“Wood made beautiful”
Parquet primer based on sulfopolyester chemistry

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1. Abstract

Natural wood flooring systems for on-site applied parquet coatings is a significant market for suppliers of waterborne coating systems in Europe. Customers in that market value highly the aesthetic and long lasting beauty of wood.
Regulated by the deco paint directive 2004/42/EC on-site applied coatings are mostly water borne and more than 50% of the market is currently using acrylic 1K water-based technology[i]. Despite the wide use very often waterborne coating systems are described as having poor Anfeuerung. The reasons for this often center on the issue of wetting and penetration of the coating into the wood at areas of differing density and porosity. In addition the risk of possible colour change resulting from reaction of the coating with acidic extractable materials present in many wood species provides challenges and room for improvement.
To enhance and maintain the appearance of wood and to preserve the investment for many years to come Eastman is continuously developing ways to improve the coating systems.

2. Introduction

The European parquet market is principally split in two large segments: industrially finished floor and on-site applied coatings typically applied by professionals. There are some products for the DIY market but due to the difficulty of finishing a valuable wood floor this is seen as a small niche segment. The total European market for on-site applied floor coatings 2010 was estimated to be approximately 28,000MT; the most commonly used wood species is oak[ii].

During extensive interviews and discussions with coatings customers and applicators, several areas of improvement for current waterborne coating systems were highlighted. These included aspects about appearance, often described with the German word Anfeuerung, better wetting for improved pore image and colour stability.

Eastman Chemical Company has been embarking on an evaluation of the family of Sulfopolyester polymers for the on-site flooring application in the past year. This work is described, in part, later in this paper and was performed in co-operation with the widely respected consultancy firm 3P-ICC, Germany, who has many years of experience in the formulation and testing of wood coating systems.

3. Sulfopolyester Polymer Chemistry

Sulfopolyester polymers are based upon monomer building blocks[iii], acids and 5-(sodiosulpho) isophthalic acid (SSIPA). By varying the ratio of the glycols in the formulation, the hydrophobicity and stiffness of the final product can be altered to give varying final film properties whilst sufficient SSIPA is incorporated into the polymer backbone to facilitate dispersibility into water. It is the inherent ionic nature of the SSIPA component in the polymer backbone which allows the polymer to disperse in water whilst the glycol level determines many of the physical characteristics of the products. The use of SSIPA to provide dispersibility in water eliminates the need for amines and provides electrostatic stabilization which reduces the need for surfactant.

Figure 1 illustrates the different polymer dispersions in our range of Sulfopolyester polymers with varying glycol and SSIPA content.

Properties	Sulfopolyester Polymers				
	1000	1100	1200	1300	1400
Water dispersibility	++	+++	+	++	++
Glass Transition temperature Tg °C	38	55	63	36	29
Minimum Film Forming temperature MFFT °C	<5	5	27	12	<5
Hydroxyl Number	5.0	5.3	<10	<10	5.0
Solids, wt%	30	33	30	30	30
pH	6.0	6.2	6.6	6.0	6.0
Viscosity, cP	60	89	99	14	15
Particle diameter. nm	27	20	13	54	34

Figure 1 Sulfopolyester Dispersion Types

The key features of the product range are: neutral pH, relatively low solution viscosity and exceptionally small particle size. The solids content of the dispersions are all between 30-33 wt. %. All of these key features can be explained by an understanding of how the Sulfopolyester products are dispersed and stabilized in water.

3.1. Sulfopolyester Electrostatic Stabilization

Figure 2 illustrates diagrammatically the principle of electrostatic stabilization exhibited by Sulfopolyester polymers in water. Such dispersions are neither clear like a true solution polymer nor opaque like a traditional latex dispersion. They are actually colloidal dispersions consisting of a suspension of very

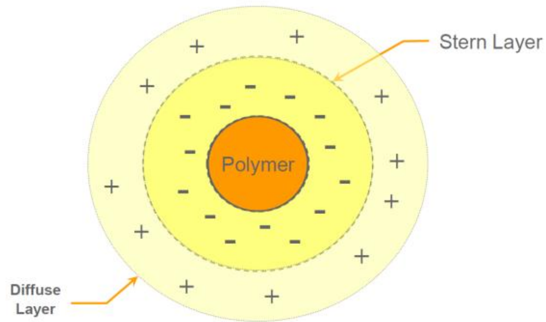

Figure 2 Electrostatic Stabilization

small particles with the SSIPA molecules orientated to the outside of the particle's surface. Since the SSIPA is ionised in water, the polymer particle is negatively charged. The sodium counter ions are located further out in the water resulting in a double layer which provides the electrostatic stabilization due to repulsion forces between other similarly charged particles. This stabilization mechanism limits the level to which the polymer particles can be crowded together resulting in typical solids contents of Sulfopolyester dispersions around 30%. If this level is exceeded, this results in a rapid increase in viscosity due to increased repulsion of the polymer particles. Prior to this point, the solids content of the Sulfopolyester dispersions can be increased without significant increase in viscosity. Figure 3 illustrates the viscosity solids relationship for the product range whilst Figure 4 shows the viscosity vs. shear rate plot for one of the products in the range (Polymer 1100) as a function of solids content.

