How to Produce High Performance UV Curable Multilayer Coatings for Prefinished Parquet

Speaker	Jean-Pierre Bleus
Authors	Marc Decaux, Matteo Vasconi, Marc Heylen, Michel Philips, Jean-Pierre Bleus
Company	CYTEC Surface Specialties Drogenbos, Belgium
☞	jean-pierre.bleus@cytec.com
☎	+32 2 3345922
Fax	+32 2 3345370

Abstract
UV curing technology has been used for at least 20 years for wood parquet finishing.
Aliphatic urethane acrylates (100% solids) have been the preferred binders for a long time.
Nowadays, other binders have been developed to meet very specific requirements, technical as well as economic.
In this paper, new products for improved primer adhesion and for improved abrasion resistance of the sealer are presented. It is possible to get good performances by using products other than aliphatic urethane acrylates.
In view of the upcoming legislation for flame retardancy, phosphorus modified binders have been developed and will be presented.

Introduction
UV curing technology has been successful for many years in the finishing of wood parquet.
Aliphatic urethane acrylates were originally chosen for their properties of abrasion resistance, non-yellowing and excellent flexibility-hardness compromise.
Because of specific technical requirements (adhesion, abrasion resistance, flame retardancy, scratch resistance) and also because of economic pressure, new binders have been developed.
For adhesion, water-based products (partially water soluble and emulsions) are used more and more: they give outstanding adhesion and wood wetting.
To avoid the use of water with wood, specially designed 100% epoxy acrylates can also be used to formulate adhesion primers.
The sealer coat, which is the most important as far as coating thickness is concerned, is generally based on aromatic urethane acrylate, as sole binder or combined with flexible polyester acrylate(s) or hard epoxy acrylate(s). These combinations offer a wide choice of properties. Aromatic urethane acrylates have replaced aliphatic ones for price reasons.
If flame retardancy is needed, primer and sealer coats have to be based on phosphorus containing oligomers. A thickness of about 100 g/m² is necessary to meet the specification ISO 9239-1.
Aliphatic urethane acrylates still remain the best choice for the topcoat which has to be chemical and scratch resistant. They also reduce the yellowing of the total system.
All these different coatings with different purposes are applied in a certain sequence:
A thin coat (~ 15 g/m²) of adhesion primer is applied to sanded wood. In the case of water-based primer, water evaporation is not always necessary. Due to the small amount of water, wood fiber rising is minimized.
The sealer coat is applied in several layers to get a good appearance and also to avoid tensions in the film. A total coating weight of 50 g/m² sealer is typical.
The number of sanding steps is reduced for economic reasons.
It is preferred to apply the topcoat (8 to 15 g/m²) in two passes to achieve better flow.
Roller coater is ideally suited to apply the required film thickness on flat substrates.

Adhesion Primer
High performance is required from the parquet coating system. Therefore a good base is necessary. By experience it has been proven that water-based primer is often the best choice for adhesion to wood.

A thin coat (~ 15 g/m²) is applied to well sanded wood. Because of the water, wood fiber rising is expected. The wood swelling is minimized by an adapted wood sanding and also because of the low coating weight.

Another perceived disadvantage is the water evaporation. Once again, because of the small amount of water used, it can be evaporated by the heat and air circulation of the UV lamps. If the following coat is based on urethane acrylate it is not necessary to pass through a flash-off zone before the UV lamps. For epoxy acrylate based sealers, a short evaporation zone may be necessary.

Primers based on partially water soluble urethane acrylate (UA 1) or on emulsion (UA 2) give an excellent wood wetting, providing a good wood color.

Examples of formulations of water-based adhesion primers are given in table 1.

Table 1

Raw Material	Primer 1	Primer 2	Primer 3
UA 1	100.0	80.0	
UA 2			100.0
PEA 2		20.0	
PI 1	1.5	1.5	1.5
RM 1 (50%)			3.0
WA 1			0.5
Viscosity (mPa.s @20°C)	4000	1400	1300
Solids (%)	51	60	41

All these formulations are applied by roller coater, around 15-20 g/m² and gelled at 15 m/min, with 1 UV lamp of 80 W/cm. It is not followed by sanding because of the thin film thickness and so is economically favorable. Formulation 3 gives good adhesion even on tropical wood.

