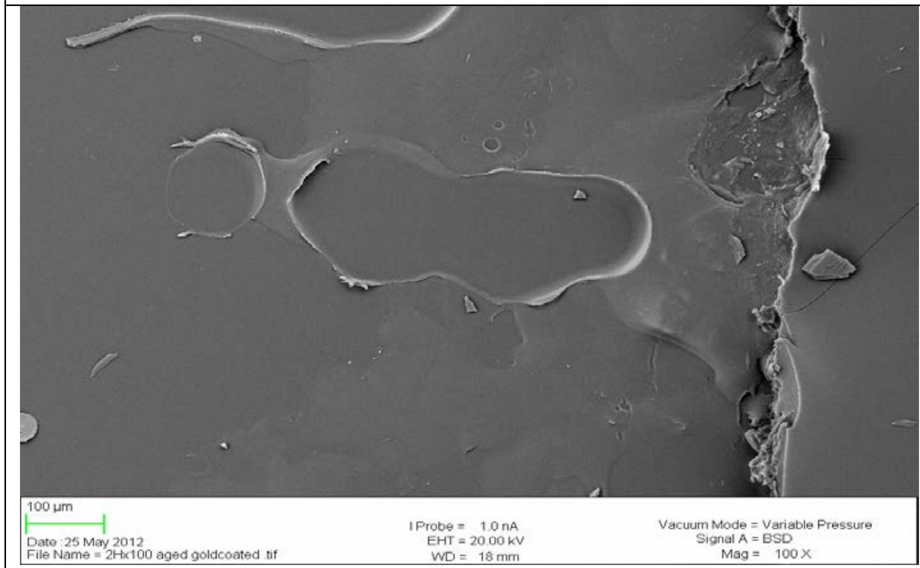


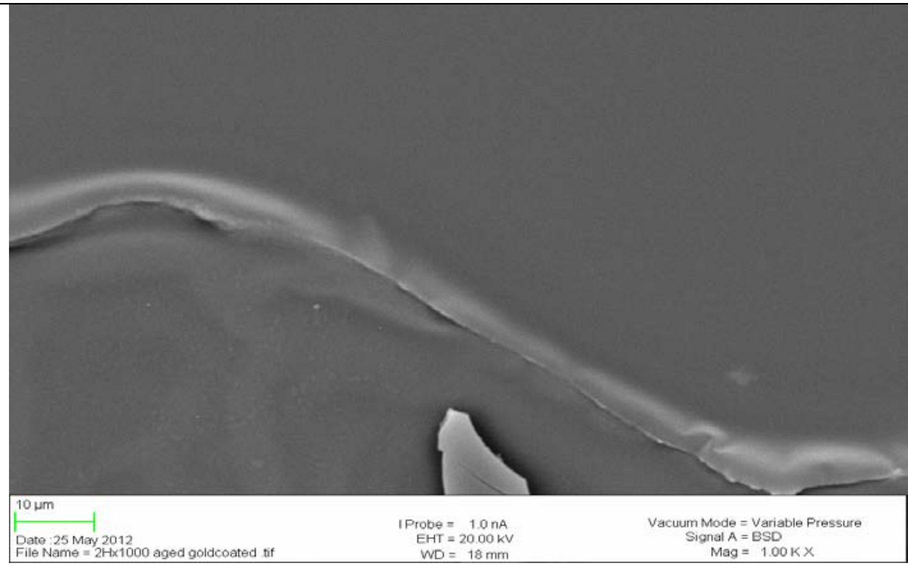


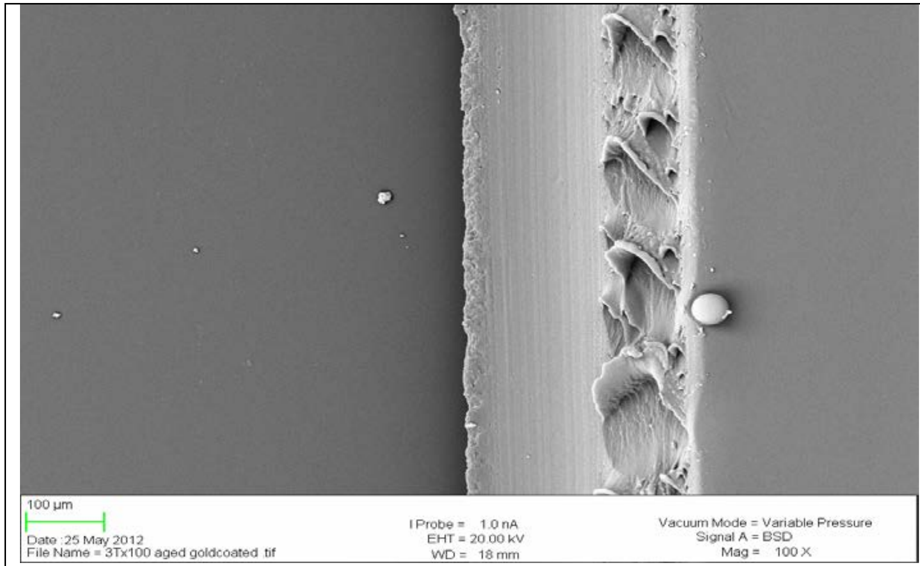
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

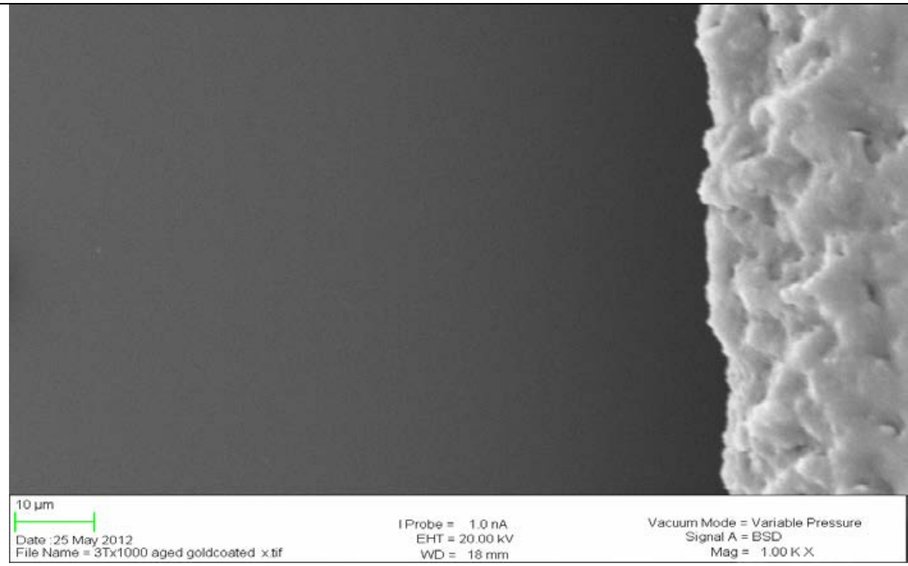


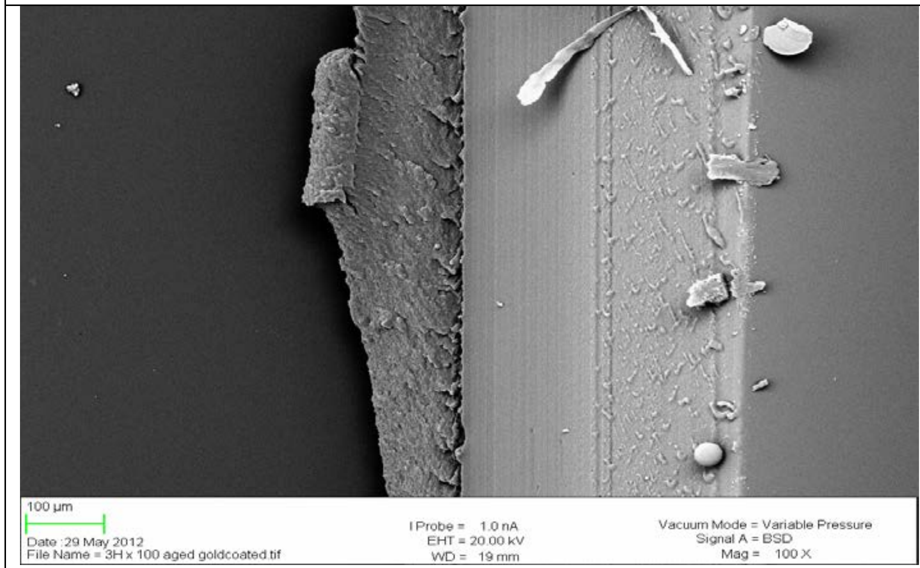







100 µm
Date :25 May 2012
File Name = 3Tx100 aged goldcoated .tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 18 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X


10 µm
Date :25 May 2012
File Name = 3Tx1000 aged goldcoated x.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 18 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 1.00 K X


100 µm
Date :29 May 2012
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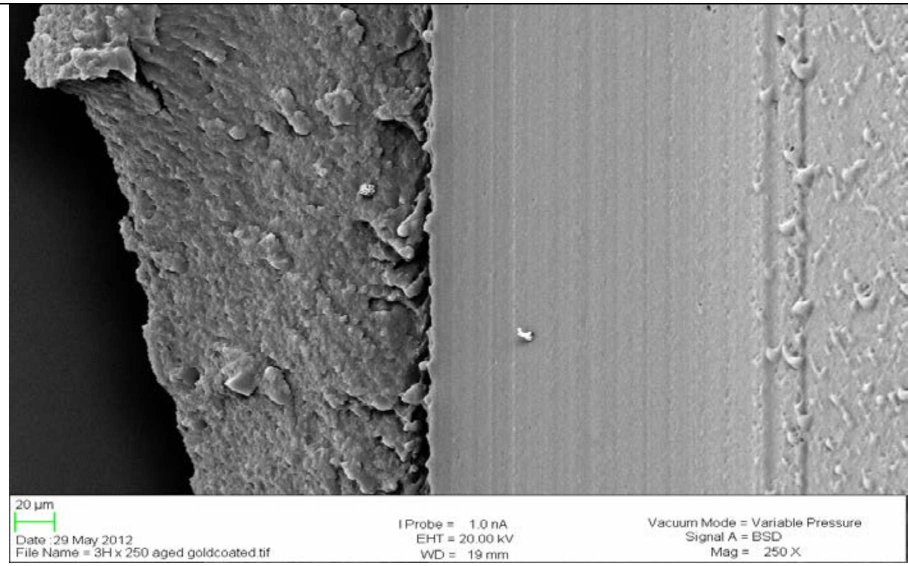
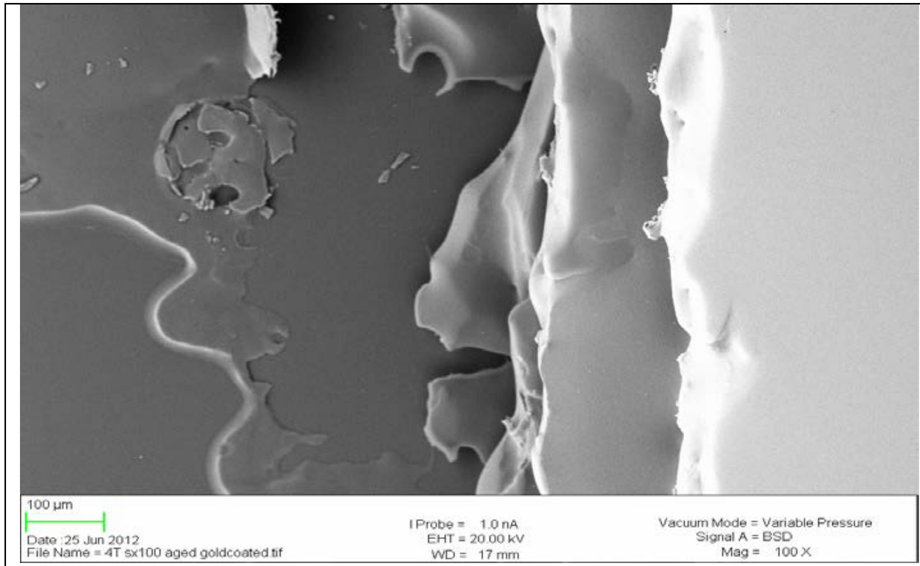
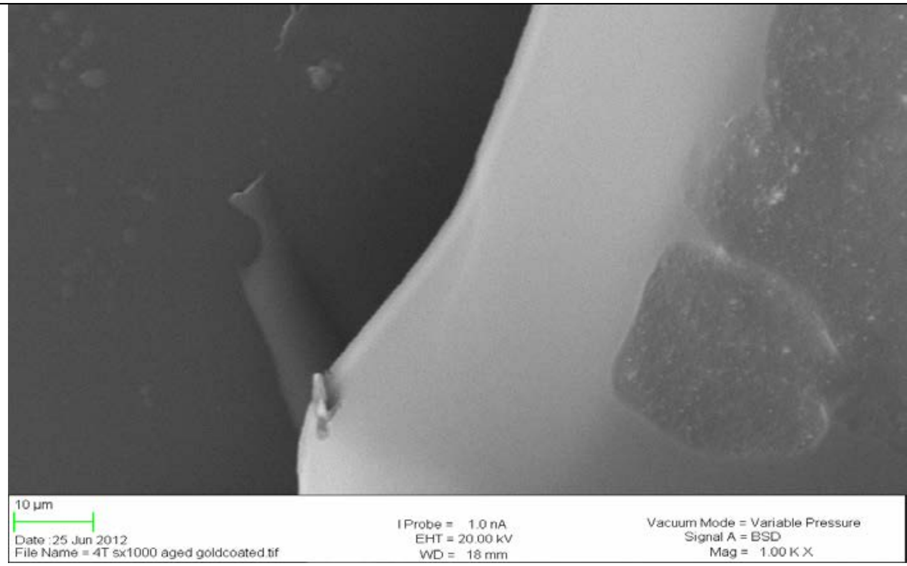
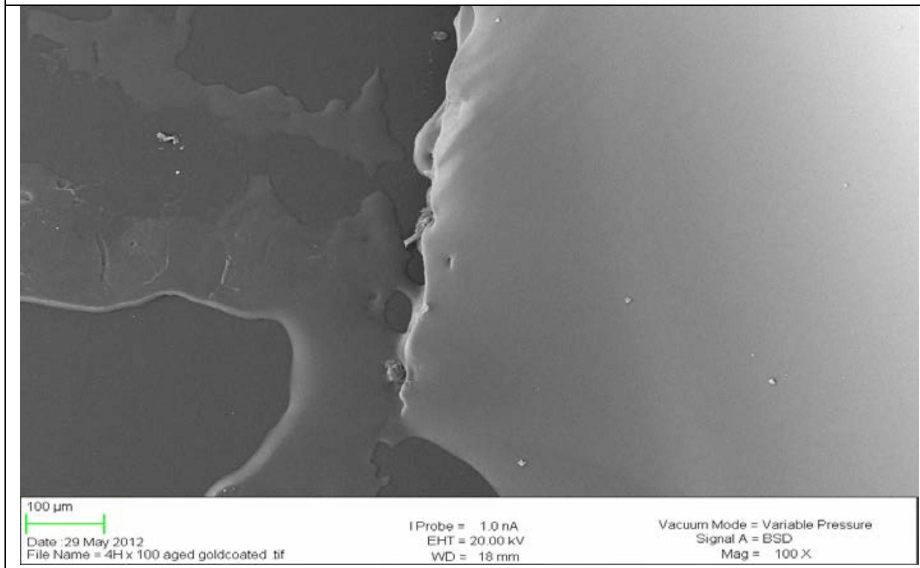
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 19 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X

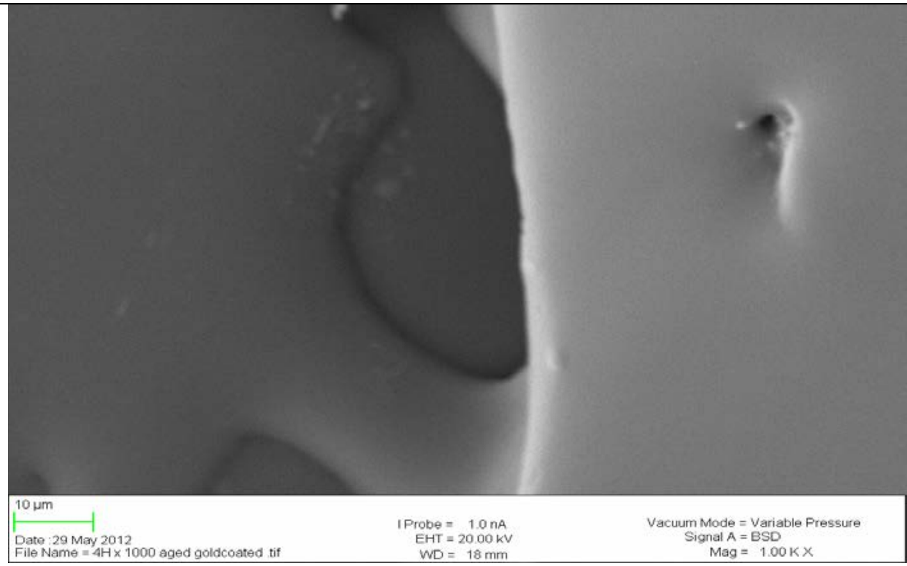

20 µm
Date :29 May 2012
File Name = 3H x 250 aged goldcoated.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 19 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 250 X

Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

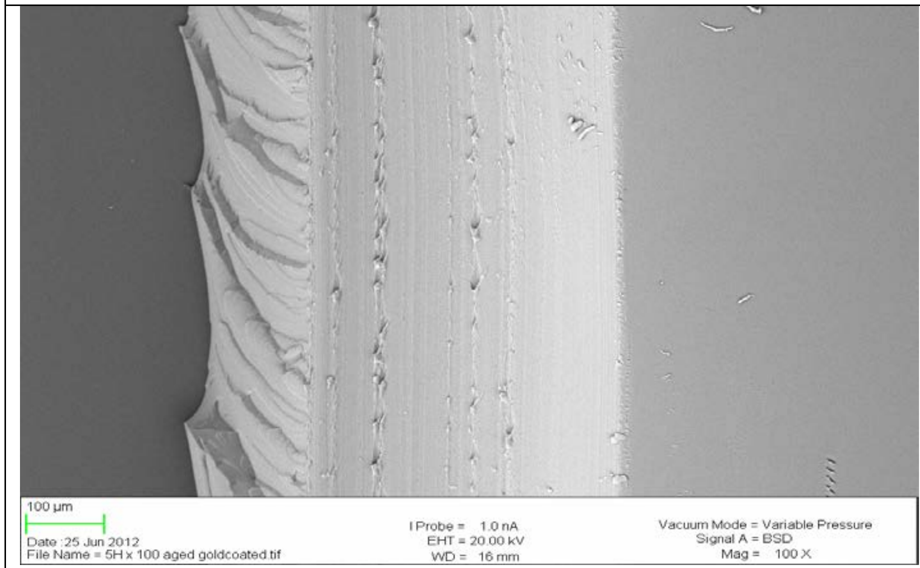


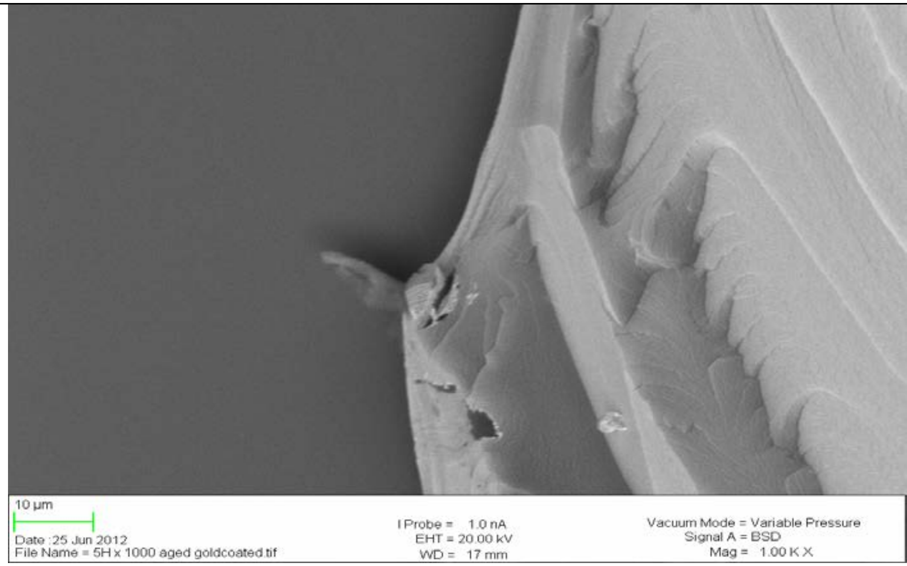




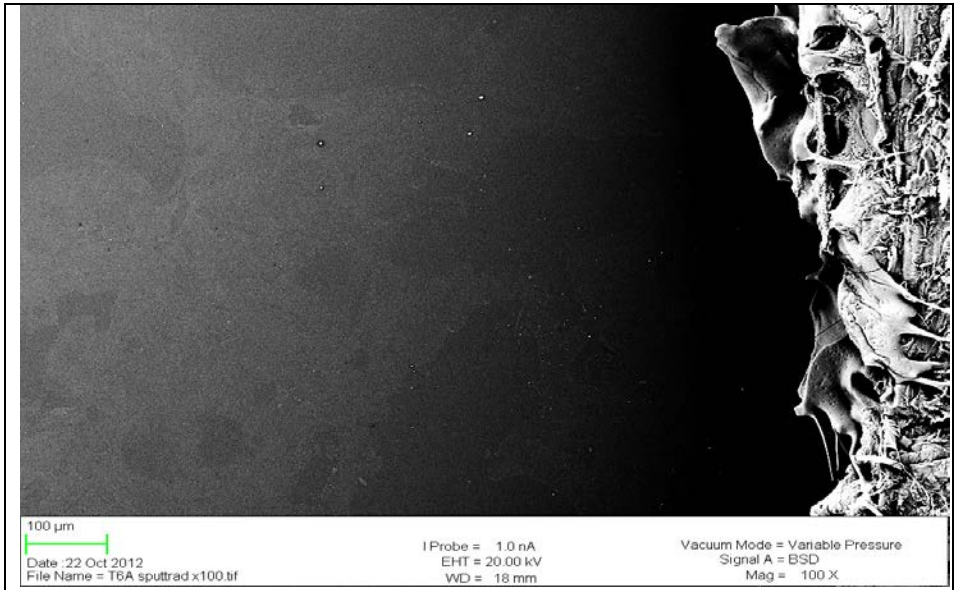


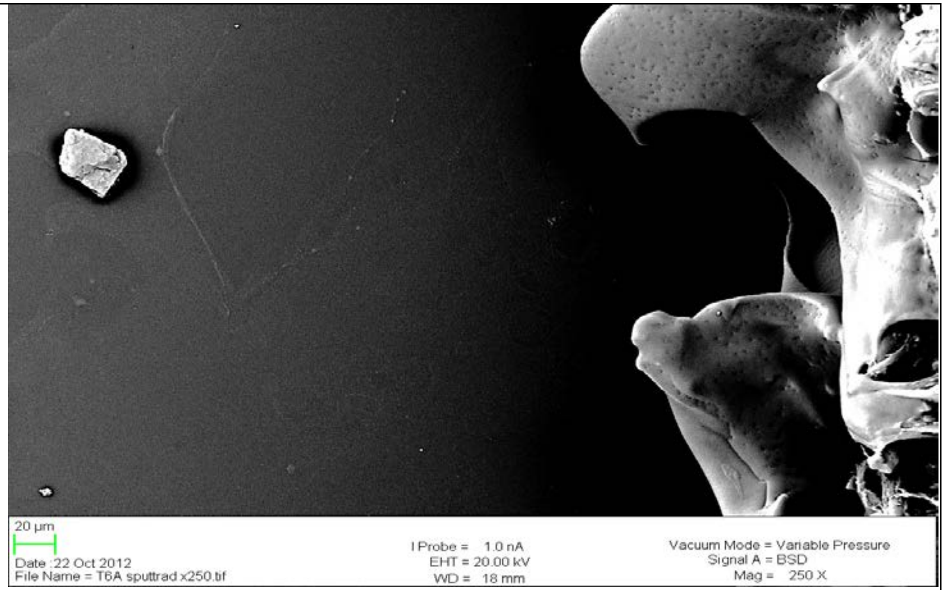
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