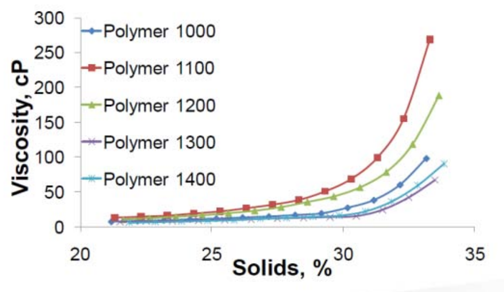

Figure 3 Viscosity/solids relationship

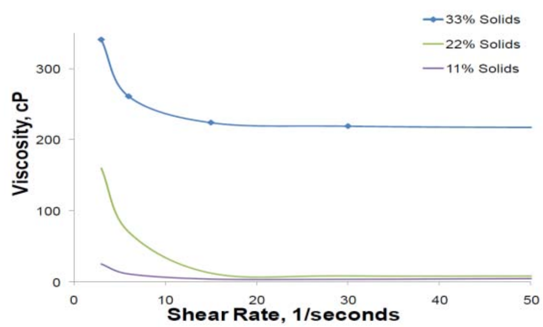

Figure 4 Viscosity/shear rate Polymer 1100

This rapid rise in viscosity with solids content is enhanced when the dispersion is applied onto a porous substrate such as wood or paper resulting in rapid drying of the coating layer.

A further interesting feature of the Sulfopolyester resins is that, due to the monomer composition, there is not a direct relationship between the glass transition temperature (Tg) of the polymer and the minimum film forming temperature of the corresponding dispersion in water.

Thus it is possible to obtain relatively high Tg films with low overall demand for film forming aids such as co-solvents. Sulfopolyester polymers form film by hydro plasticization. If a lower Tg is desired one can easily use a softer Eastek product to soften a harder grade by blending.

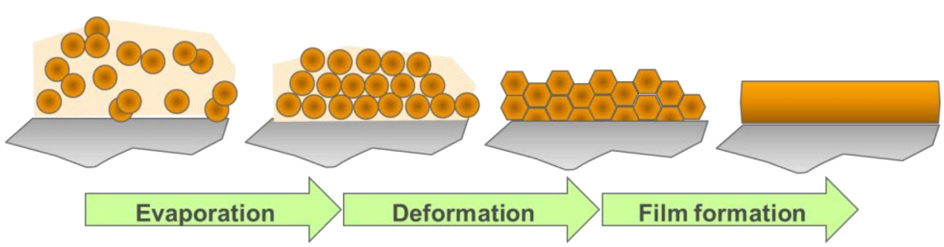

Figure 5 Film formation process

Suitable co-solvents such as butyl glycol can help with film formation for some grades and also butyl glycol acetate is an excellent coalescing aid.

3.2. Viscosity and pH Stability

Sulfopolyester polymers do not utilize carboxyl functionality to obtain solubility and as a result, the viscosity of the dispersion is not dependent on pH level. Coatings based upon the Sulfopolyester polymers are best formulated to be in the near neutral pH range where they have maximum stability. This differs from conventional waterborne dispersions which are often stabilized at high pH with volatile amines. This can be an advantage when parquet is being finished on-site during hot and dry weather conditions. Sulfopolyester based formulations exhibit excellent viscosity control during application. Additionally the Sulfopolyester dispersions exhibit excellent viscosity stability at both high and low pH; however, long term storage of such dispersions at extremes of pH level should be avoided to prevent hydrolysis and/or saponification. A further advantage of near neutral pH level is the lack of interaction and possible colour change resulting from reaction of the coating with acidic extractable materials present in many wood species. Figure 6 illustrates the excellent viscosity control of Sulfopolyester dispersions with varying pH level.