To avoid water contact with wood and minimizing the fiber rising, it is possible to apply a 100% solids adhesion primer. Examples are given in table 2.

Table 2

Raw Material	Primer 4	Primer 5
DPGDA	25.0	30.0
EA 1	65.0	60.0
Talc	5.0	
Calcium carbonate	5.0	
PI 1	5.0	5.0
AM 1		5.0
Viscosity (mPa.s @20°C)	2250	2000
Solids (%)	100	100

As for water-based primer, a thin coat (10 g/m²) is applied by roller coater. It can be gelled (Primer 5) or cured (Primer 4) if a sanding step is foreseen.

If flame retardancy is a specification for the parquet, the primer (applied directly to wood) has to be flame retardant. This primer contributes to the flame retardant properties, but also has excellent adhesion, and wood wetting. Thanks to the phosphorus which is directly bounded to the polymer, the film remains perfectly transparent. The formulation is described in table 3.

Table 3

Raw Material	Primer 6
FR 1	100.0
PI 1	4.0
Viscosity (mPa.s) @ 20°C	5000
Solids (%)	76

15 g/m² are applied by roller coater. In this case a short flash-off is necessary. After UV gel, no sanding is needed before applying the sealer.

Intermediate coats (sealer)
As the intermediate coating has the highest thickness, it is very important for abrasion resistant properties and flame retardant properties.
The application is made in several layers in order to have the best appearance possible and to achieve the optimum mechanical properties. If the thickness of the UV coating is too high there is a risk of film stress which can reduce the physical properties.
The formulation composition will determine the properties: flame retardant, abrasion testing following grit feeder, CS 10, CS 17 or S 42.

Grit feeder: Calibrated falling sand and leather wheels with a load of 1 kg.
Taber CS 10: Wheels of medium hardness with a load of 1 kg.
Taber CS 17: Wheels of high hardness with a load of 1 kg.
S 42: Wheels with sanding paper with a load of 0.5 kg.

Therefore a lot of different binders can be used: aromatic urethane acrylate UA 4 for grit feeder, aromatic urethane acrylate UA 3 for CS 10, combination of polyester acrylate PEA 1 and epoxy-acrylate EA 2 for CS 17, phosphorus oligomer FR 2 for flame retardant or epoxy acrylate EA 2 with 20% aluminum oxide for S 42. The reactivity can be increased by using amino acrylate AM 2.

Examples of formulations for grit feeder are mentioned in table 4. This testing method was originally used in Scandinavia but is now also considered in southern countries.

Table 4

Raw Material	Sealer 1	Sealer 2	Sealer 3
DPGDA		15	18
UA 3	95		
UA 4		85	32
PEA 1			48
PI 1	5	5	5
Viscosity (mPa.s) @ 20°C	3500		3500
Solids (%)	100	100	100

For optimum mechanical properties and appearance, 3 coats of 18 g/m² are applied. The two first coats are gelled; the third one is fully cured and sanded before application of the topcoat.
For improved appearance, the first coat should also be sanded.

A formulation for Taber CS 10 is described in table 5.

Table 5

Raw Material	Sealer 4 (CS 10)
UA 3	95
PI 1	5
Viscosity (mPa.s) @ 20°C	3500
Solids (%)	100

By combining EA 2 with UA 3, it is possible to meet CS 17 specification.
When S 42 specification is required, a hard binder is used: epoxy acrylates are well suited for this property. To meet the specification, Aluminum oxide (Al_2O_3) has to be added to the formulation (table 6) at a level of at least 20%. Large particle size (20 µ) is the more efficient. To avoid surface roughness, larger and smaller particles (10 µ) have to be combined. To avoid settling of these heavy extender particles, a dispersing additive (AS 1) is required.