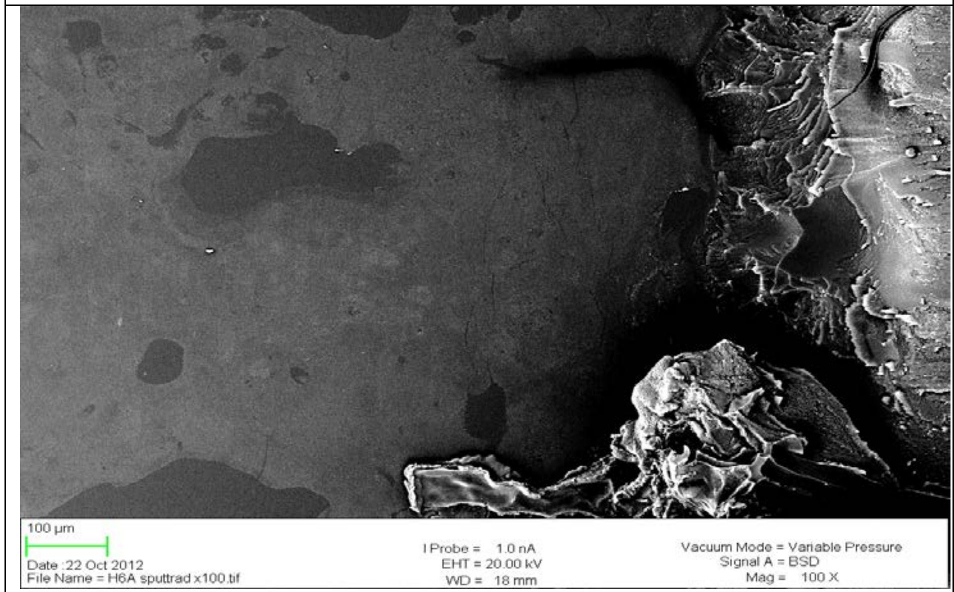


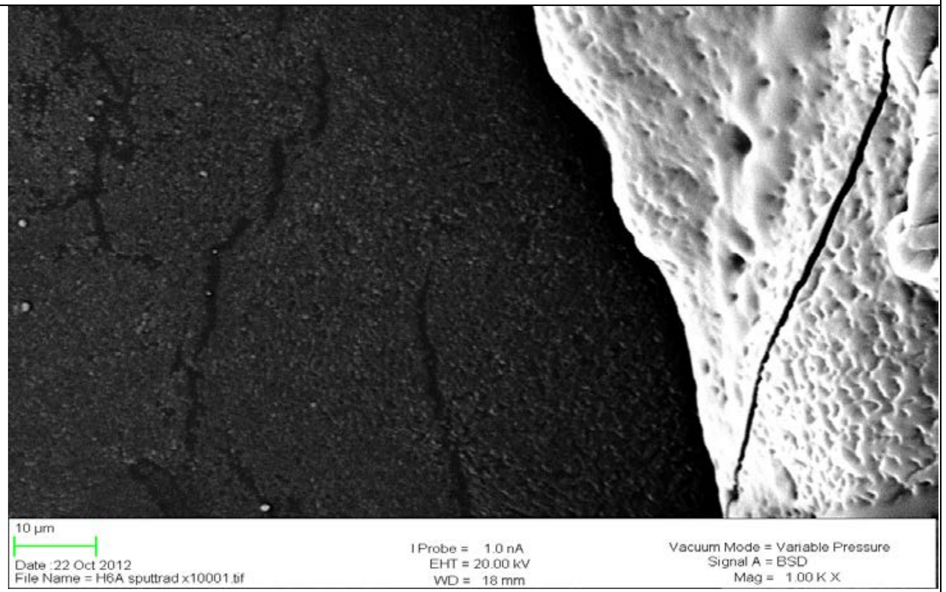


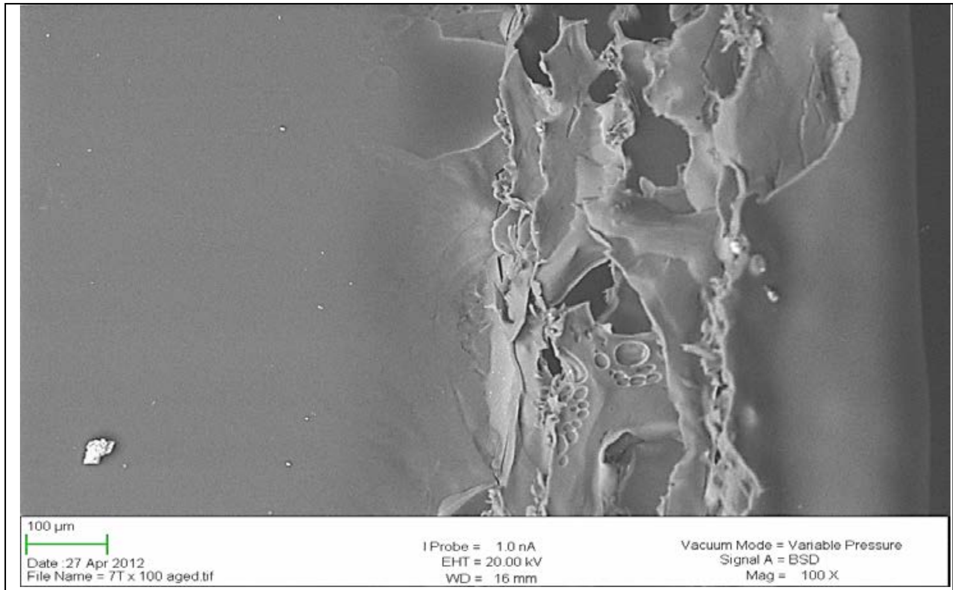
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011










100 µm
Date :27 Apr 2012
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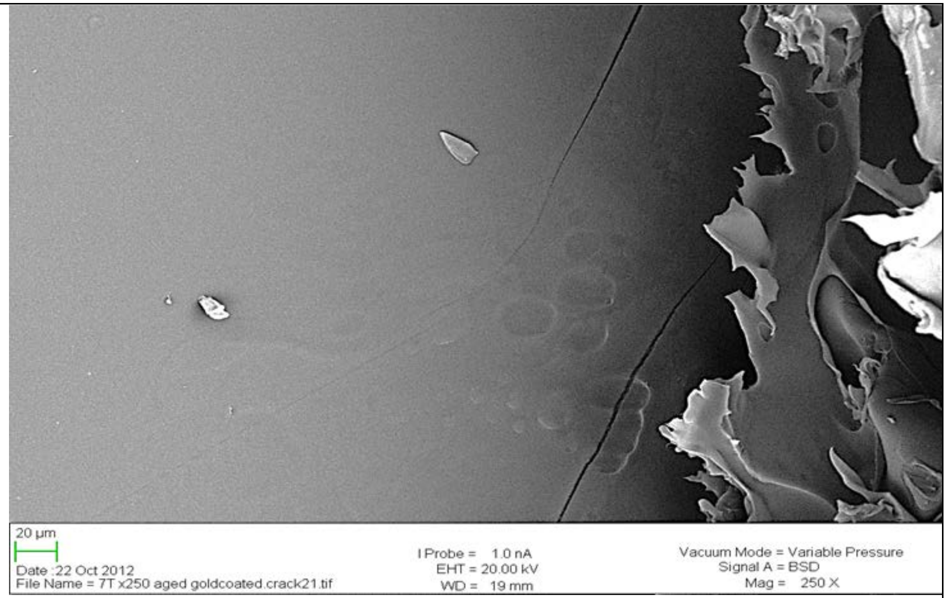
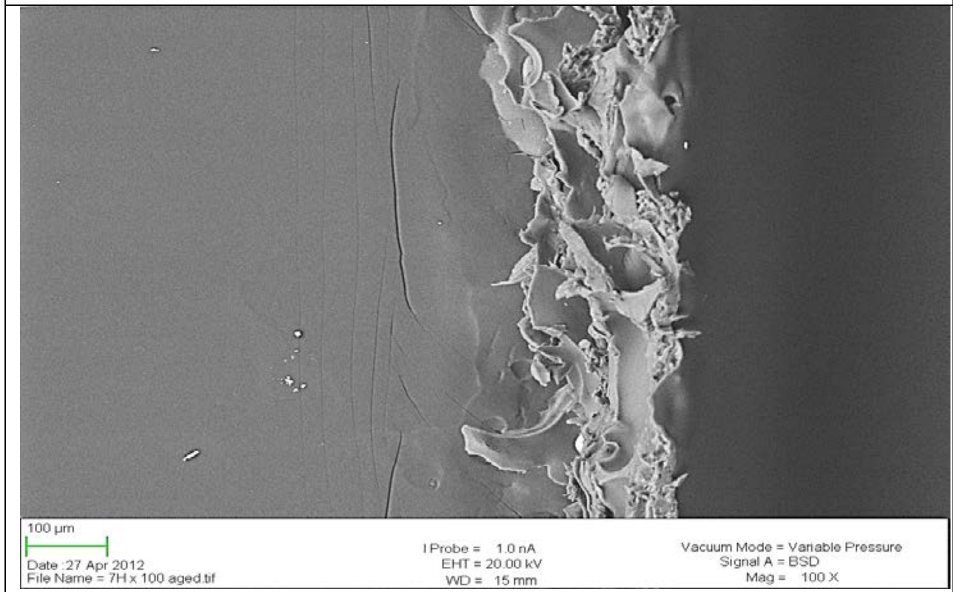
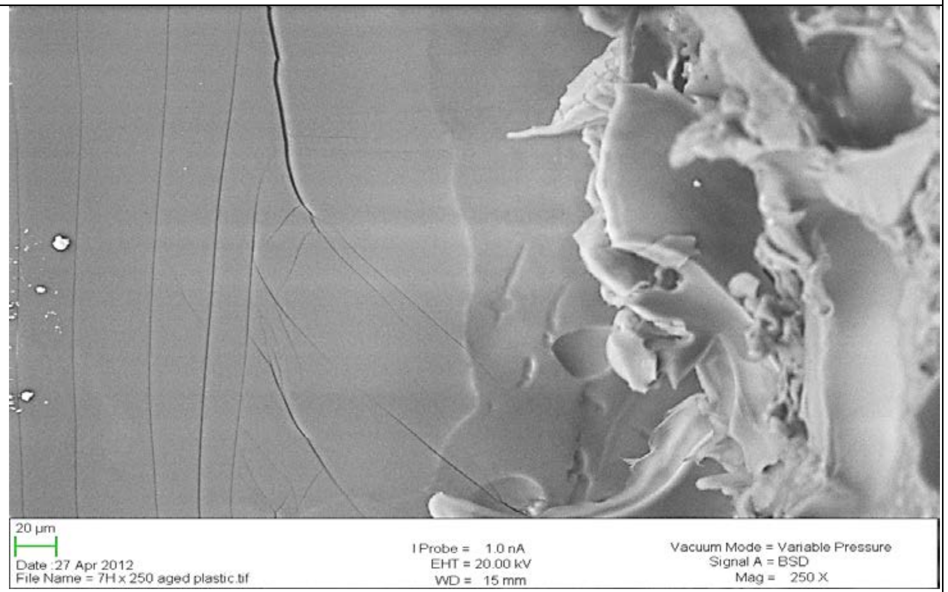
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X


20 µm
Date :22 Oct 2012
File Name = 7T x250 aged goldcoated.crack21.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 19 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 250 X


100 µm
Date :27 Apr 2012
File Name = 7H x 100 aged.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 15 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X


20 µm
Date :27 Apr 2012
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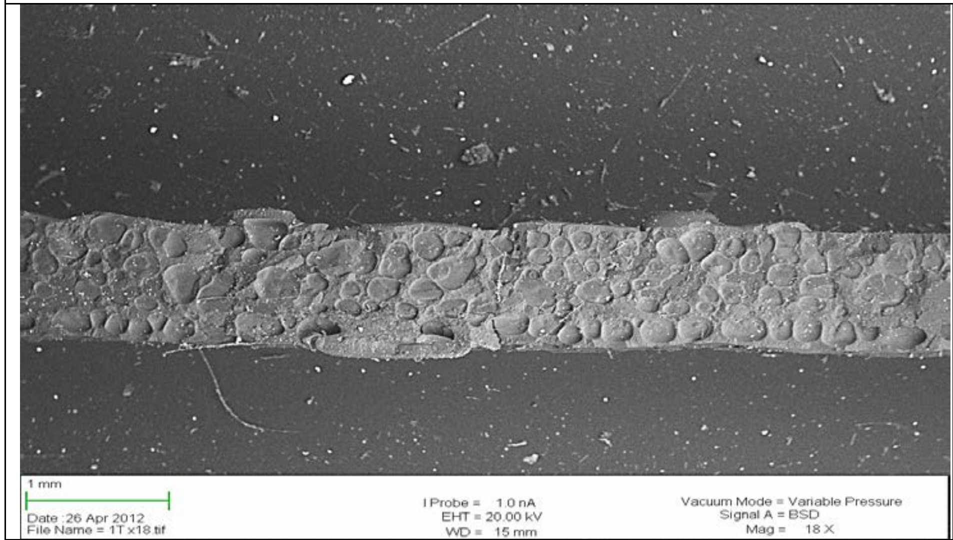
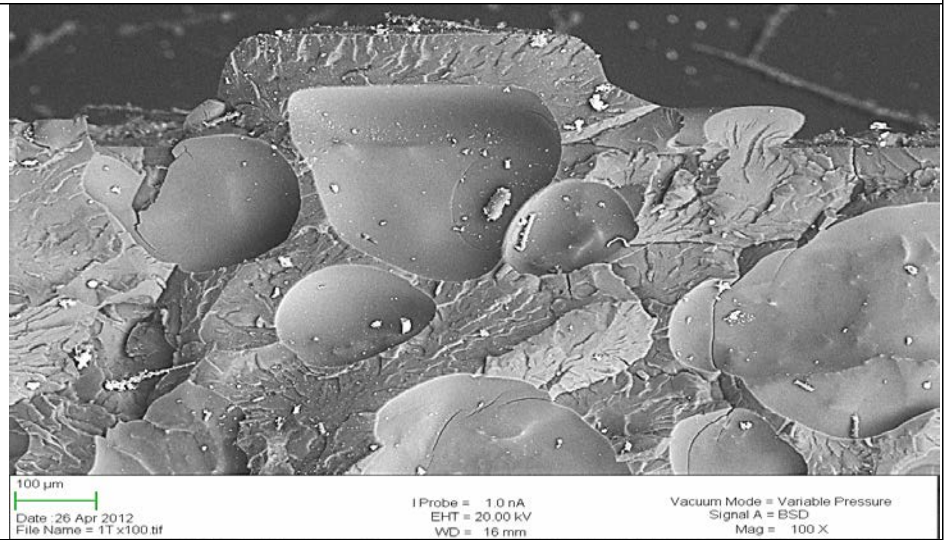
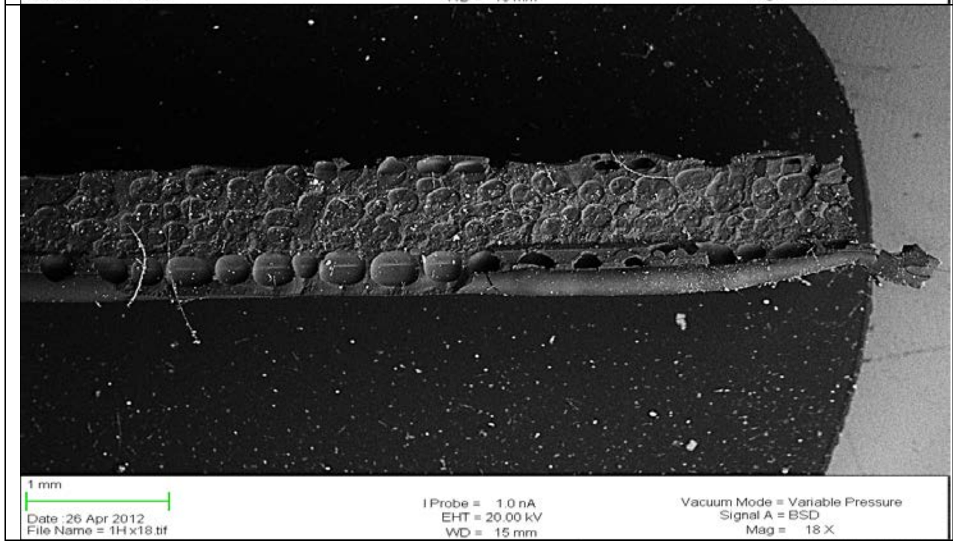
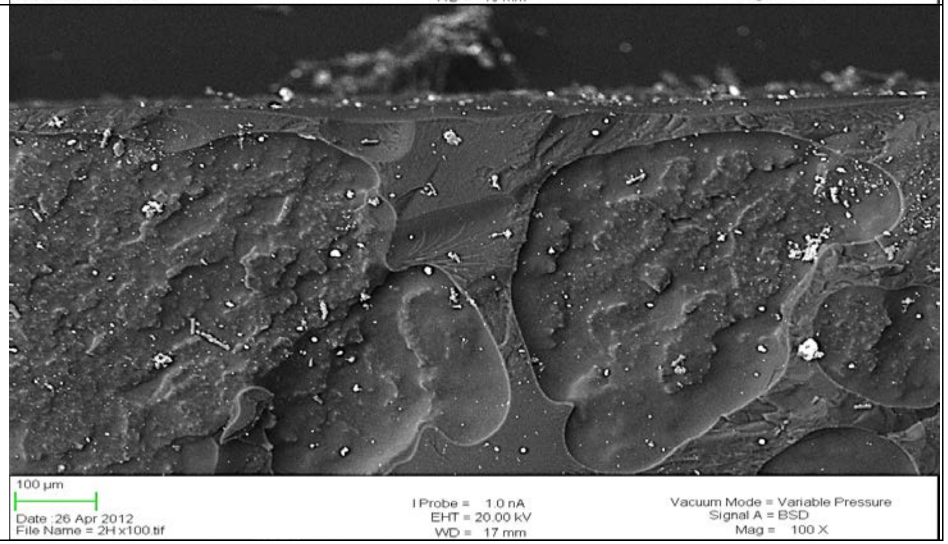
EHT = 20.00 kV
WD = 15 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 250 X

SEM Series1 Unaged










1 mm
Date :26 Apr 2012
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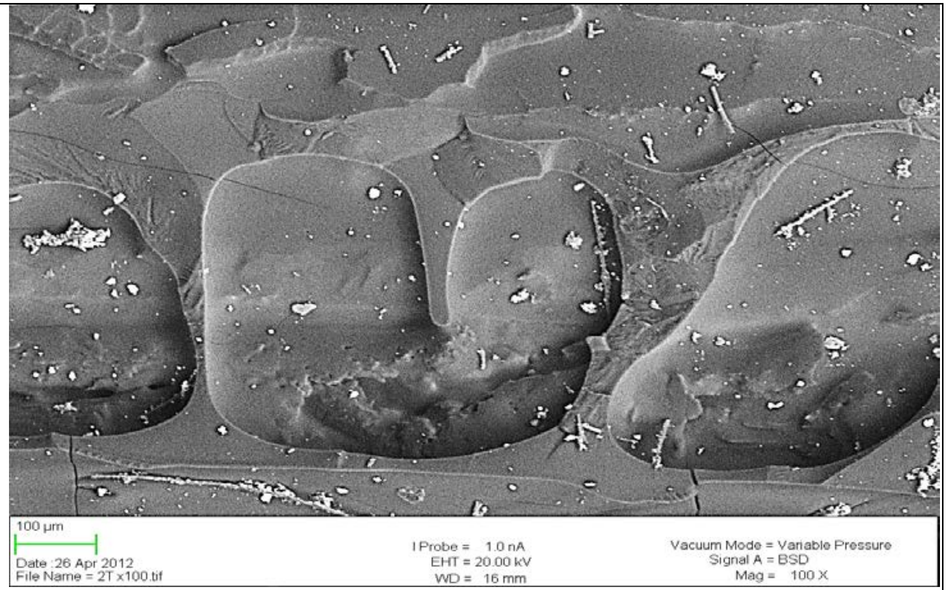
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X


100 µm
Date :26 Apr 2012
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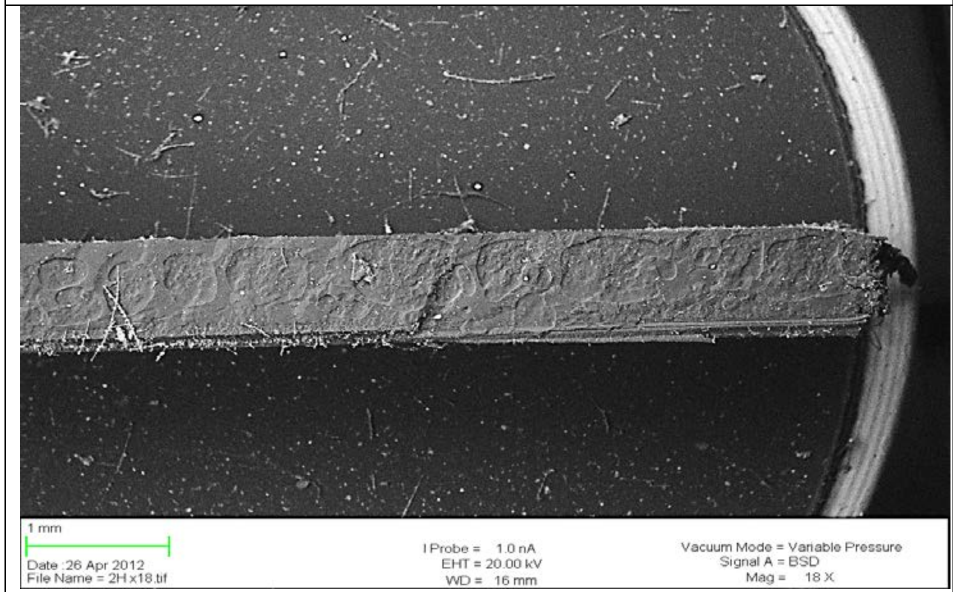
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X