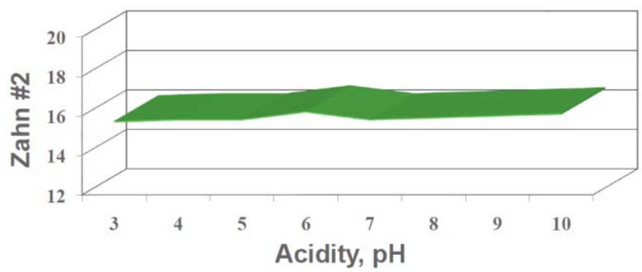

Figure 6: Viscosity stability over wide pH range

3.3. Particle Size and Solution Clarity

As described above, sulphopolyester polymers have exceptionally small particle size in the dispersed state. Figure 8 illustrates the average particle size of Polymer 1100 showing a mean particle size of approximately 20 nm. This results in an almost translucent solution which, when applied onto wooden flooring, allows the applicator to instantly observe the wetting and appearance of the substrate. This contrasts with acrylic dispersions which are often opaque and milky and take some time to become transparent. In certain conditions, such as overlap areas, acrylic dispersions may retain a small amount of opacity due to thickness effects, resulting in lap-marks being visible even after drying.

The appearance of the Polymer ™ primer application has been likened to that of solvent borne coating systems which are also characterised by excellent transparency.

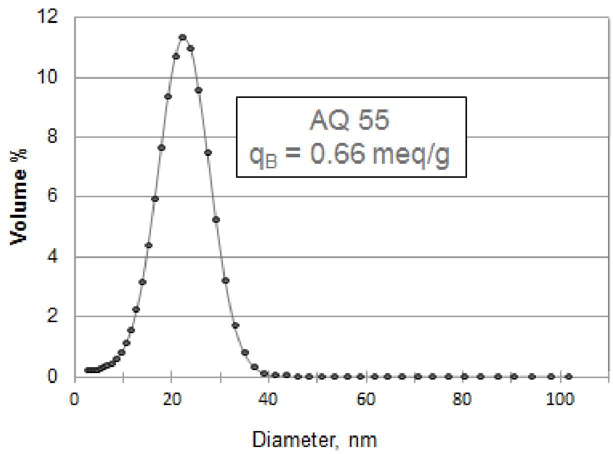

Figure 8: Particle size distribution

3.4. Film Properties

During the drying process of a Sulfopolyester film, it can be observed that the exceptionally small polymer particles coalesce which helps to provide excellent clarity and gloss. Since the dispersion does not contain any solution polymer, the Sulfopolyester dispersions have no tendency to skin during drying which allows the water to escape rapidly from the drying film. Perhaps not so relevant in the roller applied flooring application but this characteristic also prevents drying of coating residues on the container walls which could fall back into the bulk solution resulting in spray nozzle blockages or film contamination typical of acrylic or alkyd emulsion based systems.

The dried films of Sulfopolyesters have very high gloss and clarity by virtue of having a refractive index of 1.55 which is close to the measured value of cellulose fibers in airiv (Figure 9). Thus the appearance of Sulfopolyesters on cellulosic substrates such as wood is seen to be exceptional for a waterborne coating system.

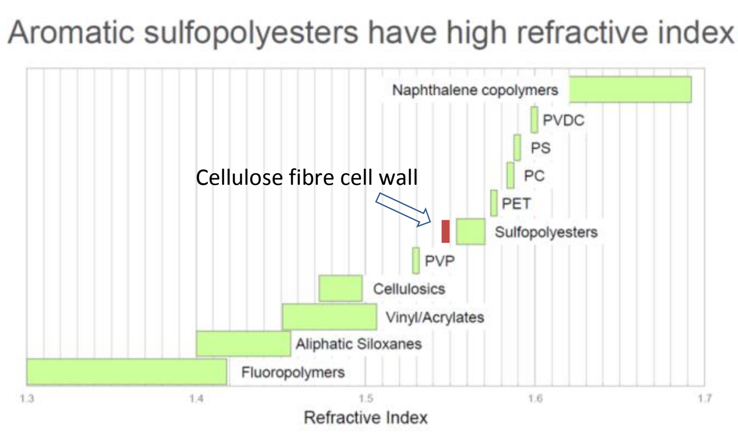

Figure 9: Refractive Index of Polymers

The high gloss and clarity are of particular interest in wood coating applications, since in many cases, the large particle size of traditional coating resin dispersions can result in poor optical characteristics and the alteration of the appearance of the wood. Very often coatings formulators and applicators describe the appearance of waterborne coatings on wood as being 'cold' or 'green' which is probably a direct result of this effect. Work performed on Eastman's behalf by 3P-ICC in Germany has indicated that coating films formulated with Sulfopolyester dispersion (Polymer 1100) had outstanding appearance and apply similar to a solventborne like coating. This level of appearance was said to be almost unknown in acrylic waterborne systems.