Table 6

Raw Material	Sealer 6
Reactive diluent	30
EA 2	25
PEA 1	25
Al_2O_3	20
PI 1	3
AS 1	0.5 – 1.0
Viscosity (mPa.s) @ 20°C	
Solids (%)	100

The two first coats of Sealer 6 are applied by roller coater (equipped with a ceramic roll to avoid damage due to the hard aluminum oxide particles) and gelled. Because of their hardness, these coatings cannot be sanded. The third coat has to be a conventional sanding sealer. So sanding is possible before applying the topcoat; this will produce a smooth finishing.

For flame retardant parquet flooring, a phosphorus based resin is used. In order to meet the specifications, a total coating weight of 100 g/m² has to be applied, including the primer 6. This is necessary to get the concentration in phosphorus needed to provide the flame-retardant properties.

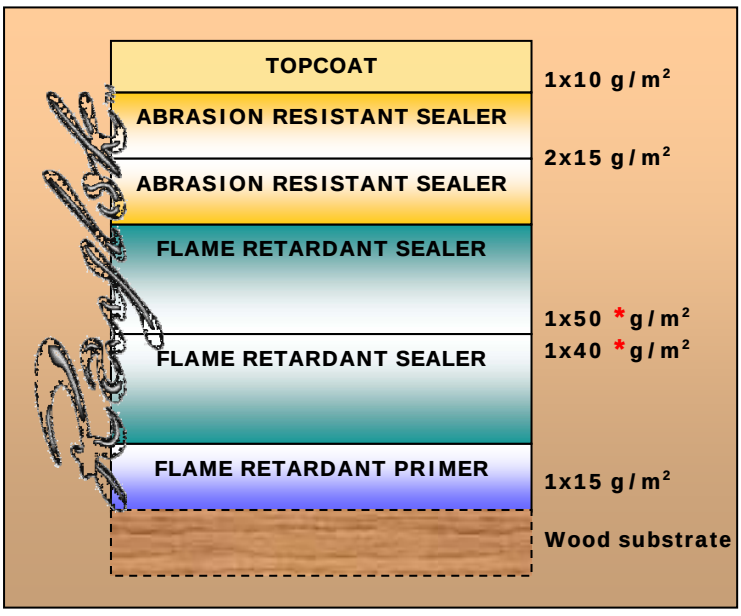
Table 7

Raw Material	Sealer 7
DPGDA	10
FR 2	80
AM 1	5
Talc	5
Crystalline silica dioxide	5
PI 1	5
Viscosity @25°C (mPa.s)	4000
Solids (%)	100

This heavy coat is applied in 2 passes (50 + 40 g/m²) by roller coater (45°C) followed by a steel smoothing roll. The first coat is gelled with 1 UV Hg lamp of 80 W/cm at 15 m/min, the second coat is cured at 15 m/min with 3 lamps of 80 W/cm.

To increase abrasion resistance, after sanding, 2 extra coats of 15 g/m² of abrasion dedicated sealer are applied (see figure 1 which illustrates this multi-layer system)

Figure 1



Topcoat

Before applying the topcoat, a sanding step is necessary in order to provide a smooth surface and obtain very good adhesion.
The topcoat has an aesthetic function; this is why thin coats are applied preferably in 2 passes.
It has also to protect against stains, chemicals and has to be scratch resistant.
Examples of formulation are mentioned in table 8.

Table 8

Raw Material	Topcoat 1	Topcoat 2 (High scratch)
DPGDA	42.0	29.0
UA 5	40.0	
UA 6		54.5
Benzophenone	3.0	
PI 1		4.0
PI 2	2.0	1.0
Matting agent	10.0	9.0
Polypropylene wax	2.0	2.0
DEF 1	0.5	0.5
Viscosity (mPa.s) @ 20°C	1300	1600
Solids (%)	100	100
Gloss (65°)	25	25

The topcoat is applied by roller coater in 2 passes: 8 g/m² gelled + 6 g/m² and is fully cured.
Topcoat 2 has an excellent steel wool scratch resistance.