1 mm
Date :26 Apr 2012
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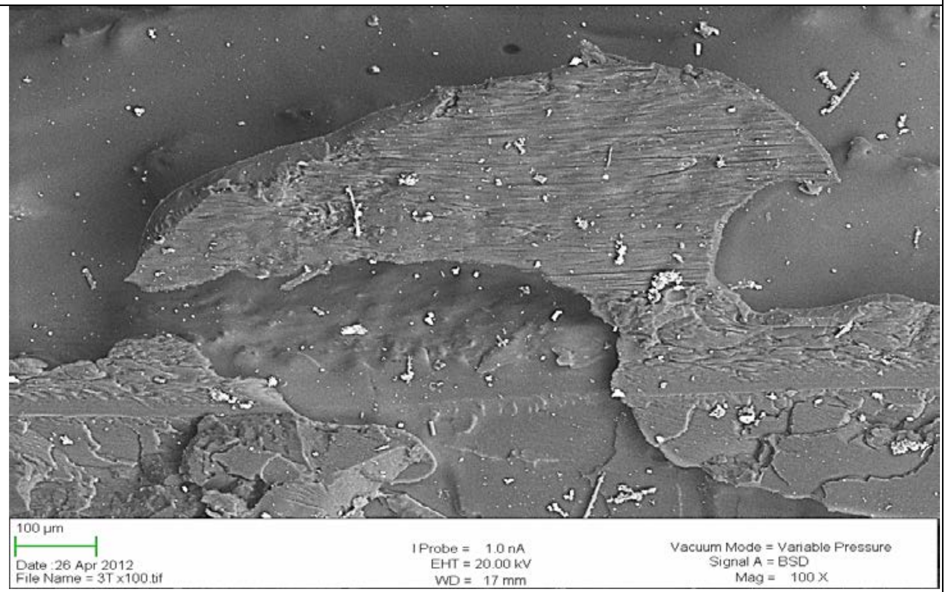
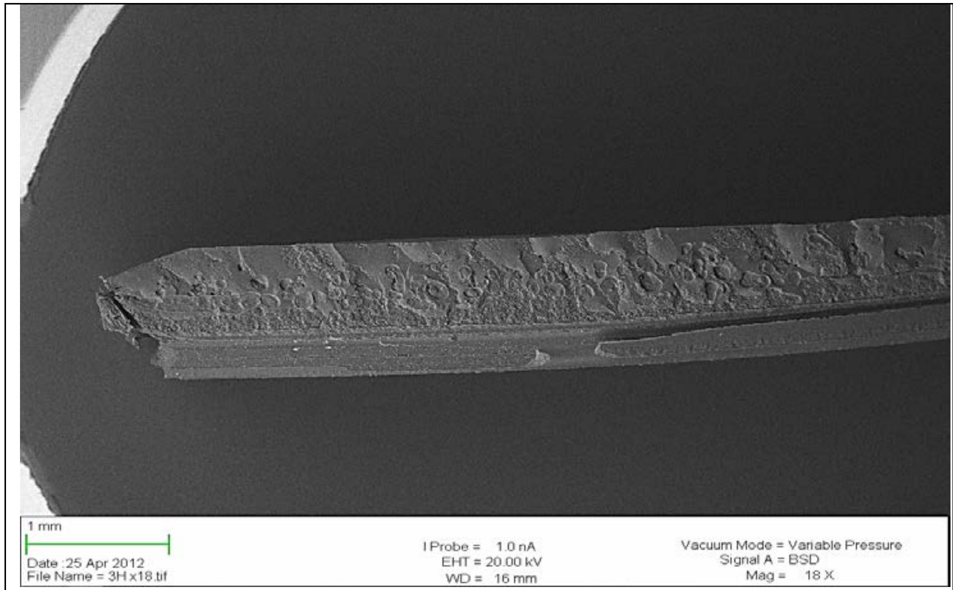
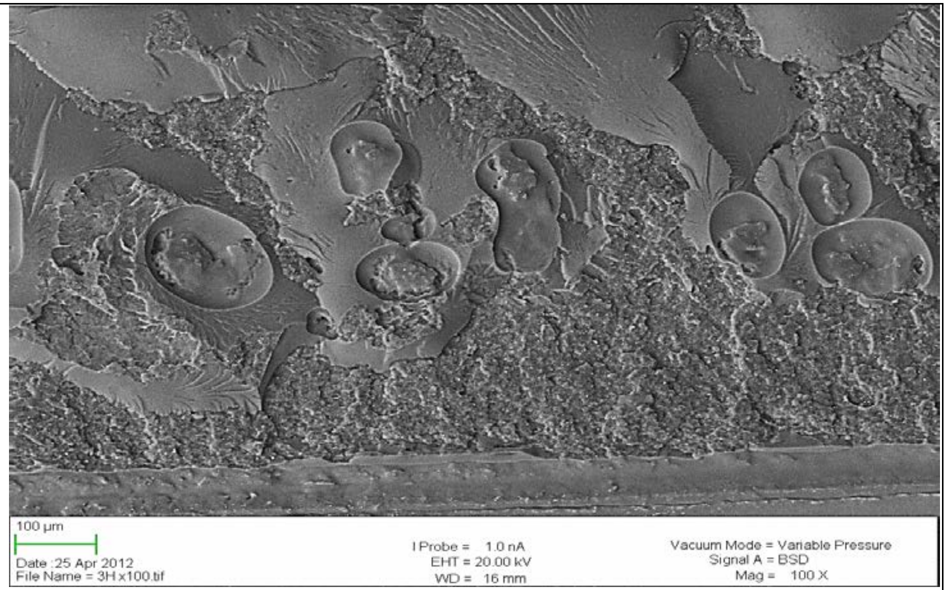
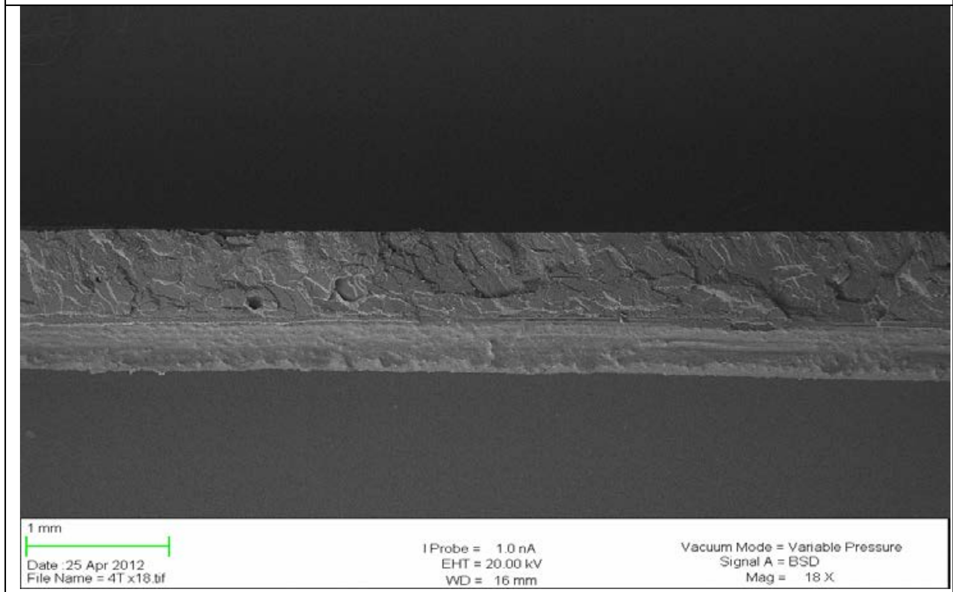
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X

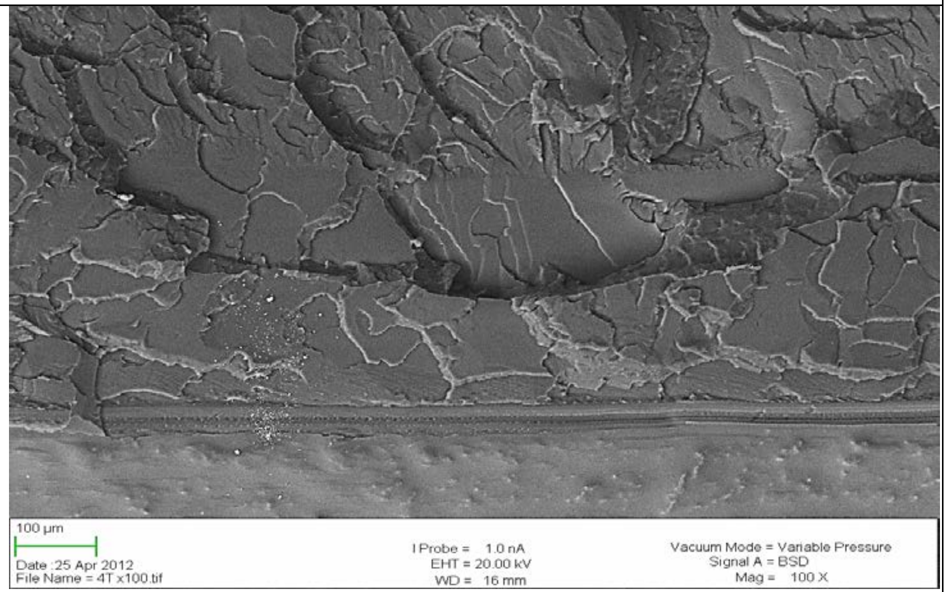

100 µm
Date :26 Apr 2012
File Name = 3T x100.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 17 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X

Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

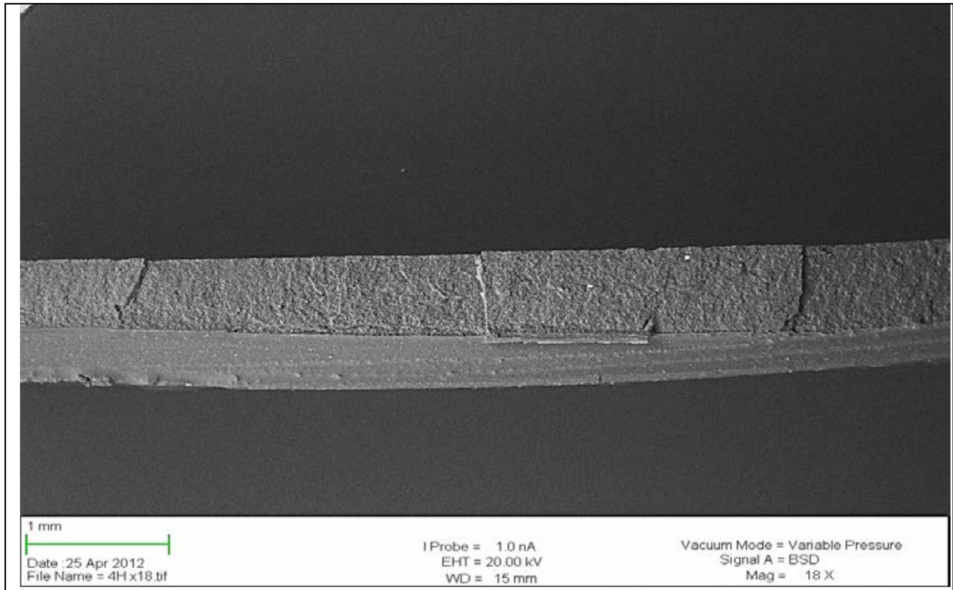


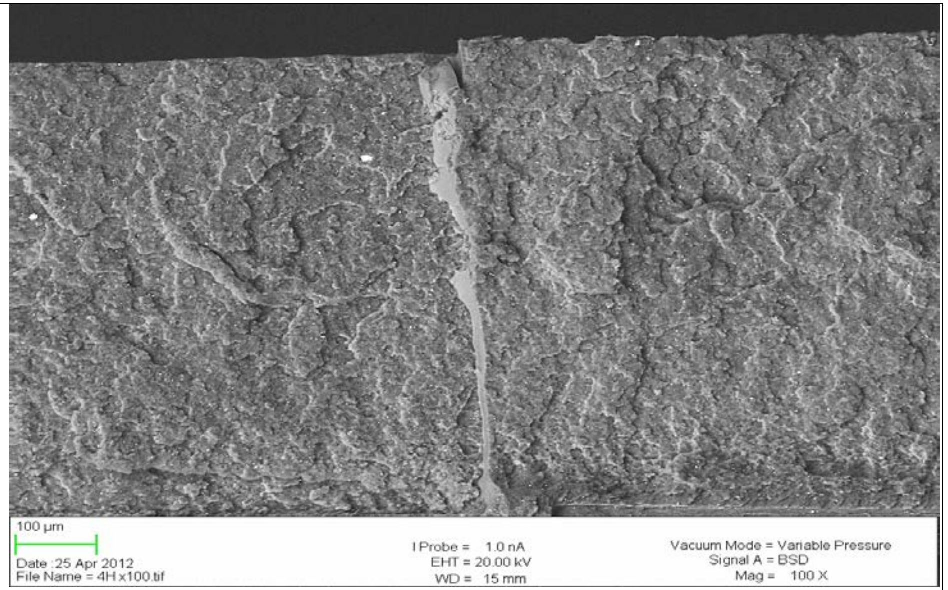


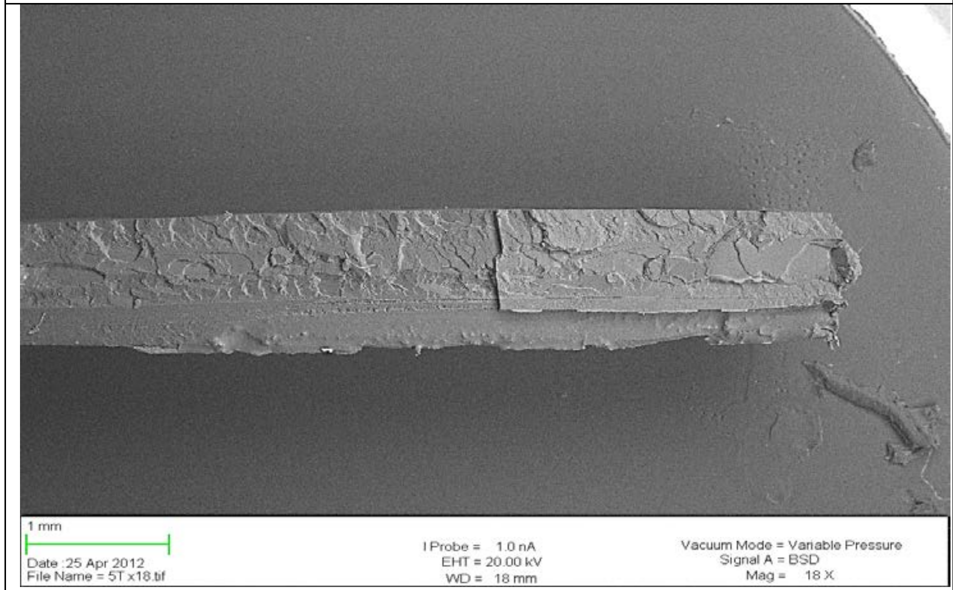


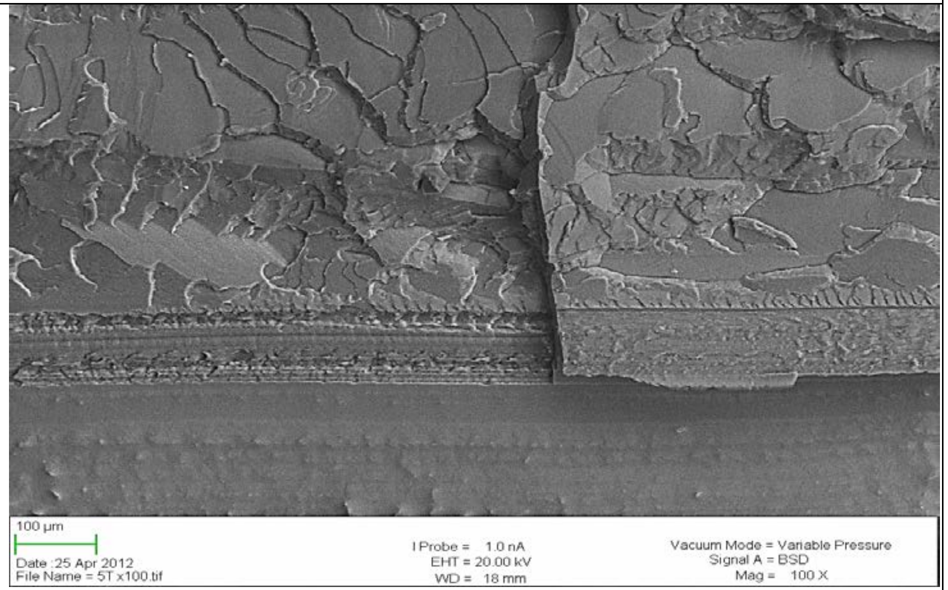


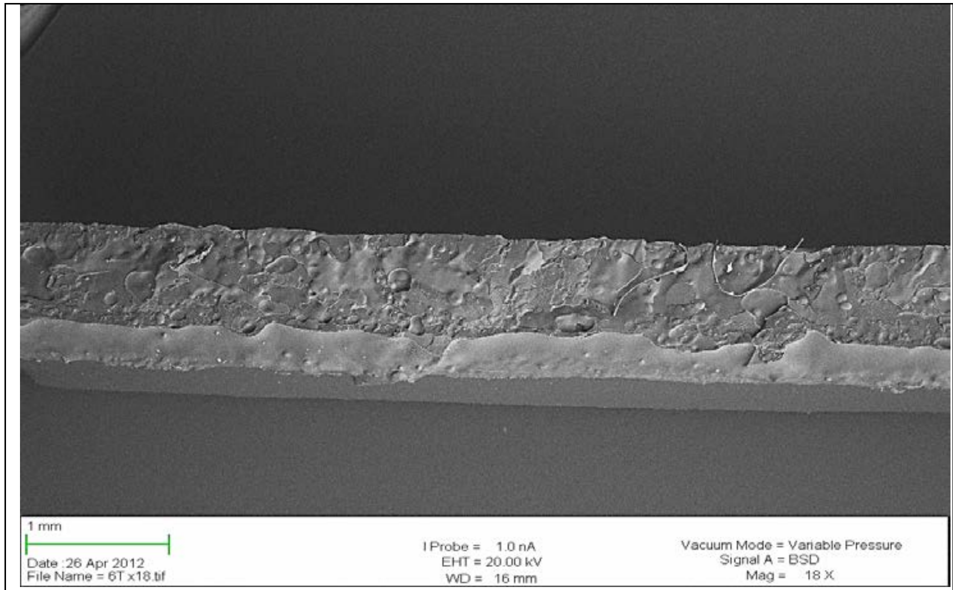
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011










1 mm
Date :26 Apr 2012
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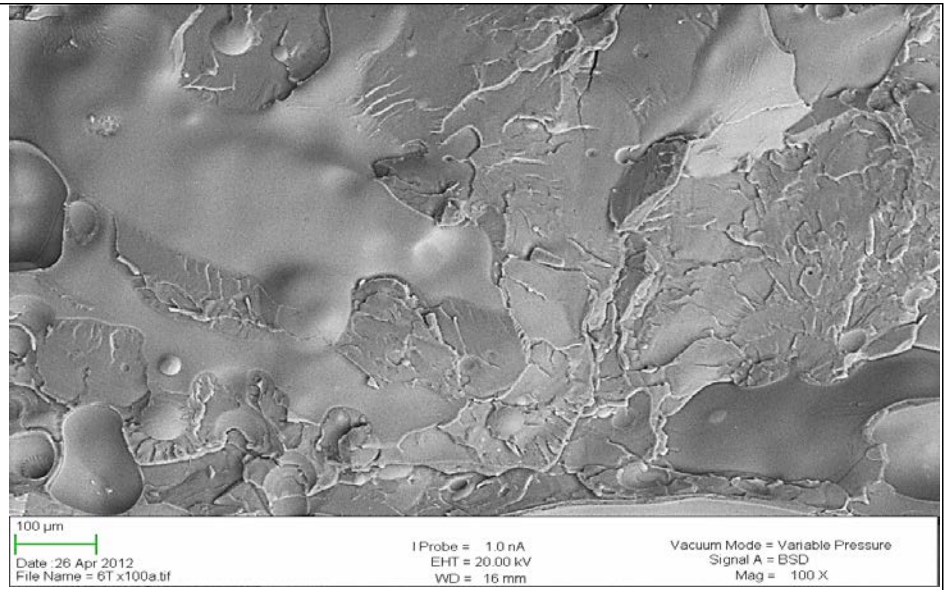
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X


100 µm
Date :26 Apr 2012
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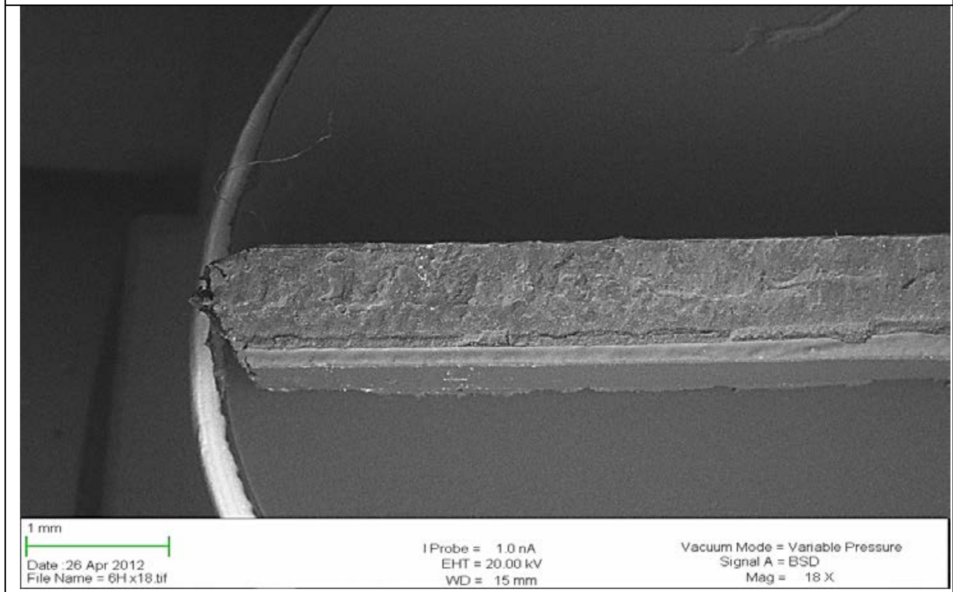
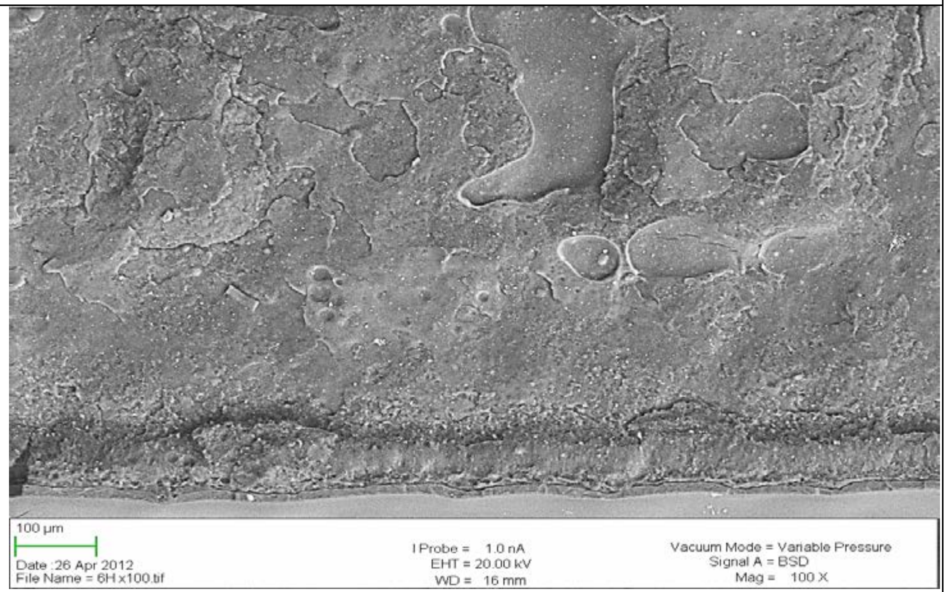
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X