4. Investigation into the Performance of Sulfopolyester Dispersion for on-site applied parquet flooring applications

An extensive program of work was performed on Eastman's behalf by the consultancy company 3P-ICC in Germany. The evaluation of Sulfopolyester dispersions for suitability as binder for primers for wood flooring against standard commercial acrylic and polyurethane systems from market leading manufacturers in Europe was done on the following performance areas:

- Drying time (sand free)
- Grain raising (visual assessment)
- Sandability 180/240 grit paper
- Anfeuerung (appearance) visual assessment on various wood species
- Cross-cut adhesion on various wood species
- Water resistance DIN68861 part 1 – 16 hours (with top coat application)
- Ball drop test (flexibility) on various wood species

4.1. Impregnation behavior & appearance

As predicted, the exceptionally small particle size of the Sulfopolyester dispersion results in excellent penetration and impregnation performance into various wood species. The tests show very good results (Figure 9) regarding wetting with an even pore image and no colour change.

Figure 9 Comparison final appearances

In order to understand if the visual difference can also be measured[v] we used a Datacolor Check Plus instrument to compare the colorimetric data with the visual assessment of the Anfeuerung. 20 data points on raw wood and coated wood have been measured and evaluated and the Sulfopolyester polymer came closest to a solvent borne coating. It was possible to see a correlation between the colorimetric measurement of Anfeuerung and the more subjective visual assessment and the results are shown in Figure 10 from left to right showing the best to worse Anfeuerung.

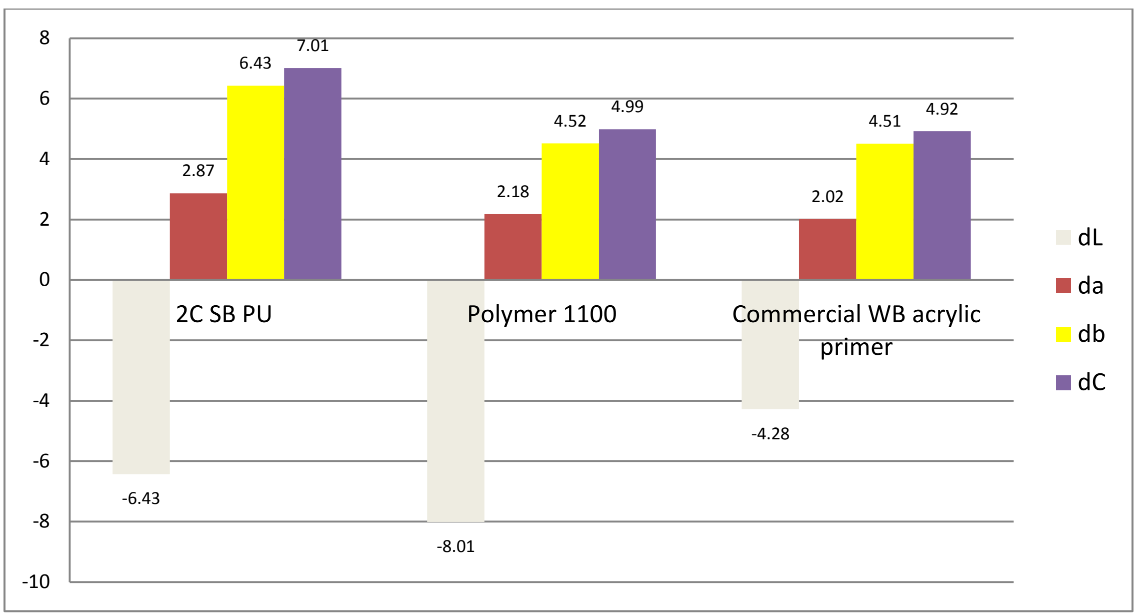

Figure 10 Colorimetric assessment of Anfeuerung

4.2. Drying performance

As mentioned earlier, the electrostatic stabilization of the Sulfopolyester based dispersion can give rise to exceptionally fast drying characteristics compared to other

water borne polymer types. Although the drying rate of a penetrating primer type formulation is also greatly influenced by the level of absorption into the wood, the Sulfopolyester dispersion would appear to offer interesting drying behaviour in an industry looking to improve productivity and throughput. In our tests the Sulfopolyester polymers showed similar drying times as water borne acrylics and significantly faster drying times than PUD. Results are shown in the summary (Figure 11) below.

4.3. Impact Resistance

The impact resistance of the Polymer 1100 as binder was measured with a steel ball test and compared to commercial primers in the total coating system (primer plus two layers of the same PUD). Microscopic pictures show significant differences with fewest cracks showing on the panels with the Sulfopolyester polymer used as primer material. This should correspond to improved durability and life expectancy of the finished flooring system.