Results

Abrasion results (average values of number of cycles to initial point) are given in table 9

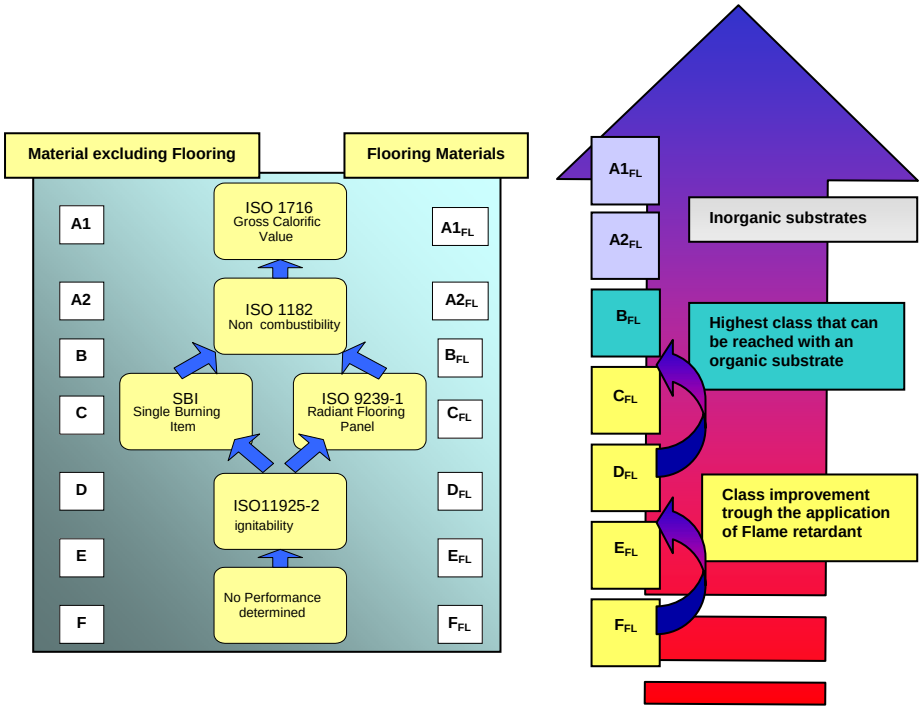
Table 9

	Grit Feeder	CS 10
Primer 1 + Sealer 1 + Topcoat 1	3500 - 4000	4000- 4500
Primer 1 + sealer 2 + Topcoat 1	2500 - 3000	3000- 3500
Primer 1 + Sealer 3 + Topcoat 1	2500 - 3000	2500

With the sealer formulations, it is possible to have a good compromise Grit Feeder and CS 10 results.

Flame retardant: Classification B_{FL} (ISO 9239-1) can be obtained, which is the highest class that can be reached with an organic substrate (see figure 2).
The abrasion properties (Grit feeder and CS 17) remain good for a total coating weight of ~ 150 g/m² (Conventional flame retardant coat weight is above 200 g/m²).
This heavy coat remains perfectly clear and transparent, which is not always the case with Flame retardant products.

Figure 2



Scratch resistance

With hexafunctional urethane acrylates it is possible to achieve good steel wool test resistance.

Wood wetting

This is illustrated in figure 3: good wood wetting (left) and bad wood wetting (right). All the primers described in the first part of this presentation give an appearance like the left side of the figure 3 (good wetting).