1 mm
Date :26 Apr 2012
File Name = 6H x18.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 15 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X


100 µm
Date :26 Apr 2012
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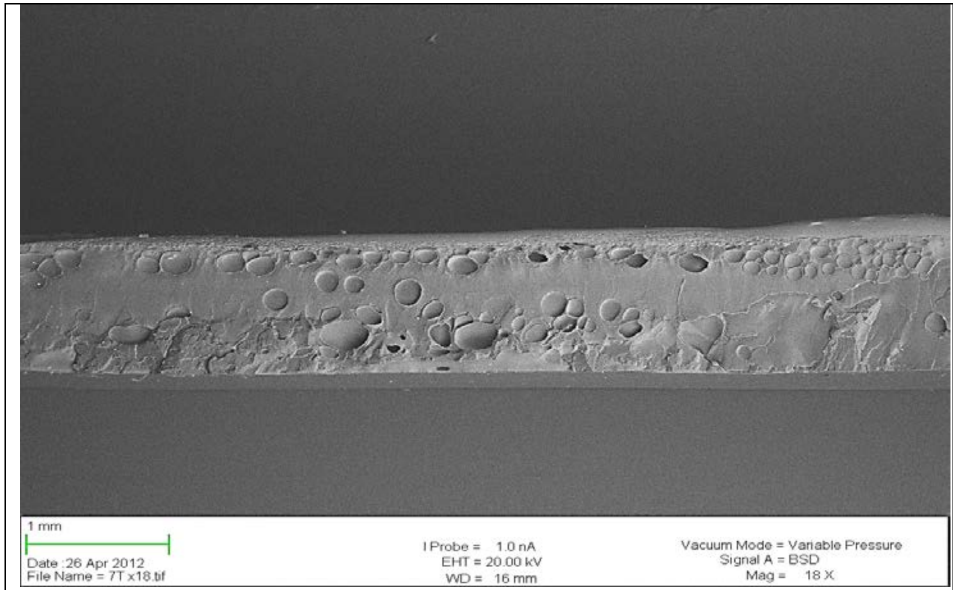
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X


1 mm
Date :26 Apr 2012
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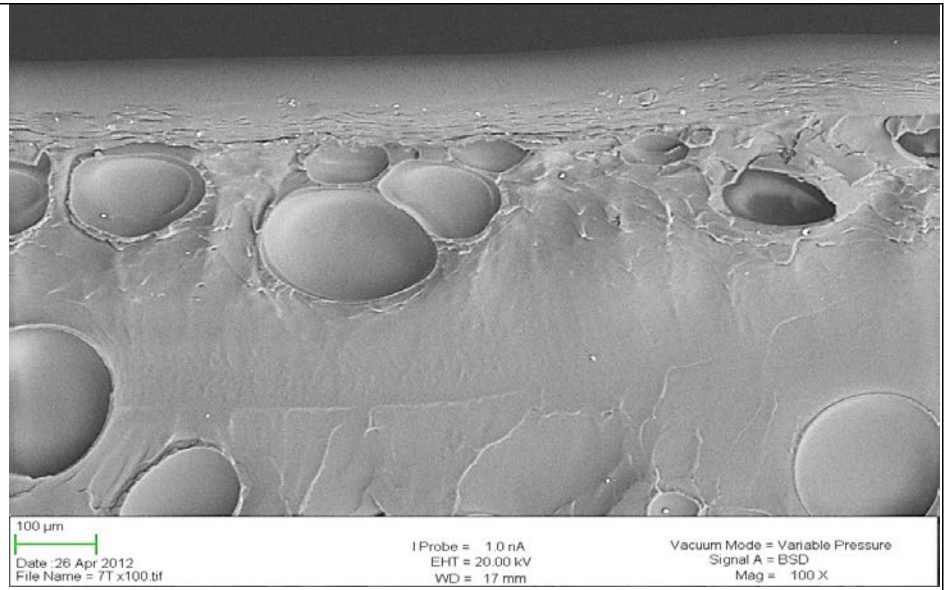
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X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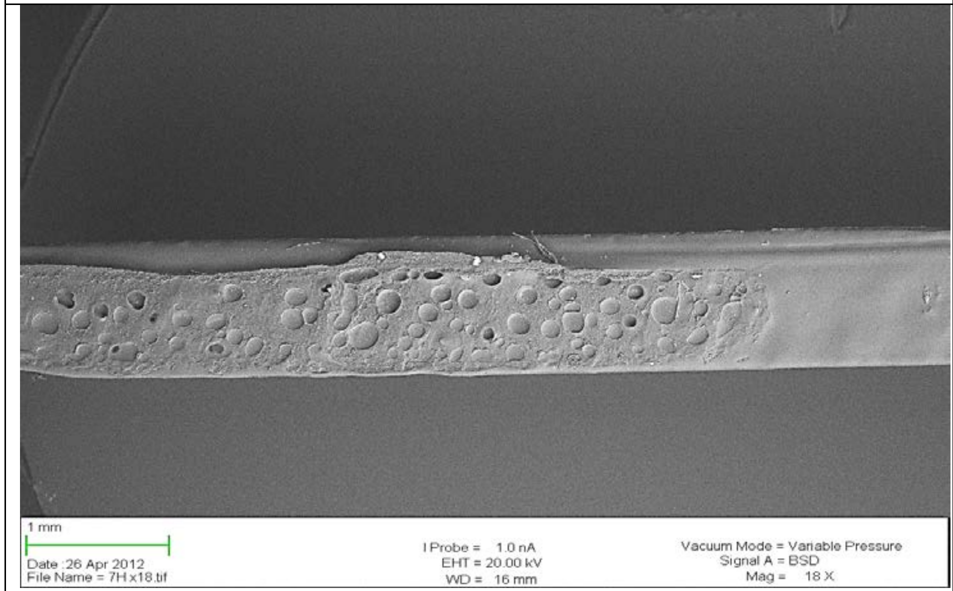
Signal A = BSD
Mag = 100 X


1 mm
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File Name = 7H x18.tif
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WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X


100 µm
Date :26 Apr 2012
File Name = 7H x100.tif
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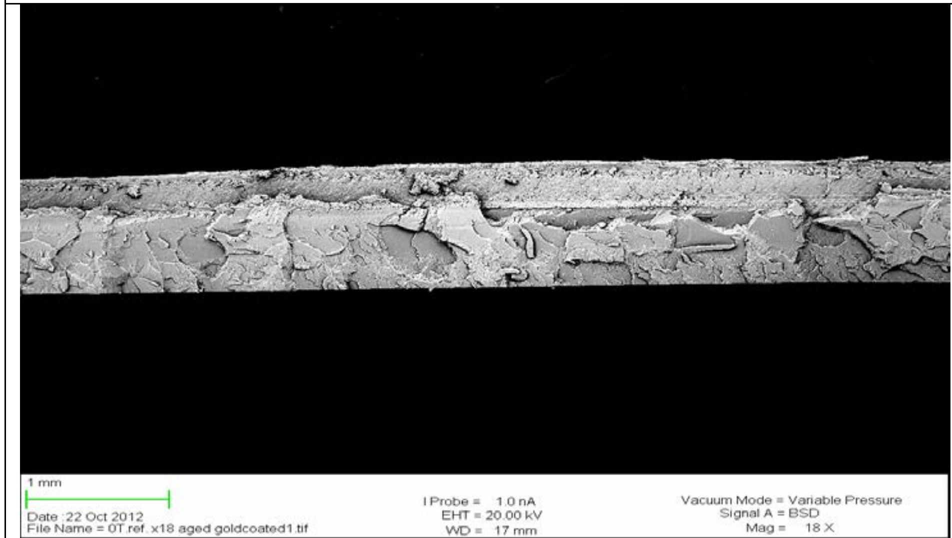
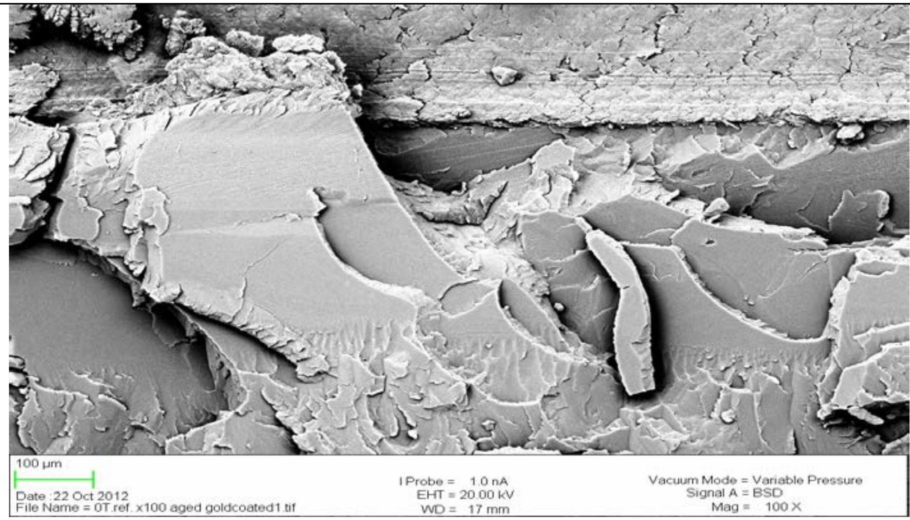
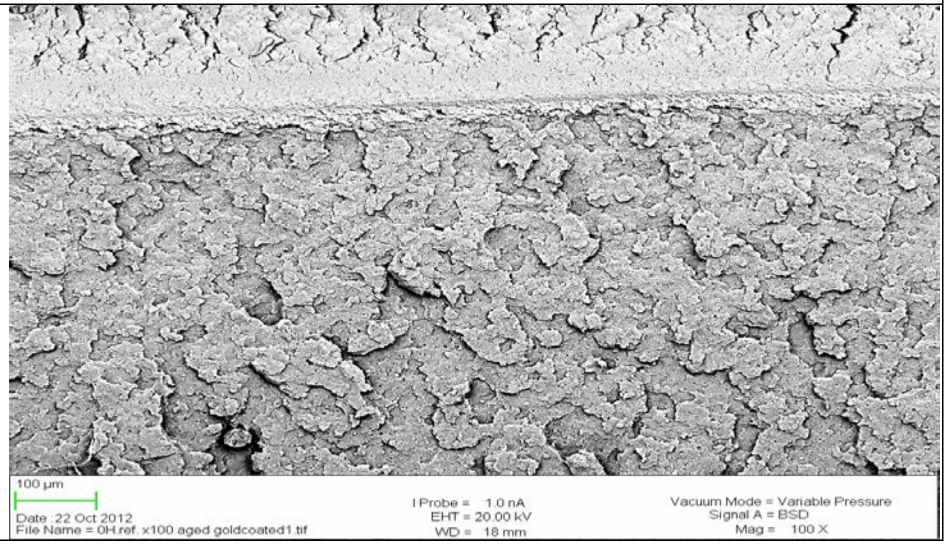
EHT = 20.00 kV
WD = 16 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X

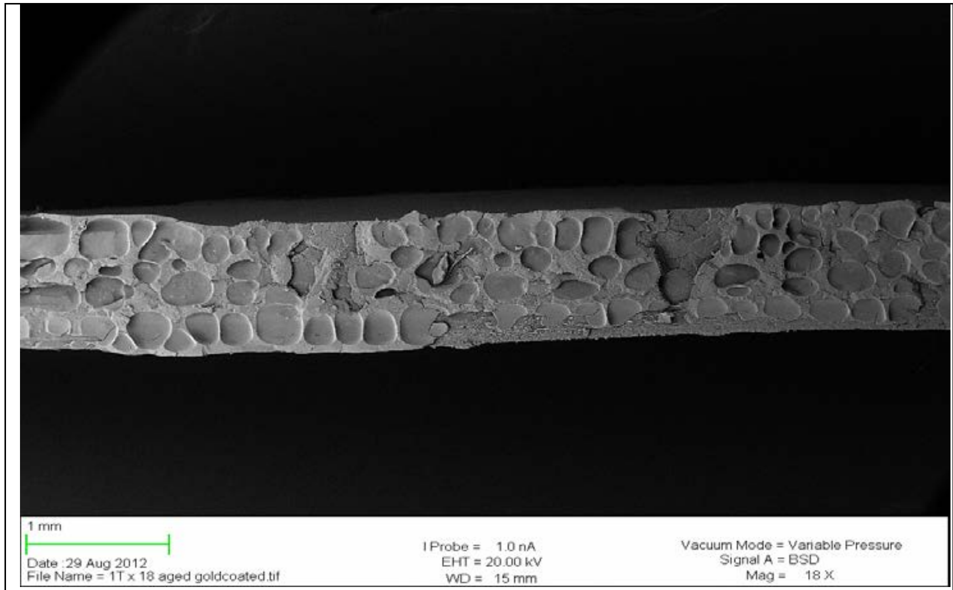
SEM Series1 Aged

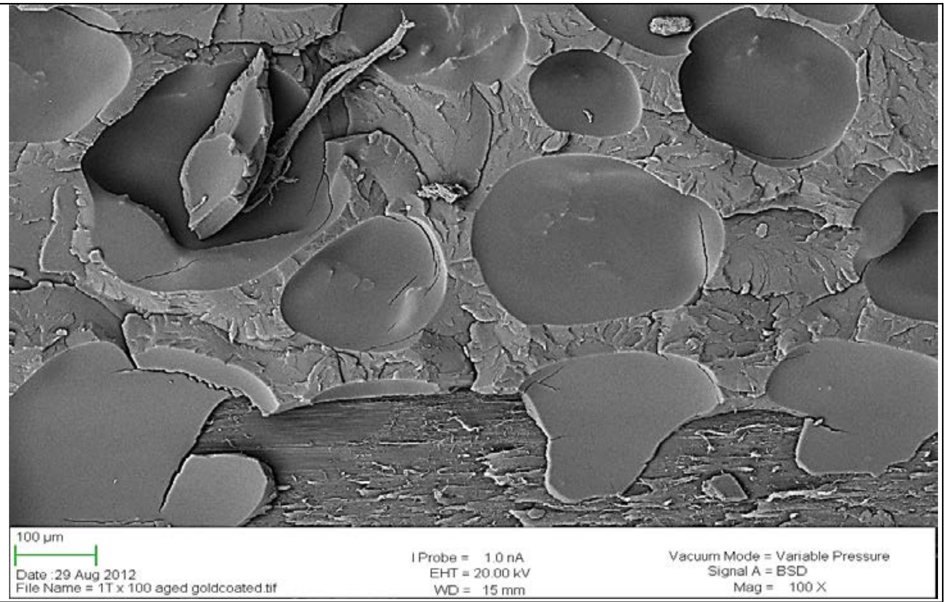


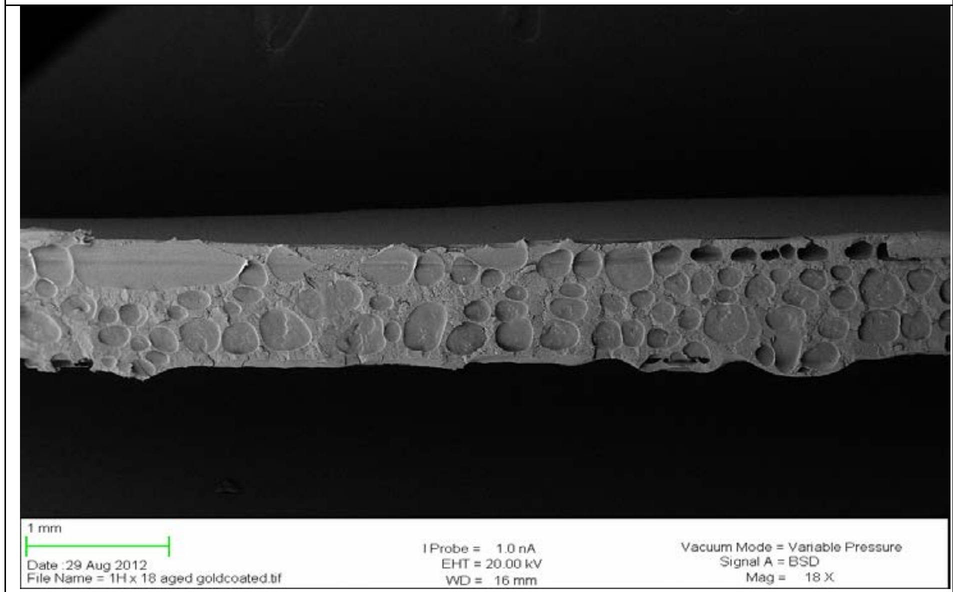


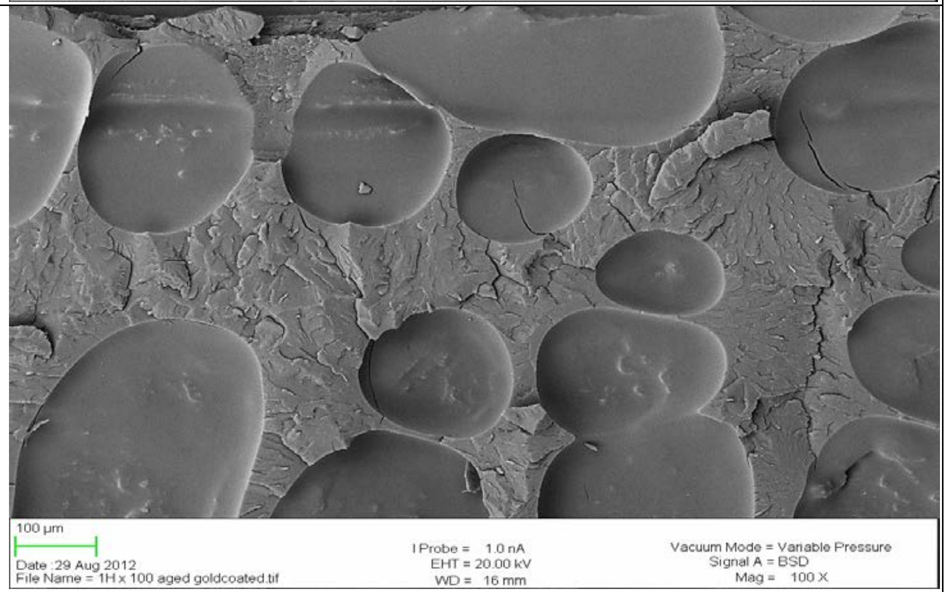


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

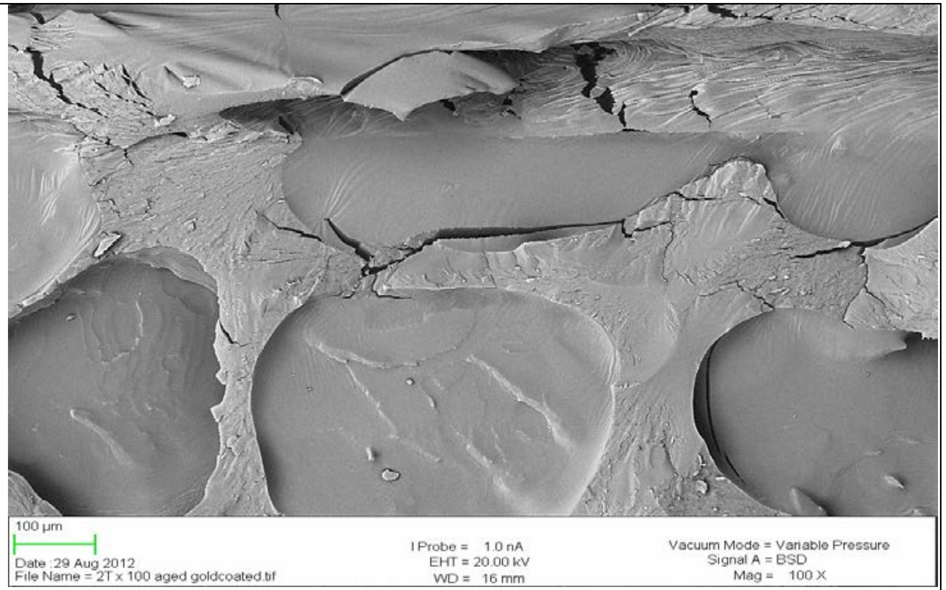


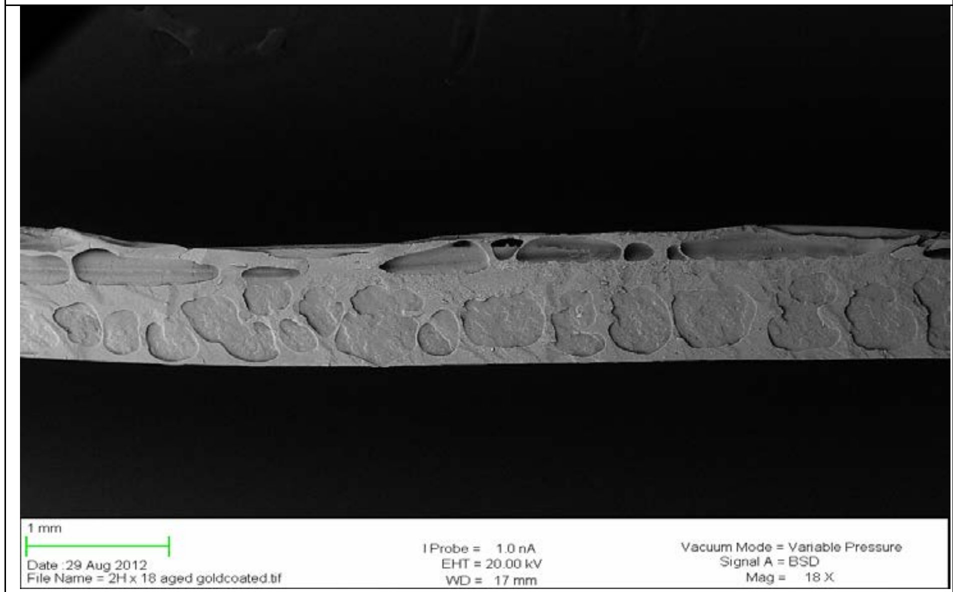


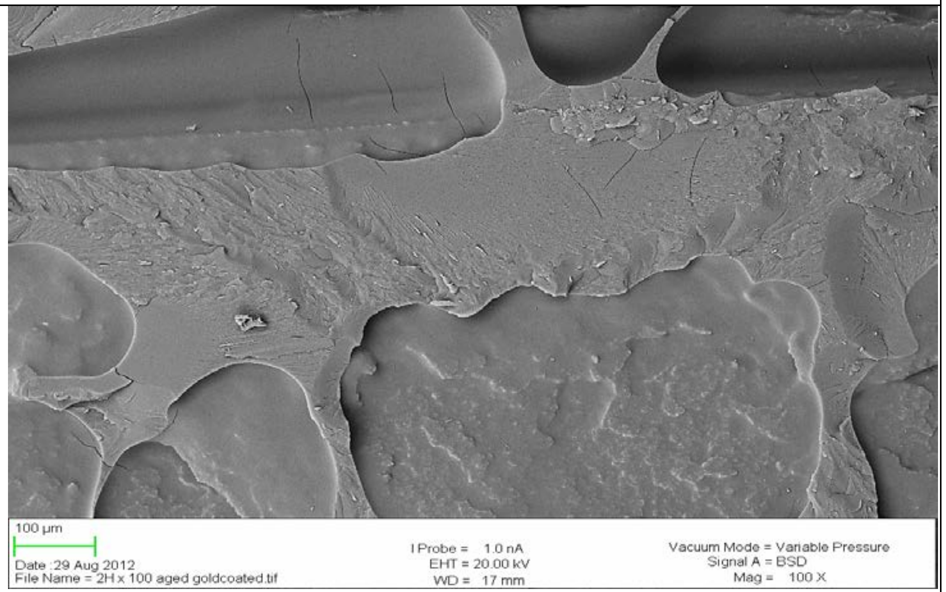




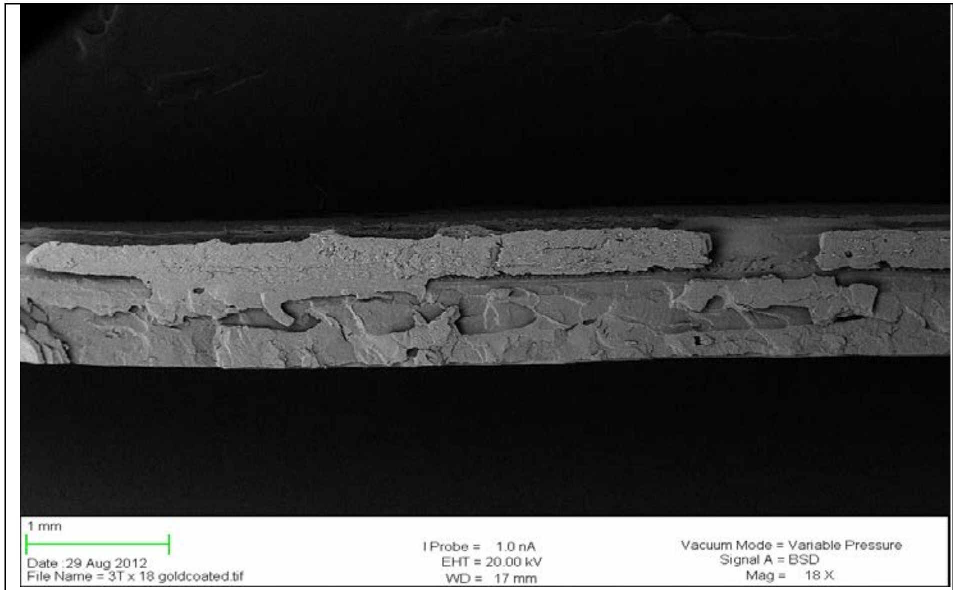
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