5. Conclusions and Benefits

In this paper we have introduced a unique family of water dispersible polyester polymers for use in on-site applied flooring wood coating systems.
Work performed on Eastman's behalf by the independent consultancy firm 3P has identified that the exceptionally small particle size of the dispersions provide unprecedented clarity and appearance on natural wood substrates which can even be compared very favourably to solventborne coatings noted for their remarkable aesthetics.

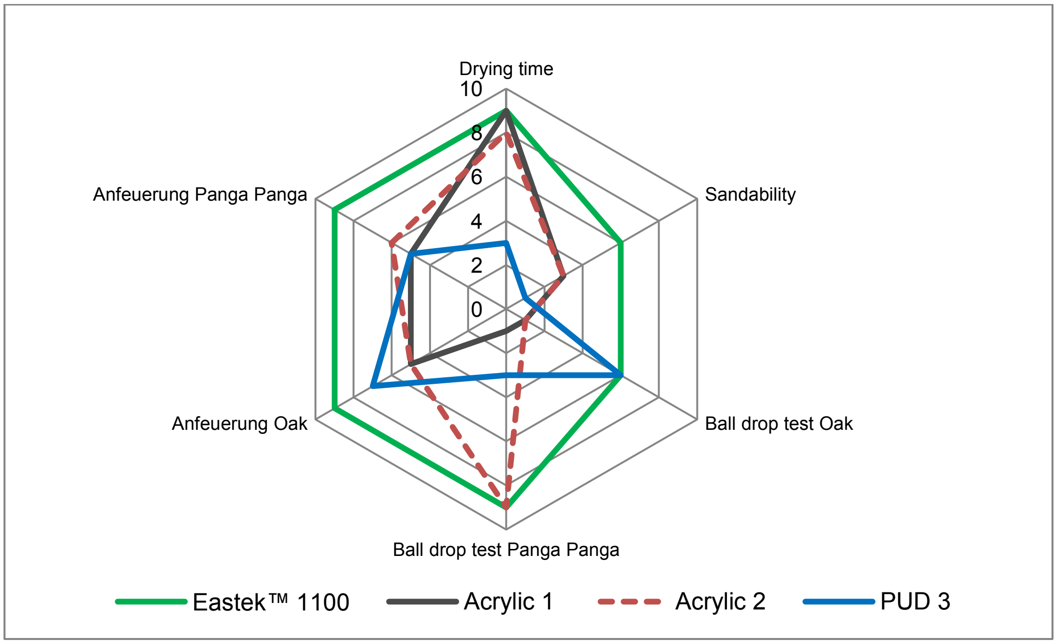

Figure 11 Key results of flooring primer evaluation

The chemical and physical nature of the Sulfopolyester dispersions produce tough, flexible coating systems which are fast drying and possess exceptional gloss and clarity. Furthermore the electrostatic stabilization of the Sulfopolyester dispersion eliminates the need for amine and surfactant based neutralization giving advantages of viscosity stabilization and low foaming.

The advantages exhibited by Polymer as binder in wood coatings primer included the following:

- Outstanding Anfeuerung (wet look, clarity, warmth) on a variety of wood types
- Harmonizing effect (improved penetration into wood of non-uniform density) ensuring even colour and coloured stain acceptance
- Low odour
- Non-skinning
- Excellent drying and hardness development
- Excellent crosscut adhesion
- Easy to formulate
- Excellent flexibility and resistance to mechanical damage with and without top coat systems

In summary we can conclude that the unique characteristics of the translucent Sulfopolyester polymer dispersions provide value to all partners in the value chain. The formulator at the paint companies will be able to reduce his additive package and formulate an amine- and surfactant-free primer that wets out very well. The brand manager will offer a product to the professional craftsman who will enjoy working with a water borne primer that applies like a solvent borne like primer. The product shows him immediate results during application on the floor and dries very well with no grain raise and leaving a harmonic pore image due to the clarity of the primer. Finally, the owner of the floor will enjoy a long durable floor that will not change colour due to reaction of the primer with wood content substances and is wear resistant.

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[i] Estimated by 3P-ICC

[ii] FEP 2010

[iii] K. R. Barton 'Sulfopolyesters: New resins for Water Based Inks, Overprint Lacquers and Primers' American Ink maker, Vol. 71, No. 10 (1993) pp. 70-72

[iv] Cornell University ACM Transactions on Graphics (SIGGRAPH 2005 Proceedings)

[v] Instrument settings: 8° angle, f=15mm, gloss