Figure 3

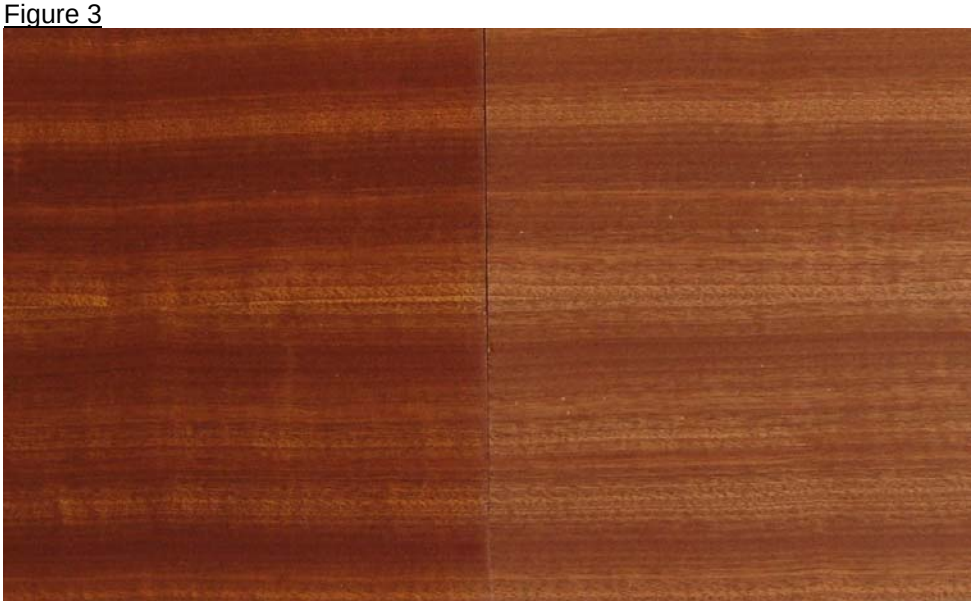


Table 10: Raw Materials

Product	Description	Functionnality	Dilution	Viscosity (mPa.s)	Used in
AM 1	Amino acrylate	NA	100%	1200 @ 25°C	
AM 2	Amine modified polyether acrylate	3,5	100%	500 @ 25°C	Sealer
AS 1	Amine neutralized fatty acid - prevents sedimentation	NA	60%	100 @ 23°C	
DEF 1	Silicone-free defoamer-air release	NA	7,50%	< 20 @ 25°C	
EA 1	Flexible epoxy acrylate	2	100%	600 @ 60°C	Primer
EA 2	General purpose epoxy acrylate	2	100%	25000 @ 25°C	Sealer
FR 1	Phosphorous based acrylated oligomer	2	75 % in water	3300 @ 25°C	Primer
FR 2	Phosphorous based acrylated oligomer	2	100%	7100 @ 60°C	Sealer
PEA 1	Polyester acrylate	3	100%	34000 @ 25°C	Sealer
PEA 2	Partially water soluble polyether acrylate	3	100%	155 @ 25°C	Primer
PI 1	Benzophenone and 1-hydroxy-cyclohexylphenylketone	NA	100%	~ 100 @ 25°C	
PI 2	2-hydroxy-2-methyl-1-phenyl propanone	NA	100%	25 @ 25°C	
RM 1	Rheology modifier (polyurethane)	NA	30%	NA	
UA 1	Partially water soluble aliphatic urethane acrylate	NA	50 % in water	4500 @ 25°C	Primer
UA 2	Aliphatic urethane acrylate emulsion	NA	40 % in water	< 200 @ 25°C	Primer
UA 3	Aromatic urethane acrylate	2	100%	4100 @ 25°C	Sealer
UA 4	Aromatic urethane acrylate	2	100%	8000 @ 25°C	Sealer
UA 5	Aliphatic urethane acrylate	3	100%	45000 @ 25°C	Topcoat
UA 6	Aliphatic urethane acrylate	6	100%	700 @ 60°C	Topcoat
WA 1	Wetting agent-Fluorene modified acrylic copolymer	NA	50%	NA	

Conclusion

This paper has shown how a high performance pre-finished parquet coating can be produced using a suitable variety of UV curable oligomers in the different layers.

Waterborne resins, partially water soluble and in emulsion, or 100% flexibilised epoxy acrylates have been proved to be the best solution for improved adhesion primers.

With recently developed aromatic urethane acrylates used in sealers as the sole binders or in combination with flexible polyester acrylates or hard epoxy acrylates, it is possible to achieve outstanding abrasion resistance properties, not forgetting the economy of the coating.

Scratch resistance and low yellowing are the key reasons why aliphatic urethane acrylates are still the best option in parquet topcoats.

Flame retardant coatings will become a more important requirement for parquet flooring in the future. Suitable resins, meeting the specifications of the upcoming EU directive, are now available to the market.

It is clear that technical innovations are still very relevant in the UV curable parquet coatings, but economy of the formulations has to be taken in account in a more competitive market environment.

This is certainly a challenging task both for raw material suppliers and coating formulators!

Home