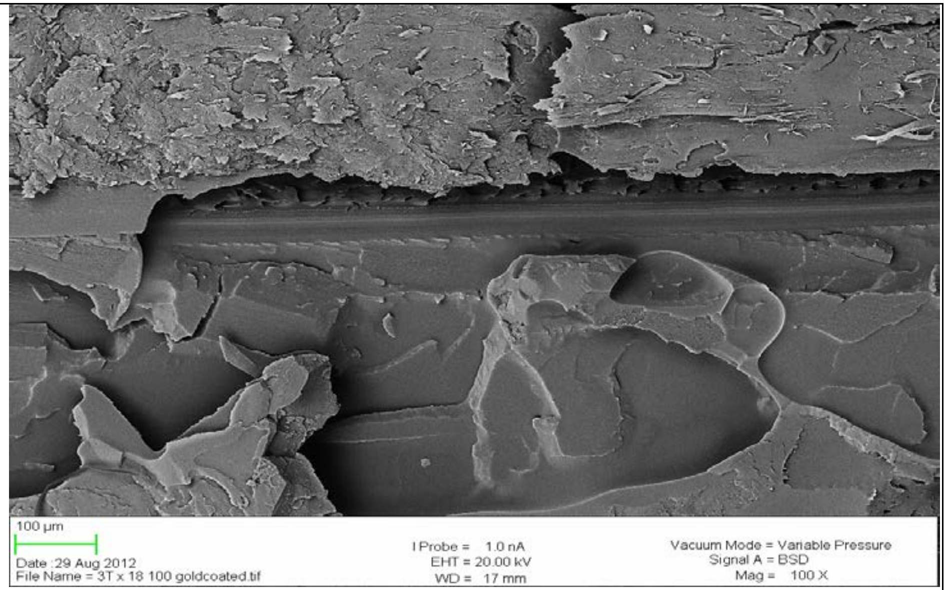


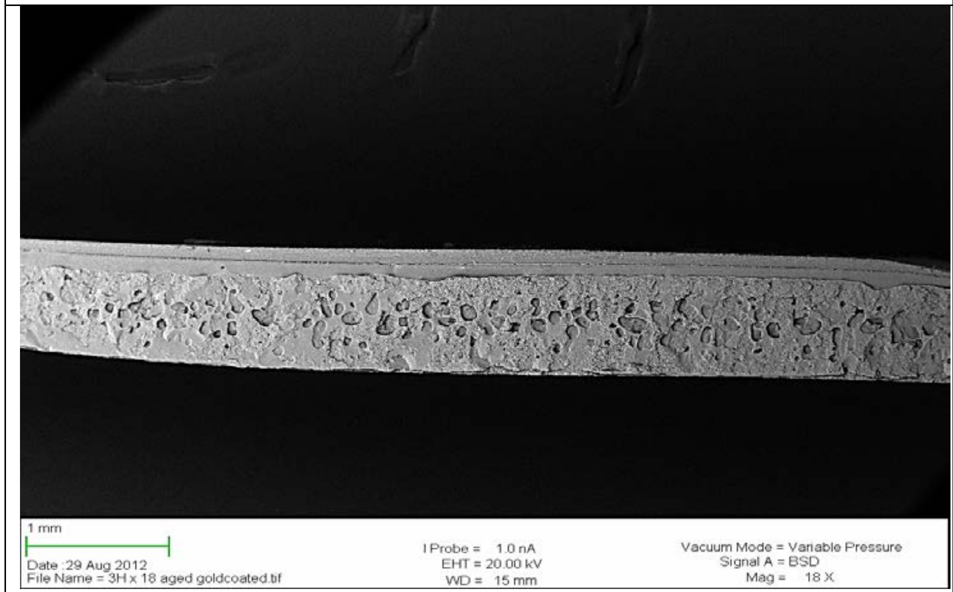


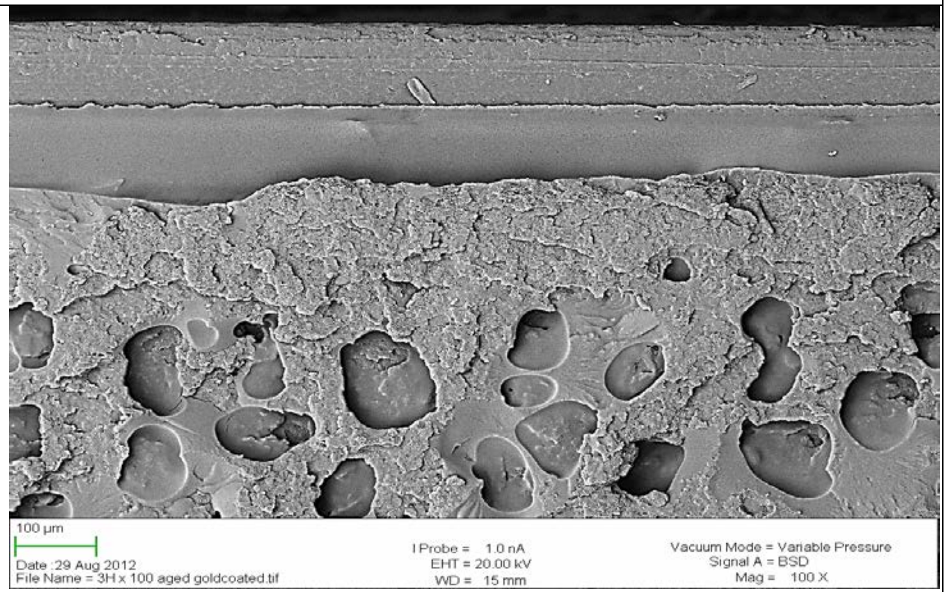


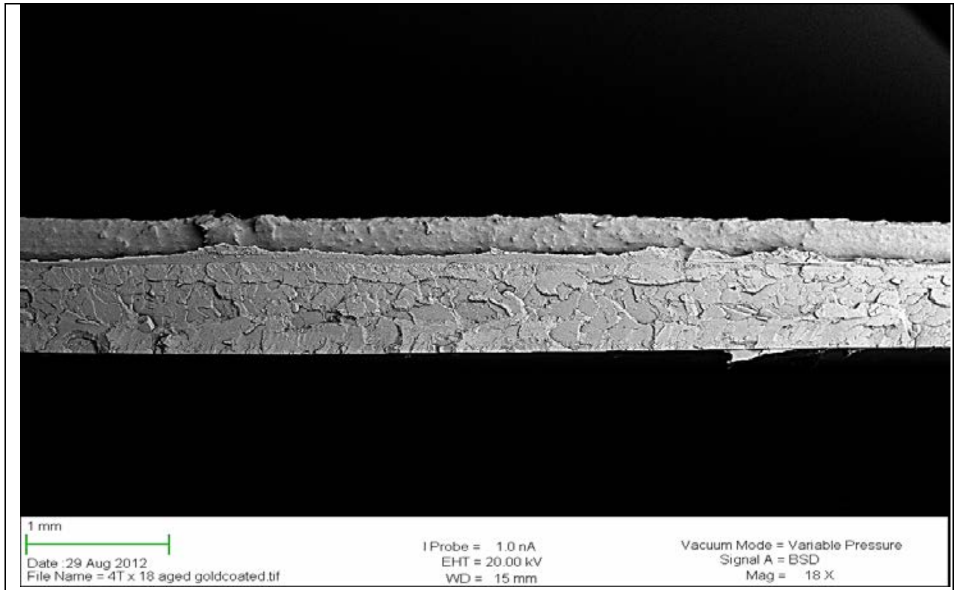
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

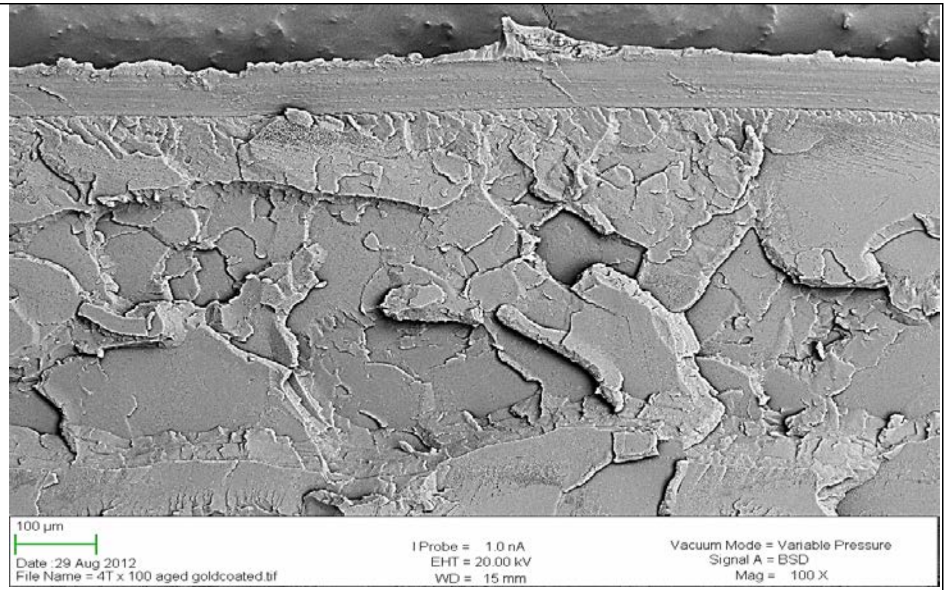


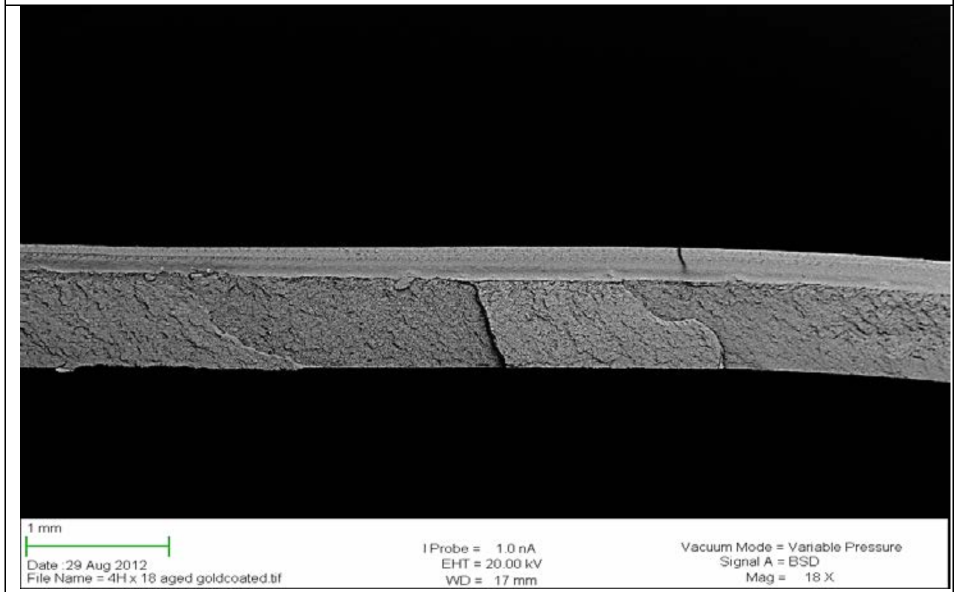


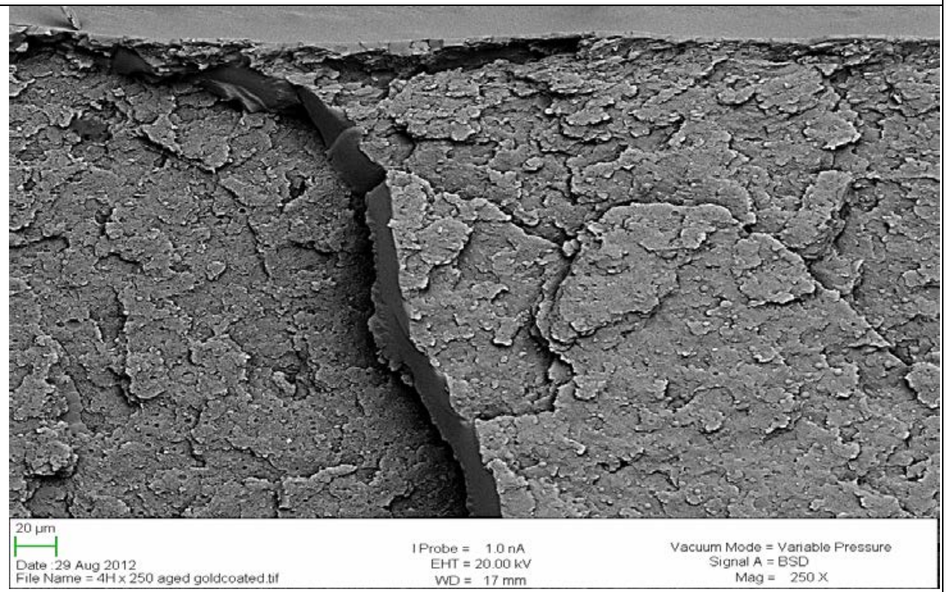




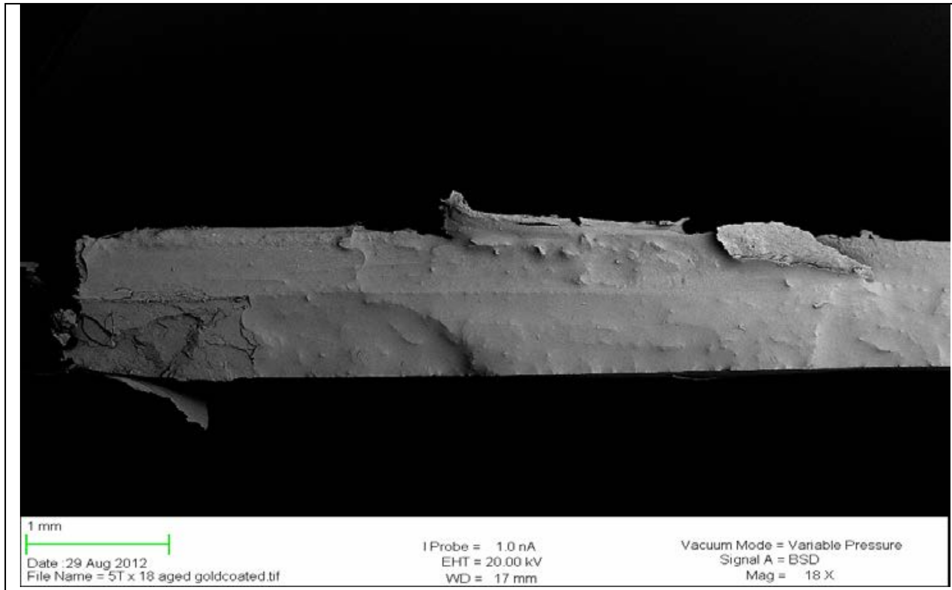

1 mm
Date :29 Aug 2012
File Name = 4T x 18 aged goldcoated.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 15 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X

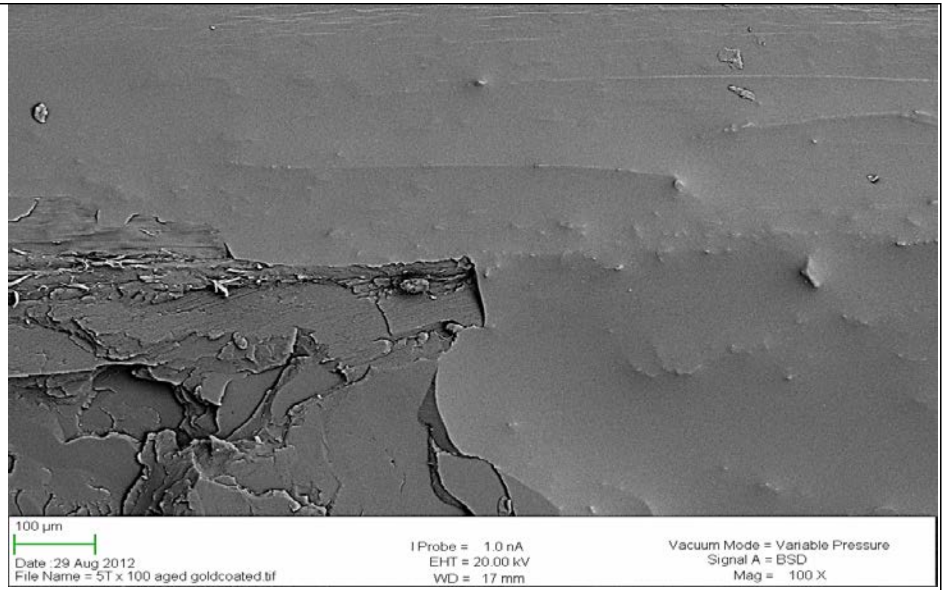

100 µm
Date :29 Aug 2012
File Name = 4T x 100 aged goldcoated.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 15 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 100 X

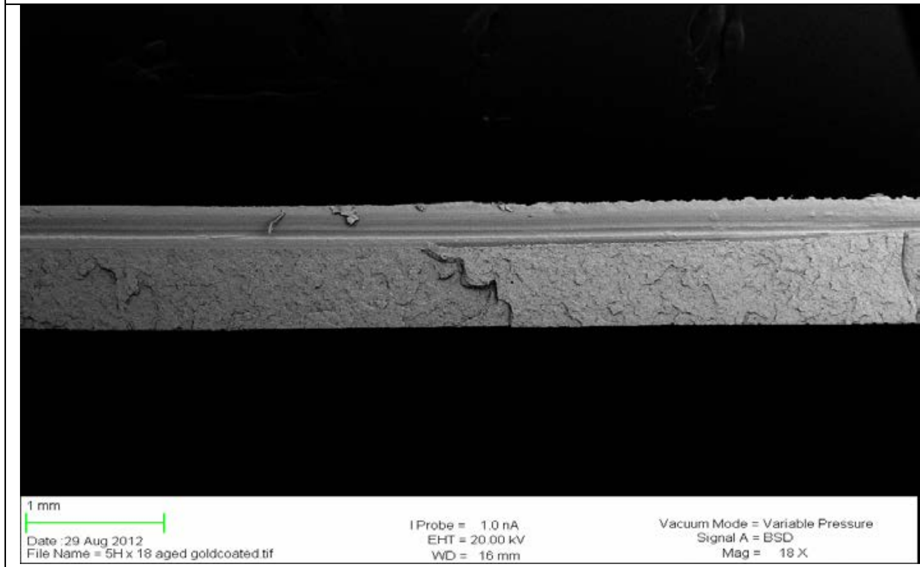

1 mm
Date :29 Aug 2012
File Name = 4H x 18 aged goldcoated.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 17 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 18 X

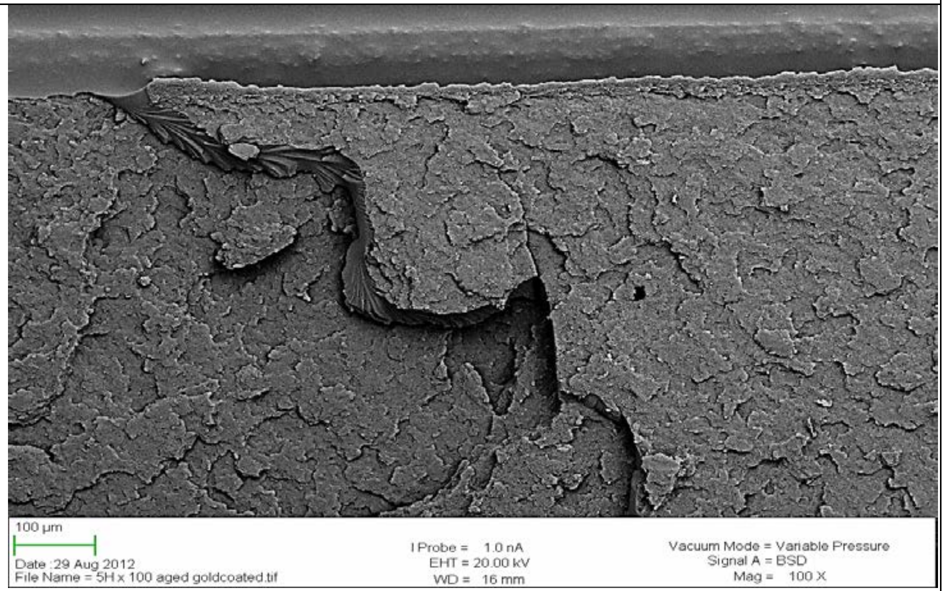

20 µm
Date :29 Aug 2012
File Name = 4H x 250 aged goldcoated.tif
I Probe = 1.0 nA
EHT = 20.00 kV
WD = 17 mm
Vacuum Mode = Variable Pressure
Signal A = BSD
Mag = 250 X

Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

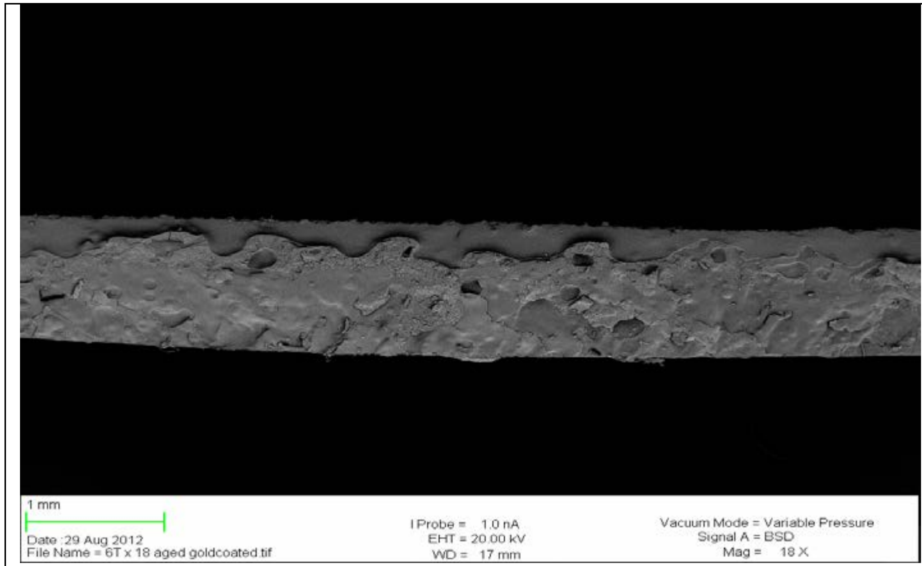


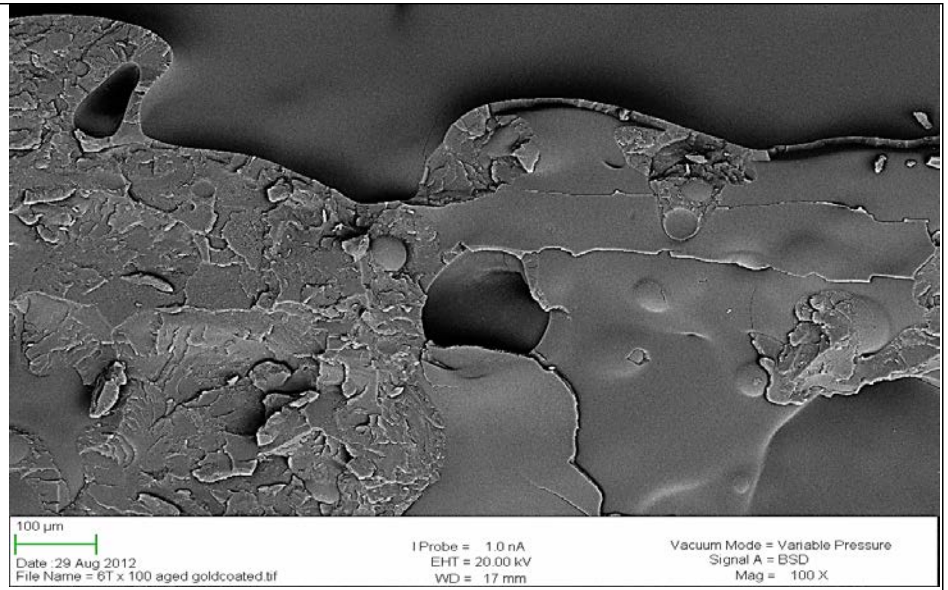


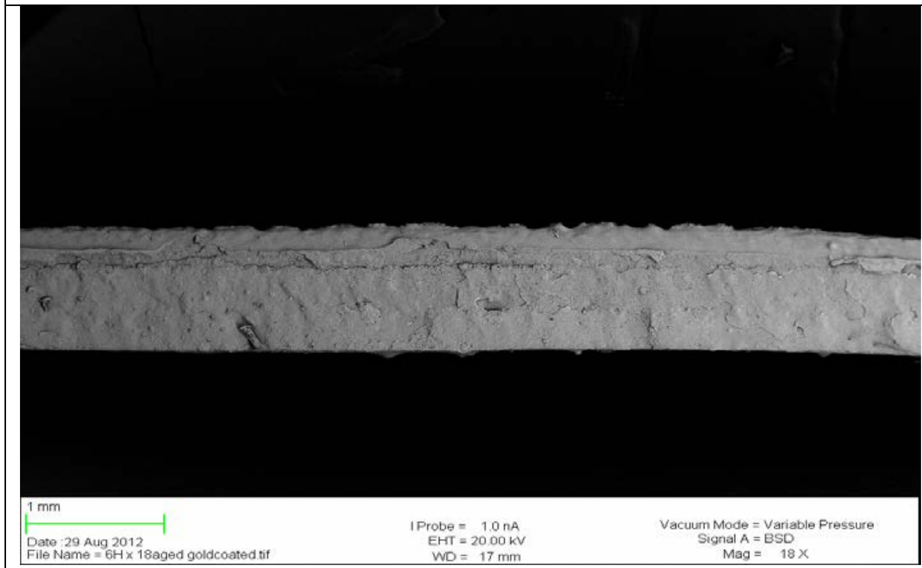


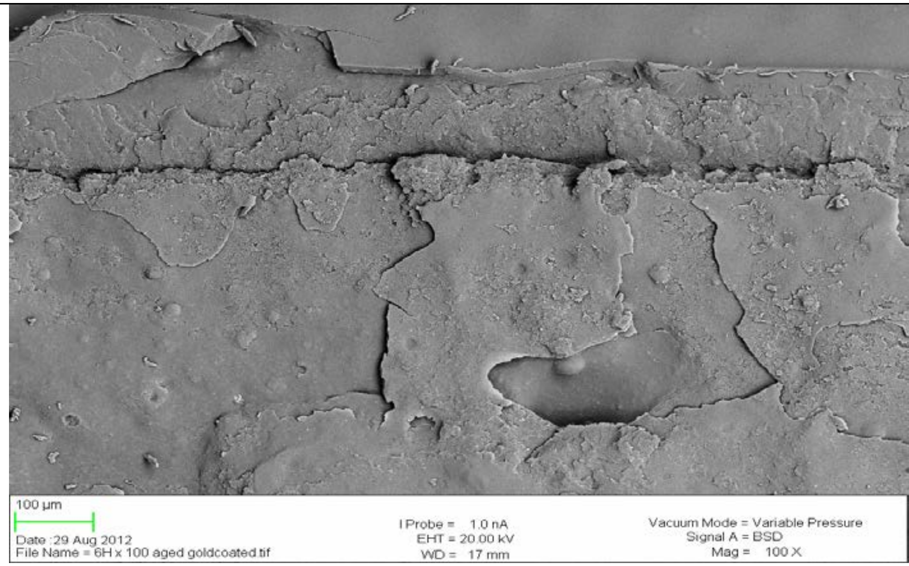


Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011

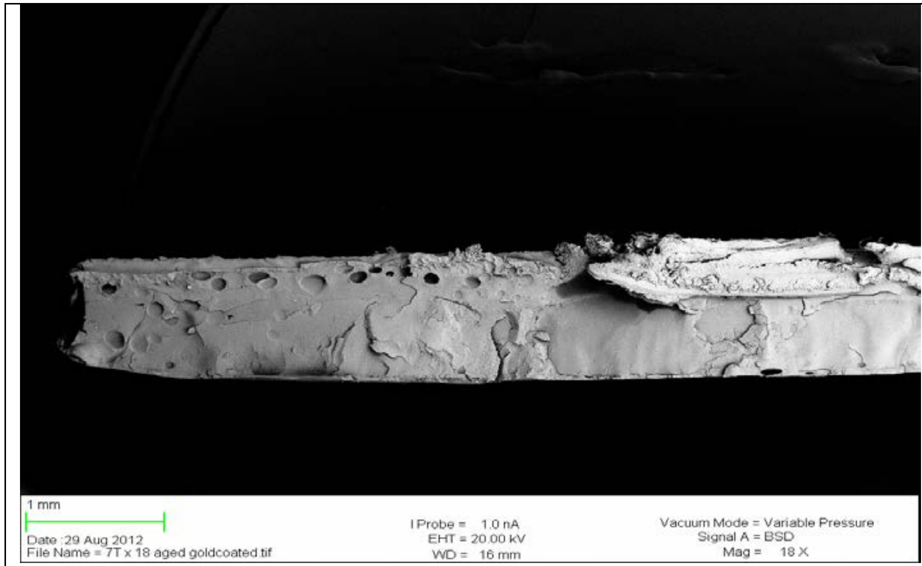


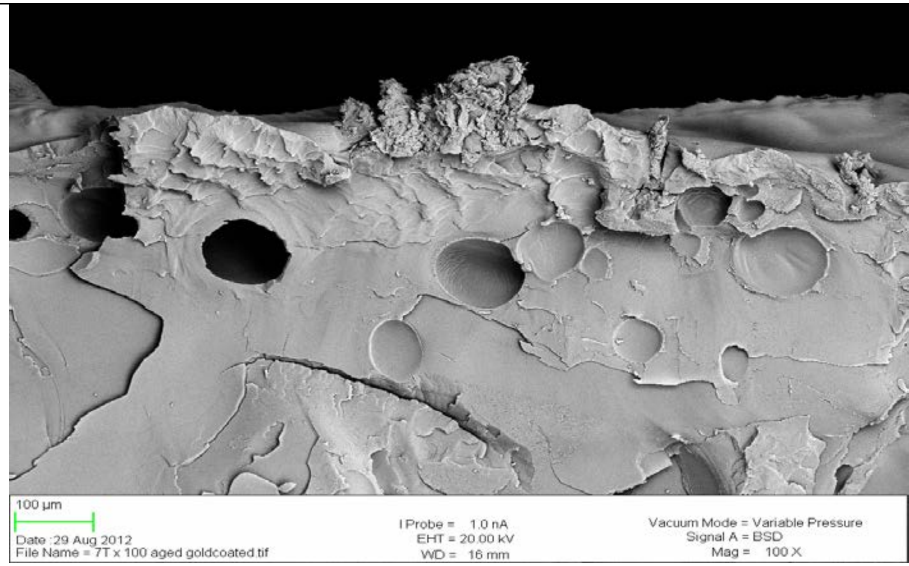


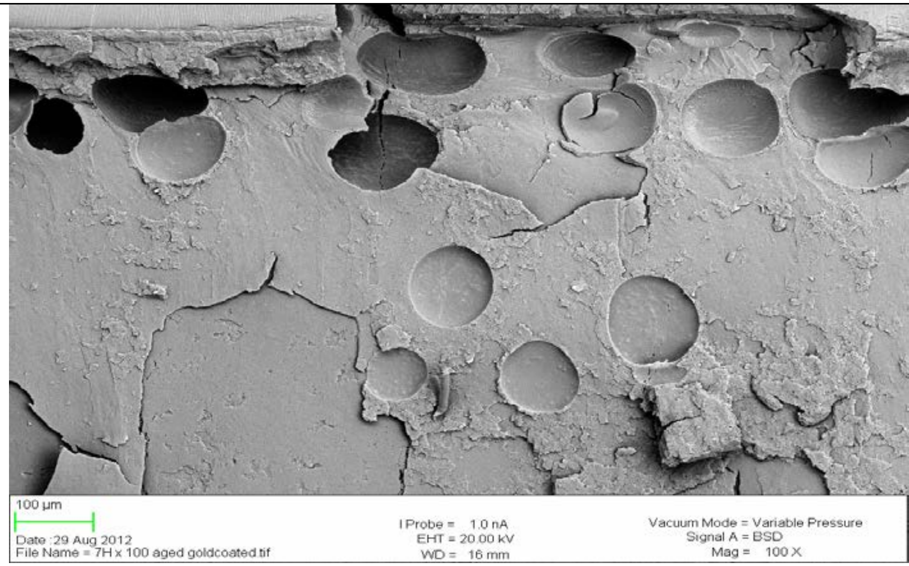




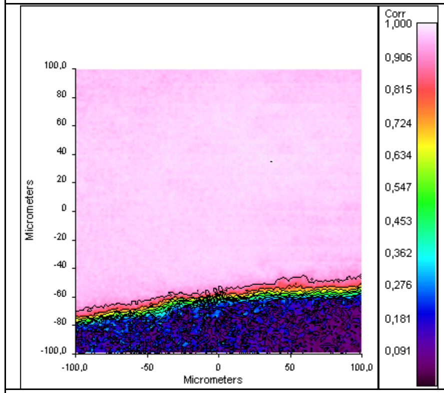
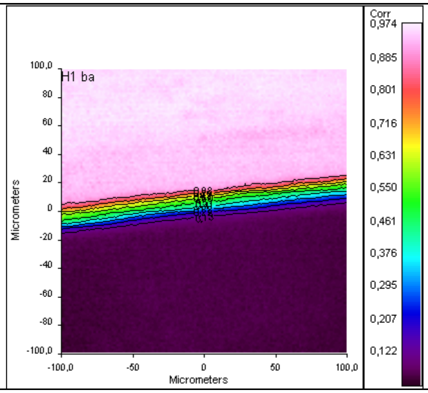
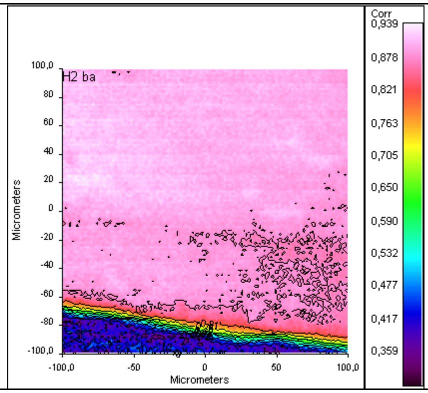
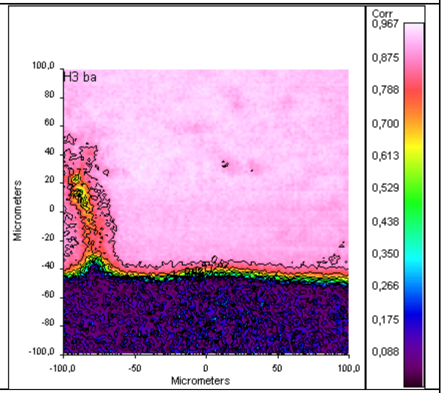
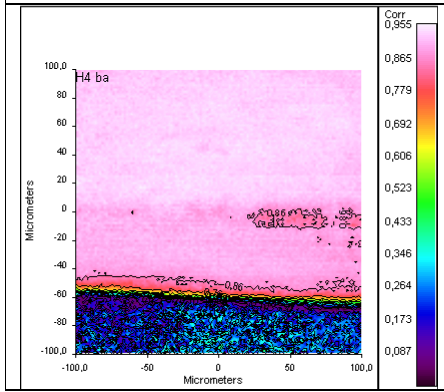
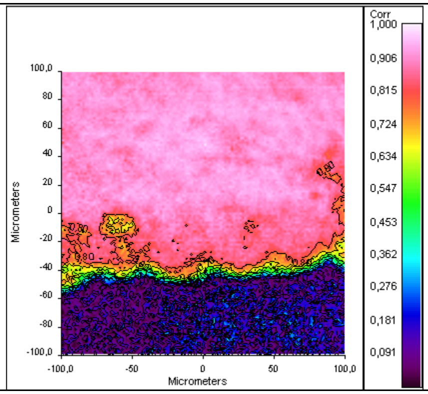
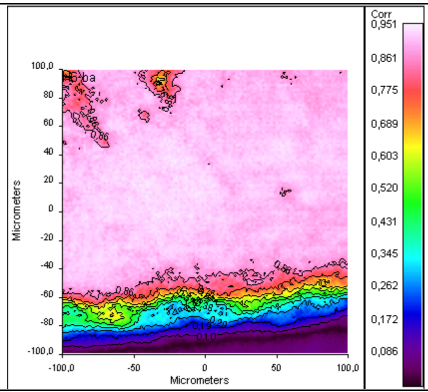
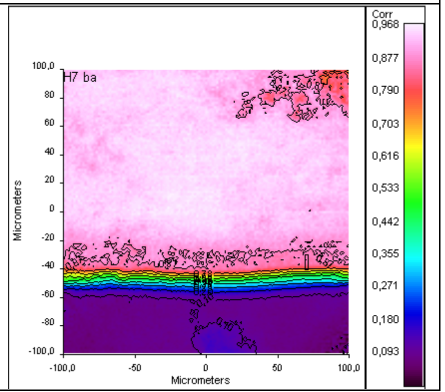
Appendix VII SEM images Joining plastics - together what happens over time? Dnr 353-03471-2011





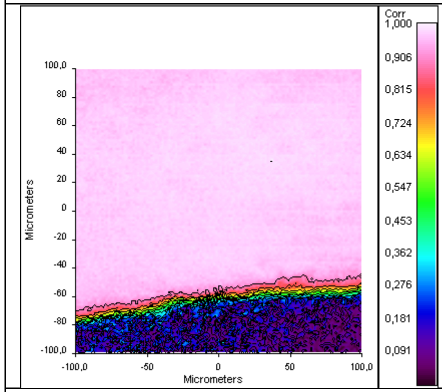


HIPS before aging (b.a.) comparison to reference plastic. Scale of correspondence to be seen to the right, i.e light pink the most similar to core plastic.

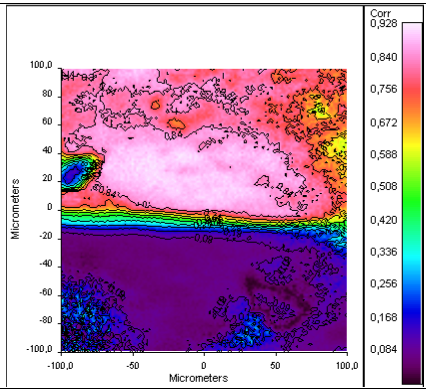
H0 b.a.	H1 b.a.	H2 b.a.	H3 b.a.
			
H4 b.a.	H5 b.a.	H6 b.a.	H7 b.a.
			

HIPS after ageing (a.a.) comparison images to plastic reference.

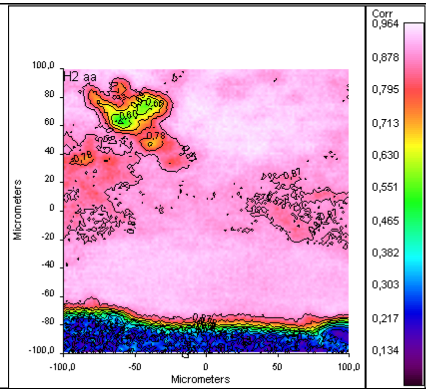
H0



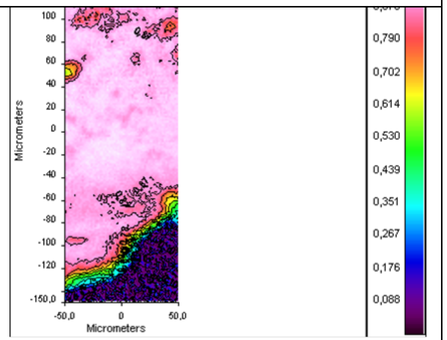
H1 a.a.



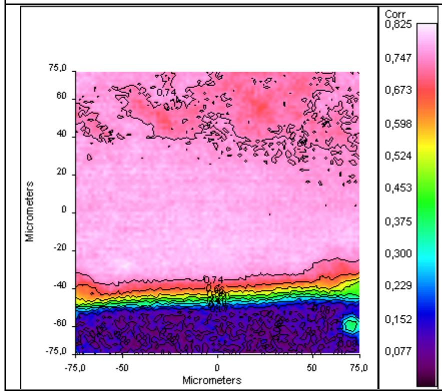
H2 a.a.



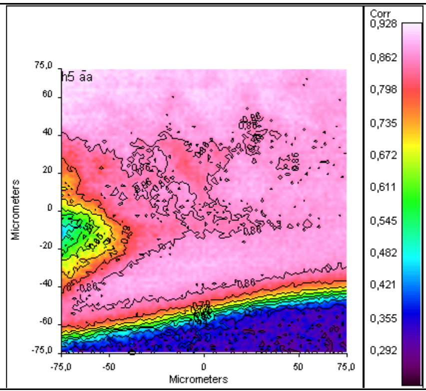
H3 a.a.



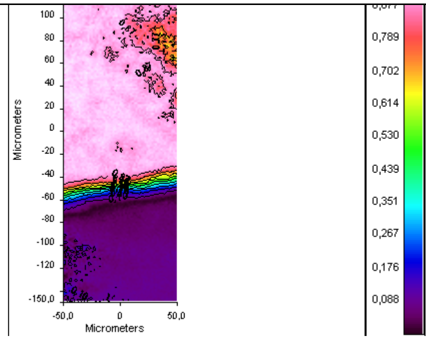
H4 a.a.



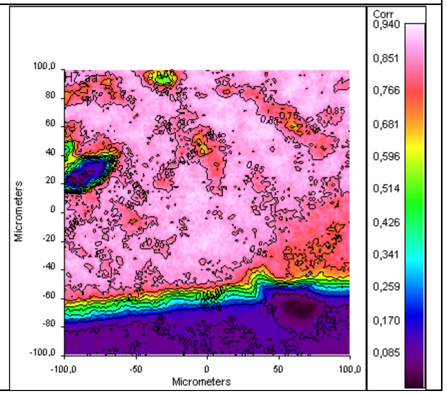
H5 a.a.



H6 a.a.

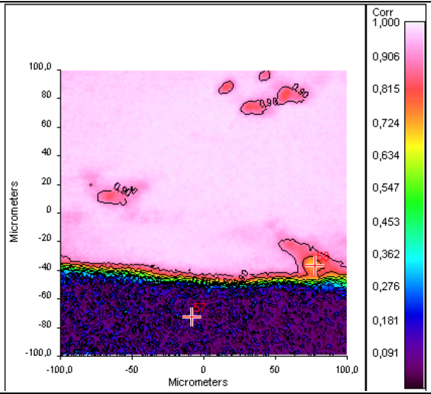
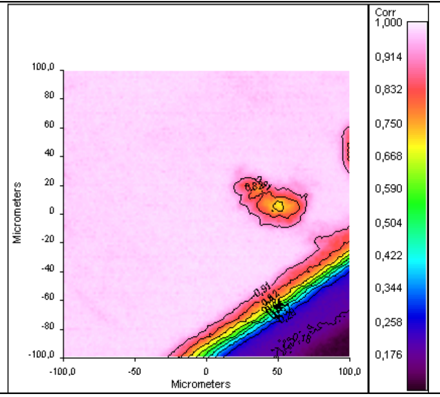
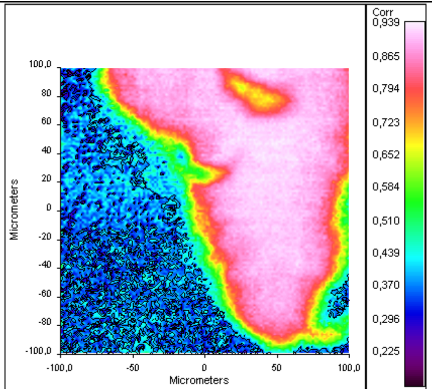
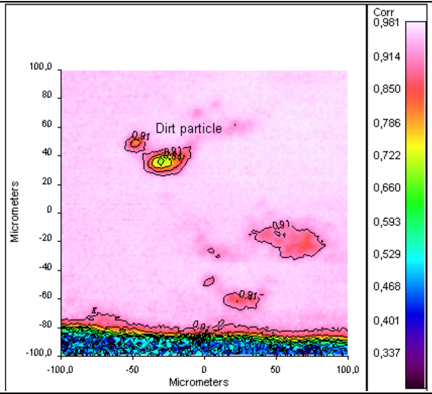
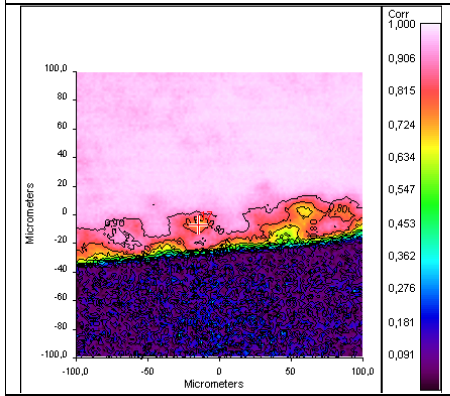
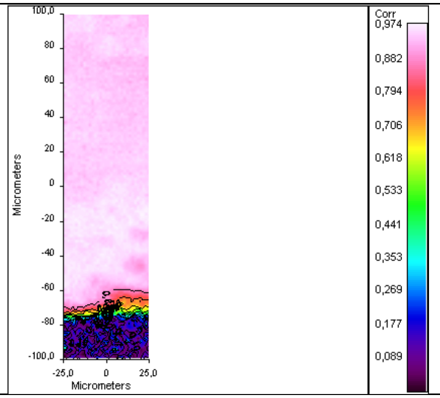
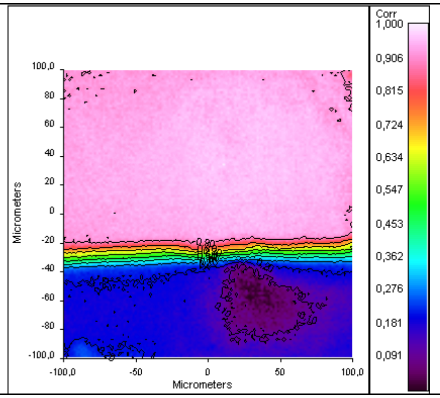
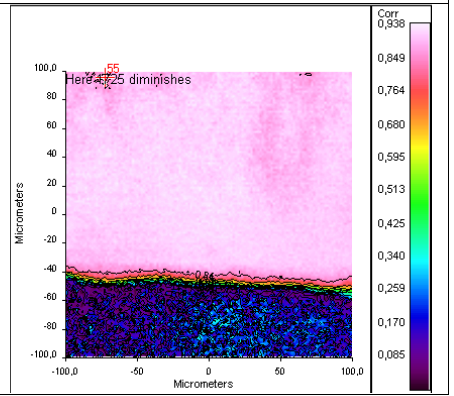


H7 a.a.



Due to shortage of time the width was diminished to 50, 100 or 150 from 200

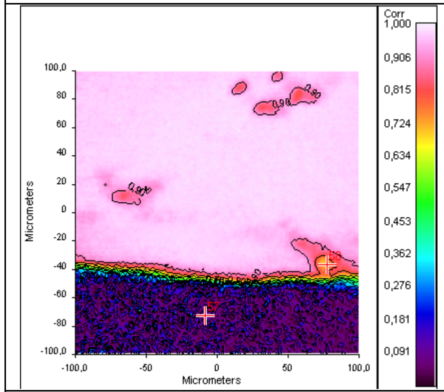
Before aging (b.a) comparison images compared to reference transparent plastic. Scale of correspondence to be seen to the right, i.e light pink the most similar to core plastic.

T0 b.a.	T1 b.a.	T2 b.a.	T3 b.a.
			
T4 b.a.	T5 b.a.	T6 b.a.	T7 b.a.
			

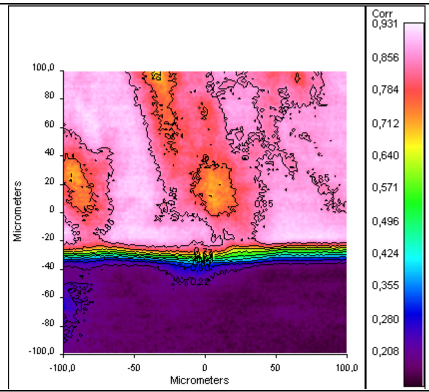
Some images did not generate complete contours in the software.

After aging (a.a.)images compared to reference transparent. Scale of correspondence to be seen to the right, i.e light pink the most similar to core plastic.

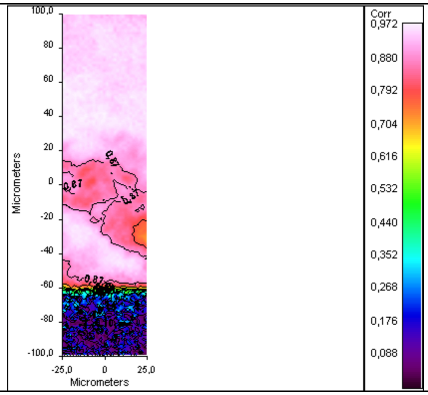
T0



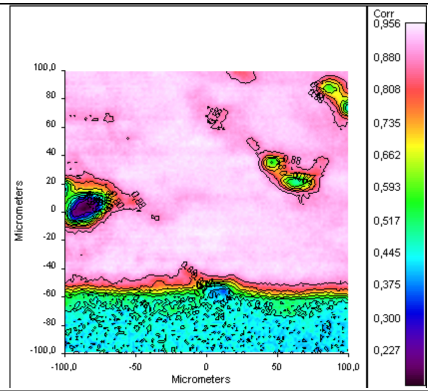
T1 a.a.



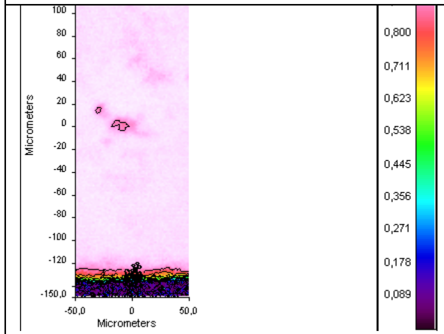
T2 a.a.



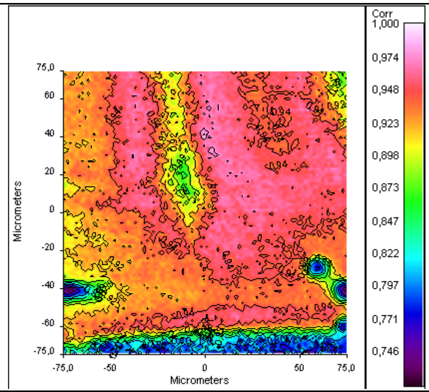
T3 a.a.



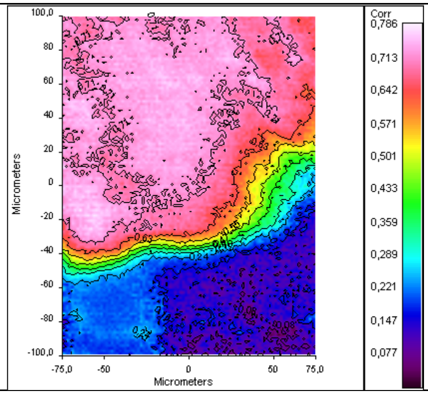
T4 a.a.



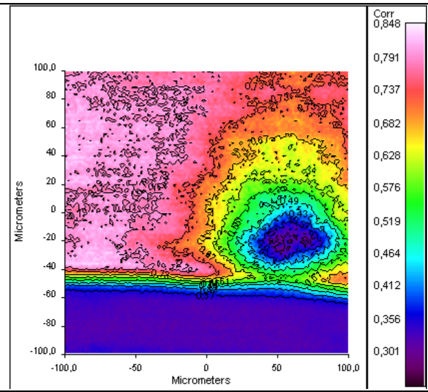
T5 a.a.



T6 a.a.

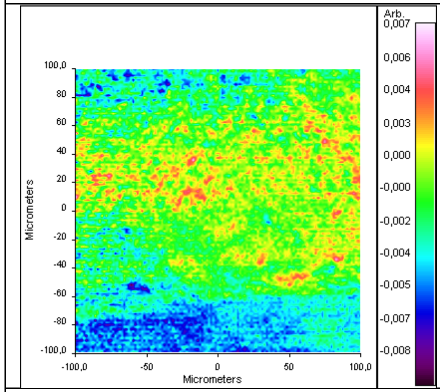
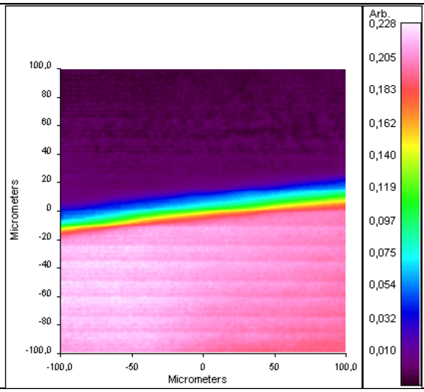
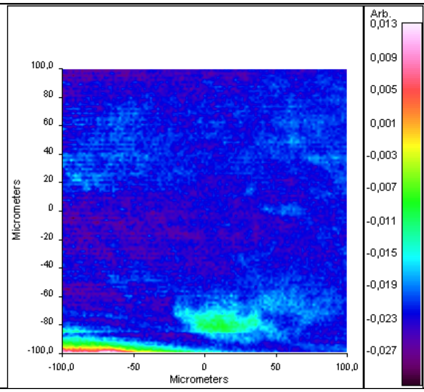
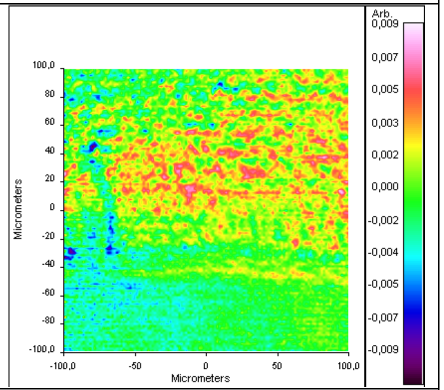
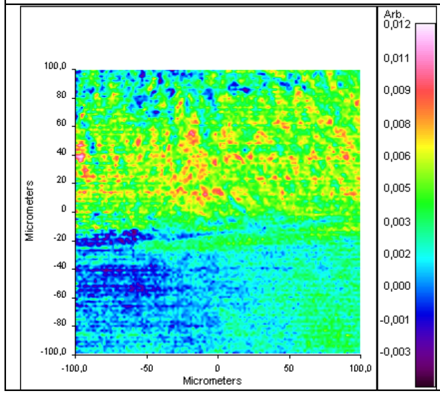
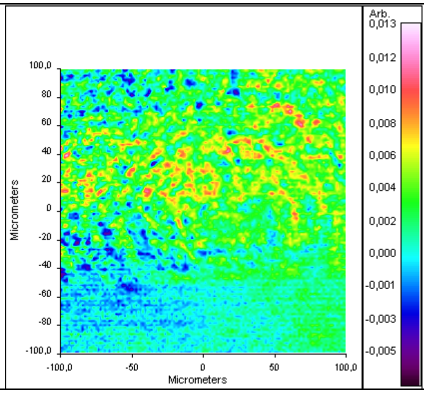
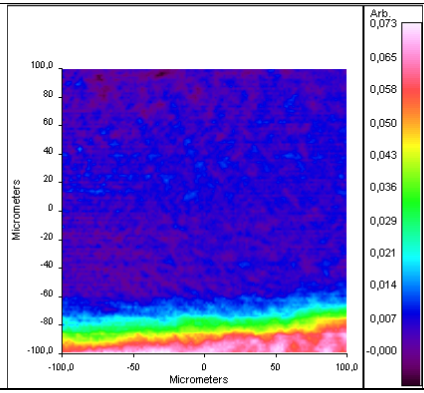
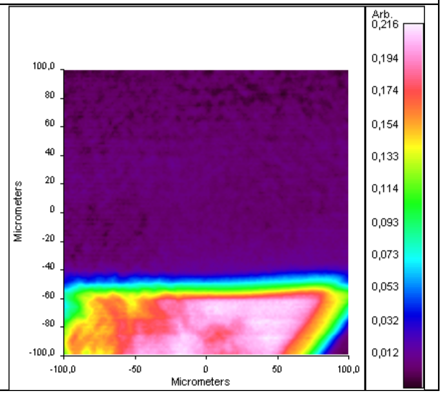


T7 a.a.

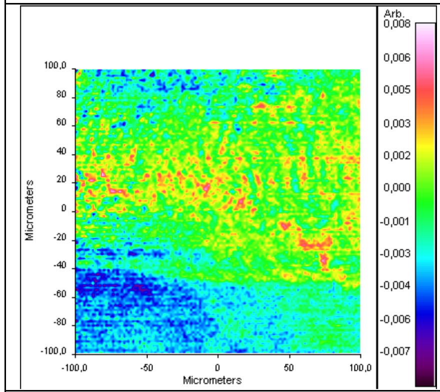
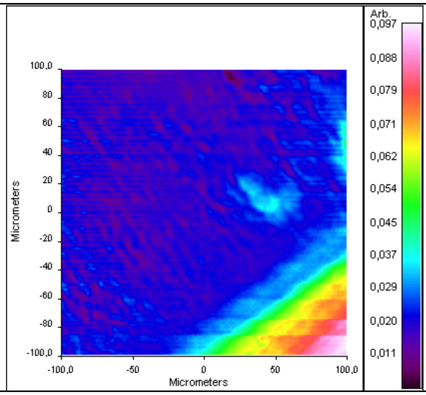
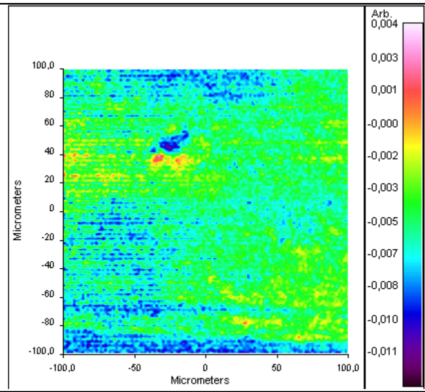
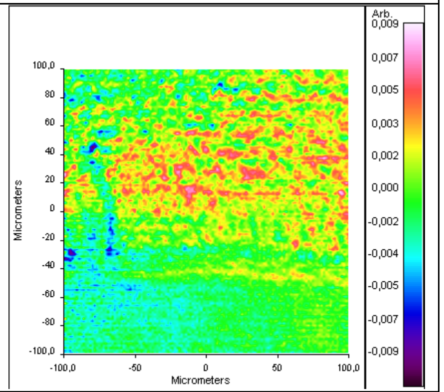
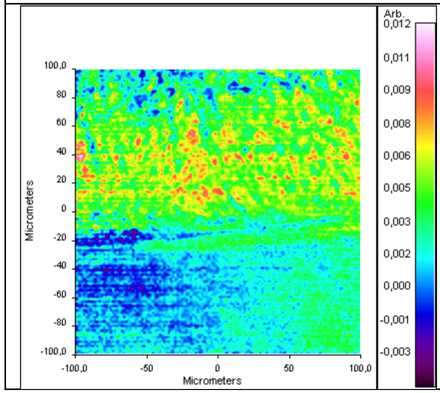
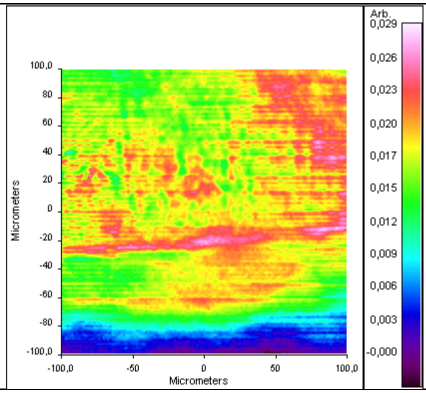
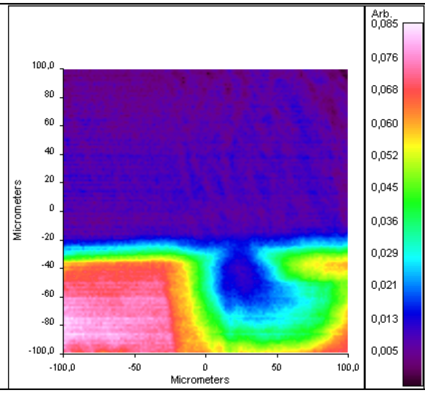
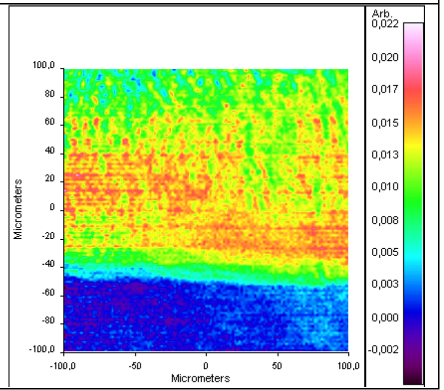


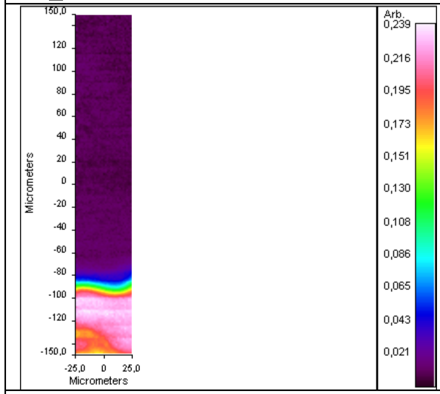
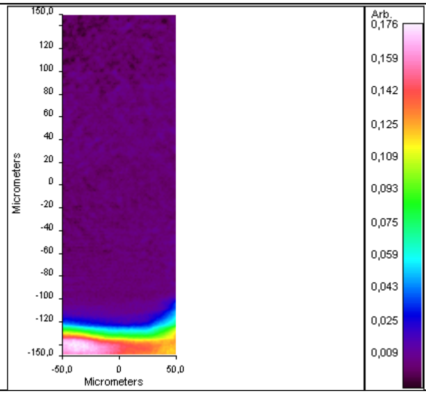
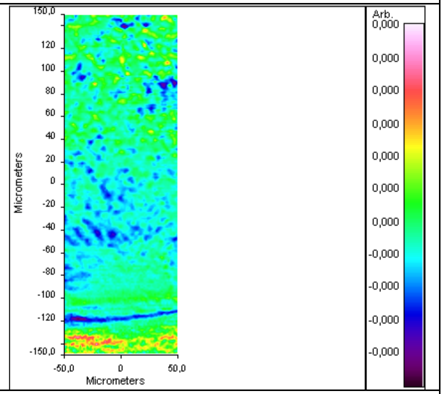
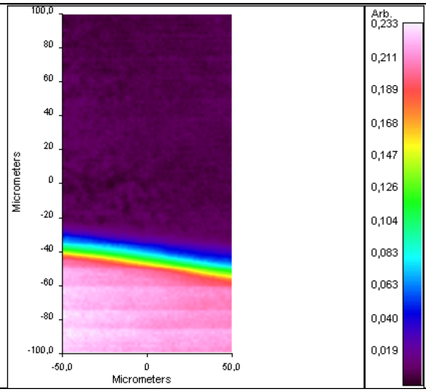
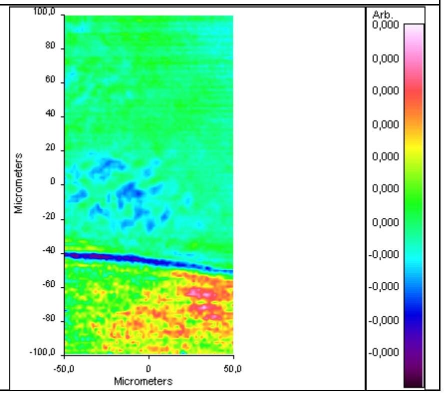
To save time the width was diminished to 50, 100 or 150 from 200.

HIPS before aging comparison to ketone. Scale of correspondence to be seen to the right.

H0 b.a.	H1 b.a.	H2 b.a.	H3 b.a.
			
H4 b.a.	H5 b.a.	H6 b.a.	H7 b.a.
			

GPPS before aging comparison to ketone. Scale of correspondence to be seen to the right.

T0 b.a.	T1 b.a.	T2 b.a.	T3 b.a.
			
T4 b.a.	T5 b.a.	T6 b.a.	T7 b.a.
			

T7_2 b.a. to ketone	H8 b.a. to ketone	H8 to alcohol b.a.
		
	T8 b.a. to ketone	T8 to alcohol b.a.
		

Appendix IX

Appendice IX Hardness measurements. Joining plastics together - what happens over time? Dnr 353-03471-2011

Durometer measurements (hardness pencil test)
(Type MS-O)

U = Unaged T = Transparent
A = Aged H = HIPS

Hardness table underneath samples:	99,7

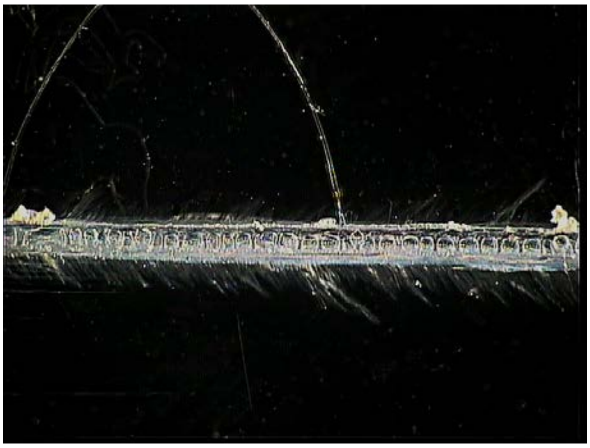
	UT0	AT0	UT1	AT1	UT2	AT2	UT3	AT3	UT4	AT4	UT5	AT5	UT6	AT6	UT7	AT7	UT8	AT8
Measurement point 1	99,3	99,5	97,9	98,4	94,1	97,8	95	96,5	98,8	98,8	98	99,1	97,3	96,8	94,1	95	97	98,1
Measurement point 2	99	99,4	97,8	98,4	96,3	96,6	94,3	96,8	99,5	99,2	97,9	99,2	96	96,1	94,2	95,1	97,5	98,2
Measurement point 3	98,8	99,5	98,1	97,6	94,4	98,7	94,3	97	99,1	99,5	98,1	98,5	95,8	96,7	93	95	97,2	98
Average	99,03333	99,46667	97,93333	98,13333	94,93333	97,7	94,53333	96,76667	99,13333	99,16667	98	98,93333	96,36667	96,53333	93,76667	95,03333	97,23333	98,1
STDV	0,251661	0,057735	0,152753	0,46188	1,193035	1,053565	0,404145	0,251661	0,351188	0,351188	0,1	0,378594	0,814453	0,378594	0,665833	0,057735	0,251661	0,1

	UH0	AH0	UH1	AH1	UH2	AH2	UH3	AH3	UH4	AH4	UH5	AH5	UH6	AH6	UH7	AH7	UH8	AH8
Measurement point 1	98,8	98,9	97,9	97,8	94,5	97,3	95	96,8	99	99,3	98,5	99,2	96,7	98	84	84,6	96,9	96,9
Measurement point 2	98,7	99	98,1	98	95,8	96,7	94,8	96,9	98,8	99,2	98,8	99,3	97	98,5	83,5	84,3	97,1	97,7
Measurement point 3	98,8	98,9	98	98,6	94,2	97,2	95,5	97	99,2	99,4	98	99,1	97,3	98,6	82,9	83,5	97	97,8
Average	98,76667	98,93333	98	98,13333	94,83333	97,06667	95,1	96,9	99	99,3	98,43333	99,2	97	98,36667	83,46667	84,13333	97	97,46667
STDV	0,057735	0,057735	0,1	0,416333	0,85049	0,321455	0,360555	0,1	0,2	0,1	0,404145	0,1	0,3	0,321455	0,550757	0,568624	0,1	0,493288

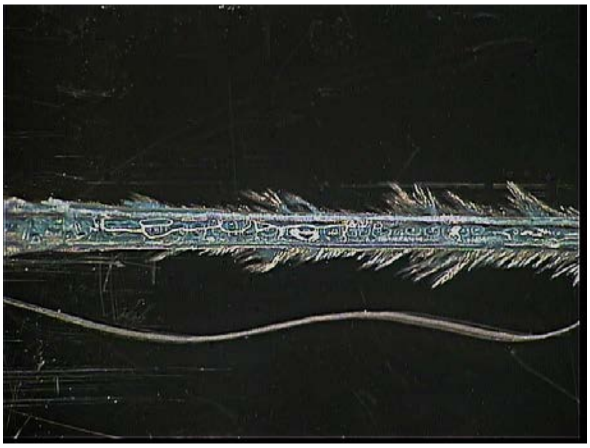
Observations:

Because adhesive nr.7 (Acrifix 116) caused bending of the plastic, the hardness measurements might have been affected by the not perfectly flat surface.
Among all seven adhesives, adhesive nr. 2 (Paraloid B67) was the only one where the pencil head caused some miniature cracks in the adhesive surface.

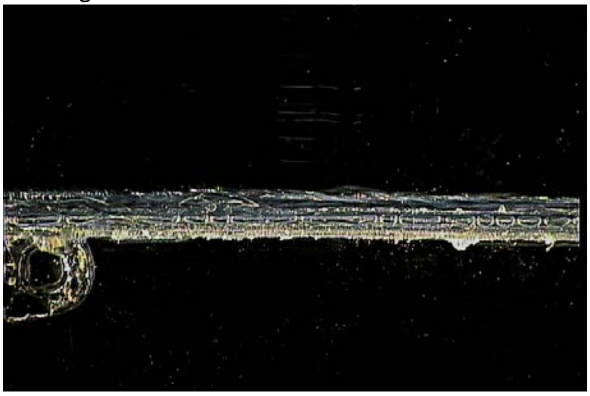
Microscope images of adhesive bonds in S1 on transparent polystyrene and HIPS. Before and after aging. Mag. X25. Cracks are originating from original break in pull-to-break in the tensile tester.



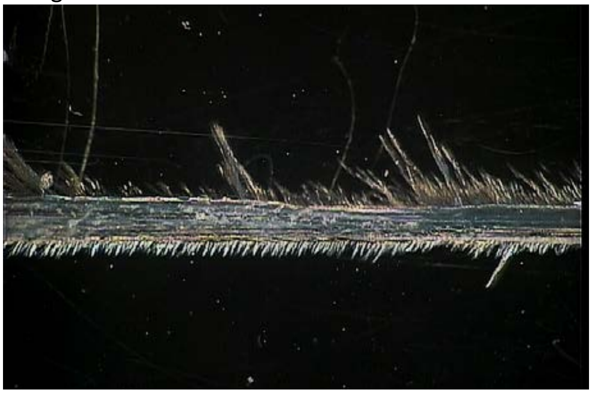
T1 Unaged



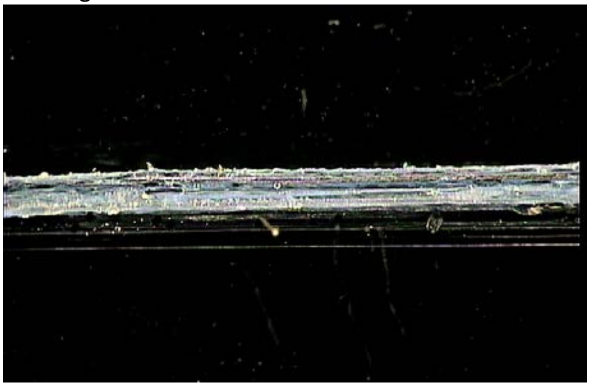
T1 Aged



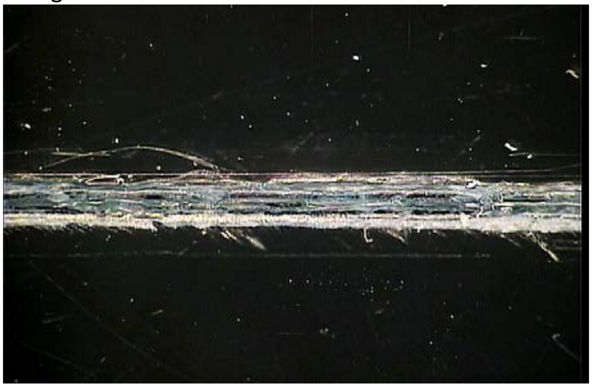
T2 Unaged



T2 Aged

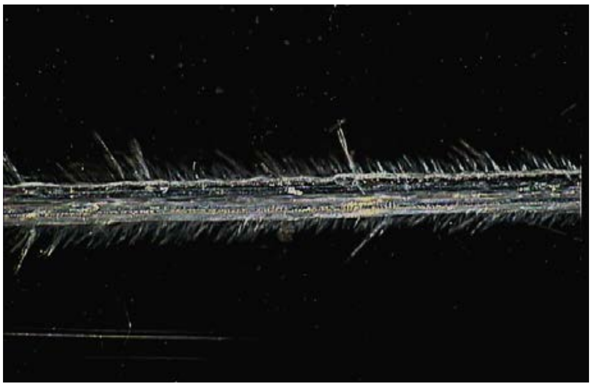


T3 Unaged



T3 Aged

Appendix X Microscopy images adhesive bonds of adhered edges (S1) Joining plastics together – what happens over time?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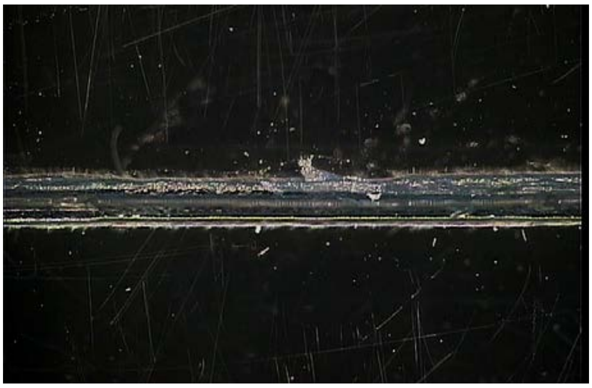
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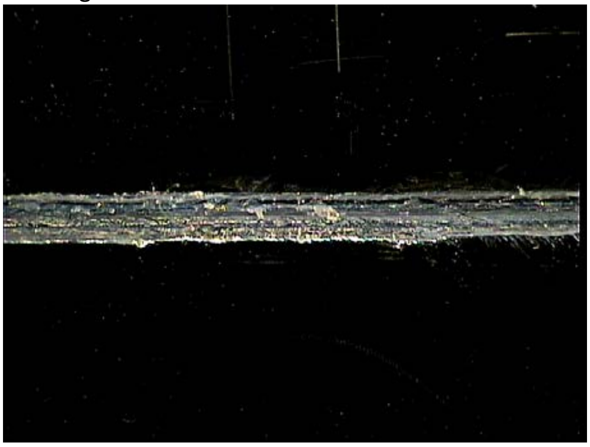
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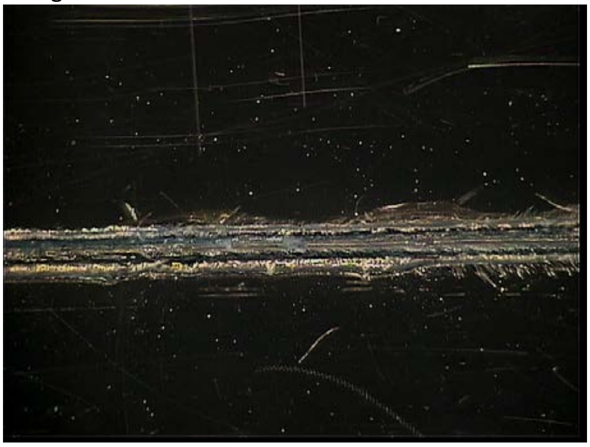
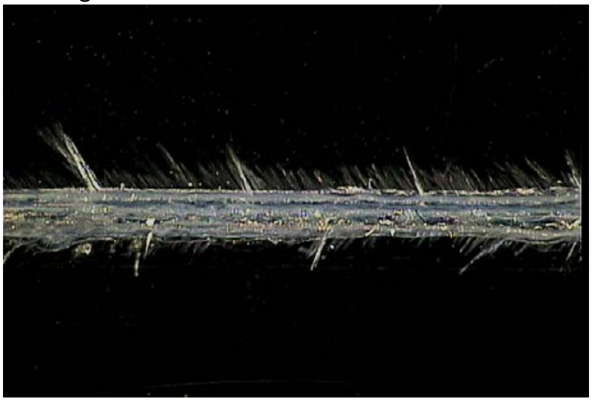

T5 Aged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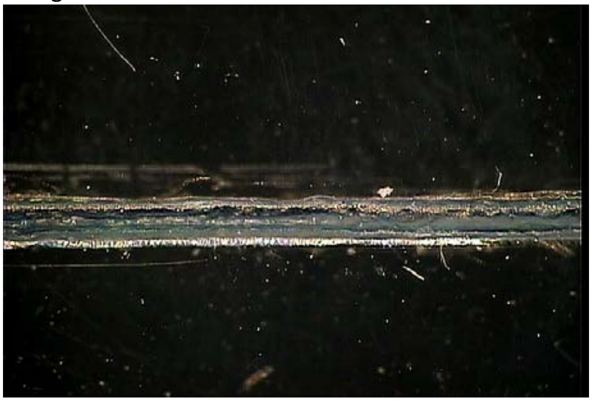
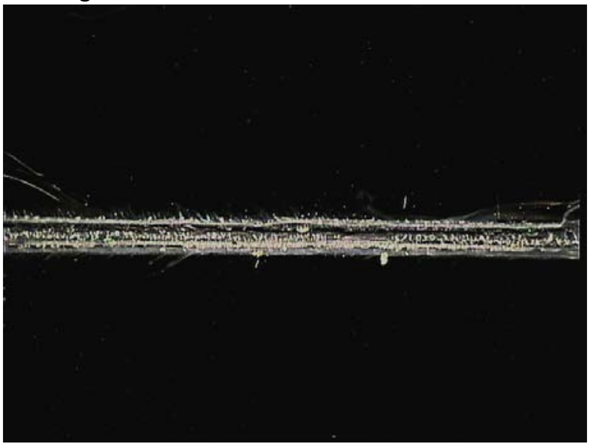
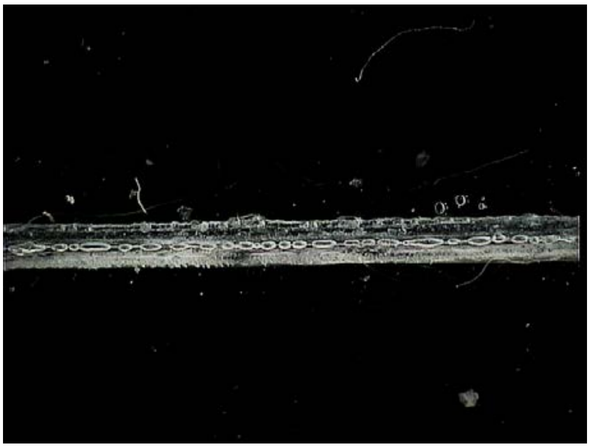
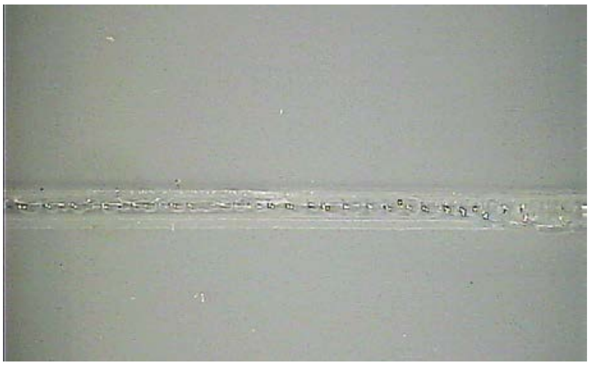

T6 Aged

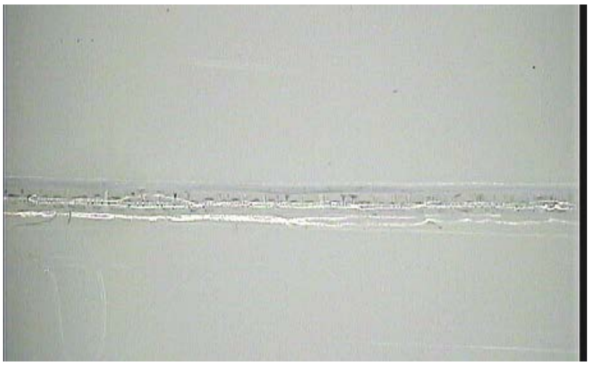

T7 Unaged

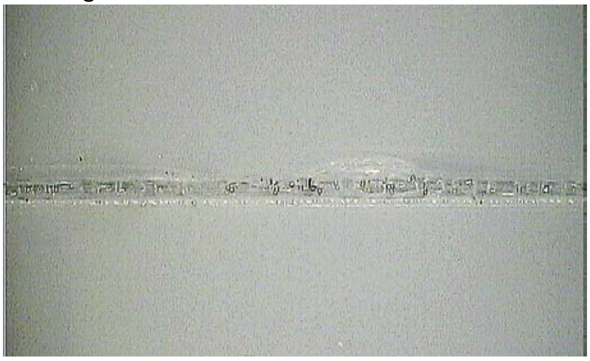

T7 Aged

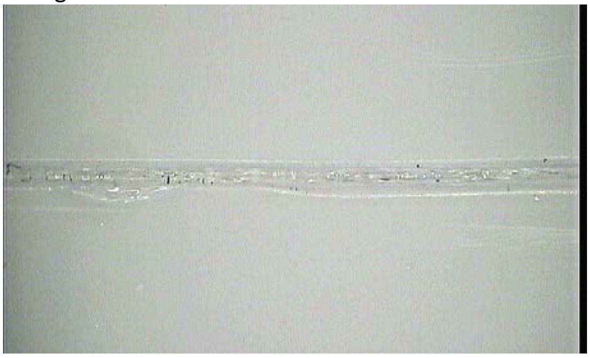
Appendix X Microscopy images adhesive bonds of adhered edges (S1) Joining plastics together – what happens over time?


T8 Unaged


H1 Unaged


H1 Aged


H2 Unaged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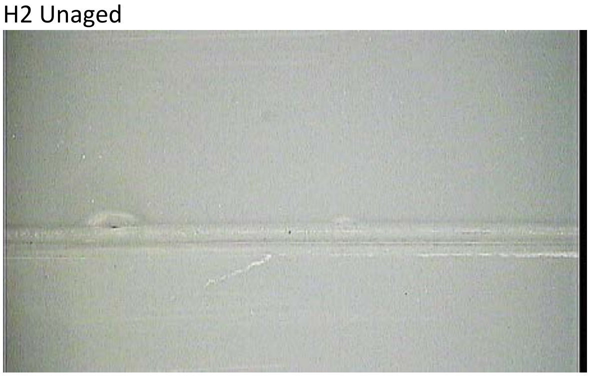
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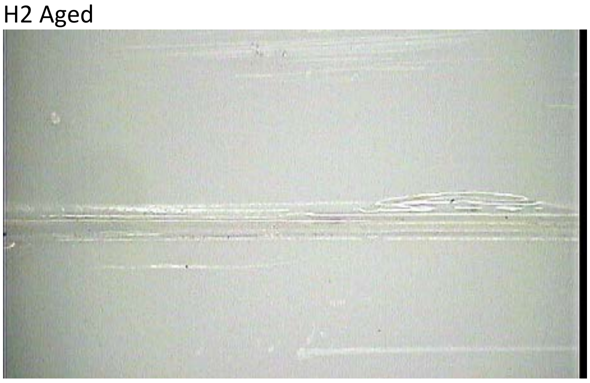
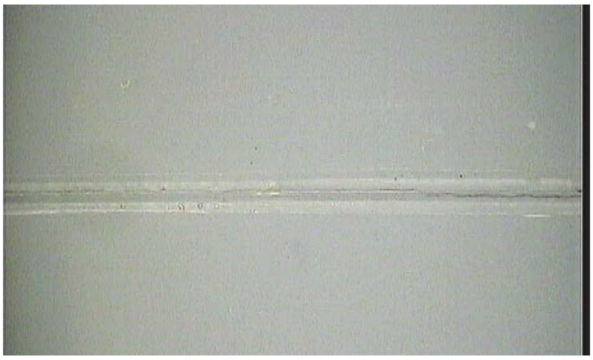

H3 Aged

Appendix X Microscopy images adhesive bonds of adhered edges (S1) Joining plastics together – what happens over time?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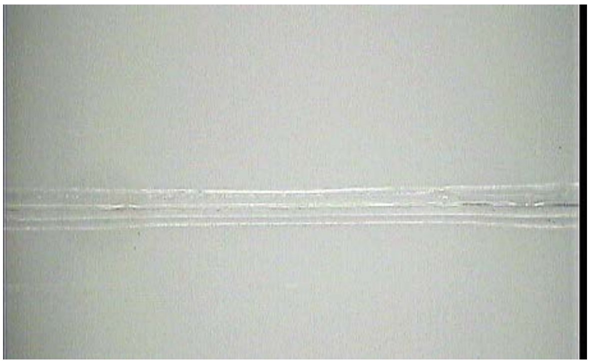
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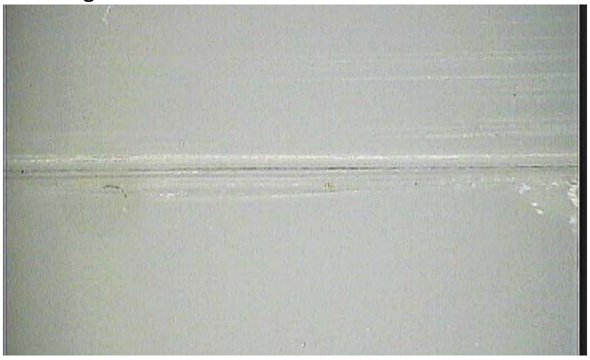
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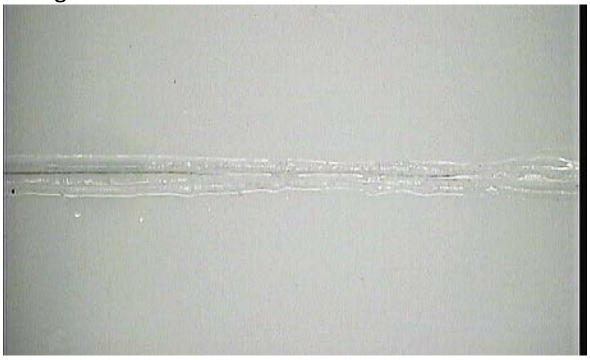
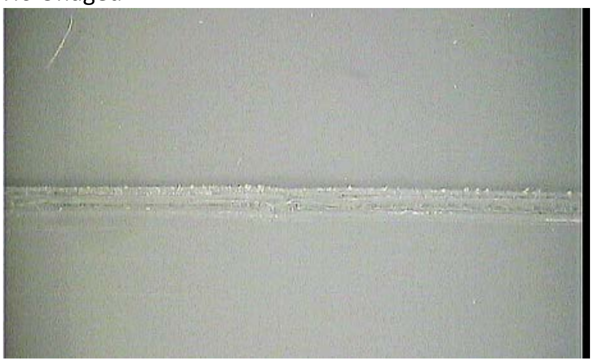
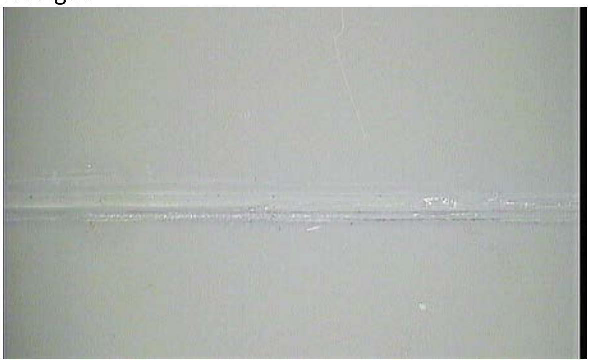

H5 Aged

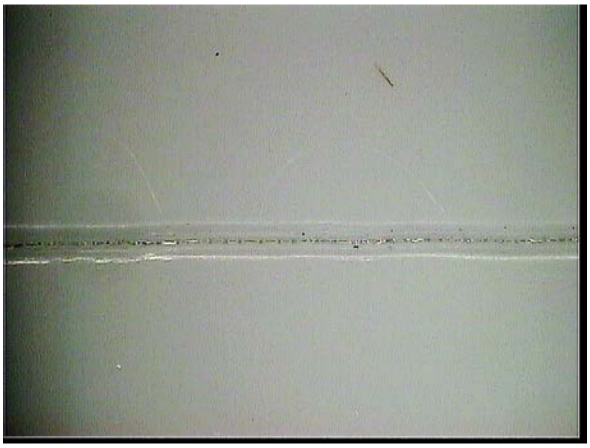

H6 Unaged


H6 Aged


H7 Unaged


H7 Aged

Appendix X Microscopy images adhesive bonds of adhered edges (S1) Joining plastics together – what happens over time?


H8 Unaged

Paraloid® B72	Kremer Pigmente GmbH & Co. KG Hauptstr. 41 – 47 DE 88317 Aichstetten Germany. http://kremer-pigmente.de/en
Paraloid® B67	Kremer Pigmente GmbH & Co. KG Hauptstr. 41 – 47 DE 88317 Aichstetten Germany. http://kremer-pigmente.de/en
Primal® AC35	Kremer Pigmente GmbH & Co. KG Hauptstr. 41 – 47 DE 88317 Aichstetten Germany. http://kremer-pigmente.de/en
Hxtal® Nyl-1	Kremer Pigmente GmbH & Co. KG Hauptstr. 41 – 47 DE 88317 Aichstetten Germany. http://kremer-pigmente.de/en
Araldite® 2020	Huntsman Advanced Materials 10003 Woodloch Forest Drive The Woodlands, Texas 77380. http://www.huntsman.com/advanced_materials/a/Home
Loctite® Super Attack Precision	Henkel. http://equipment.loctite.com/
Acrifix® 116	Evonik Industries AG Rellinghauser Straße 1—11 45128 Essen Germany
HIPS	Iroplast SB Thermoplastische Kunststoffe A-4843 Ampflwang, Ort 57 Austria http://www.vitasheetgroup.com/en/iroplast.htm
GPPS	Nudec Pintor Vila Cinca Polinya Barcelona Spain www.nudec-plastc.com