Flame Retardant Radiation Curable Coatings For Wood Application

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Abstract

Due to the continuous trend in more stringent safety regulations, search for polymers with flame retardant (FR) properties is important. In the case of coatings (radiation curable or conventional), their flammability can contribute to the fire propagation. In some wood coating applications, significant level of fire-retardancy is required. In this paper UV-curable oligomers containing phosphorus FR moieties covalently bound to the backbone will be presented. It will be shown that their application in wood coatings significantly improves the fire-retardant properties of the coated materials.

Introduction

Since the early seventies, radiation curing technology has enjoyed an uninterrupted growth in the field of coatings, printing inks and adhesives and this trend is expected to continue into the first decade of this century. The major factors fuelling the growth of radiation-cured formulations include the outstanding performance of the coatings (gloss, durability, adhesion to substrate), very fast curing (within seconds or fractions of seconds without the need for heating), low process costs per square meter of surface, product stability on the application machines and the low space requirements of the application lines.
One of the most successful areas has been the wood coatings industry, more particularly the furniture and the parquet flooring sectors. The main application technique was the roll-coater and because of its flat structure wood parquet is of course perfectly designed for this kind of application. The coating usually consists of several layers in order to obtain an optimum performance in both stain and abrasion resistance. Between the different layers intermediate curing or gelling is done and depending on the circumstances and the requirements a sanding step is included. Over the years the application and curing equipment were continuously improved. This resulted for example in higher productivity (faster cure speed) and better surface properties (scratch and abrasion resistance, stain resistance). This also allowed the development of coating systems that fill the wood pores and/or splits well. For application on flat surfaces by roller coater the 100% UV products are well introduced today and a large choice of binders is now available.
Increasing environmental pressure, the recognised need to move to non-polluting alternatives but also the benefits associated with the UV technology will stimulate the penetration of more specified applications of the wood industry like flame retardant coatings.

Due to the continuous trend towards more stringent safety regulations, the search for polymers with flame retardant (FR) properties is becoming more important. In the case of coatings (radiation curable or conventional), their flammability can contribute to the fire propagation. In some wood and cable coating applications, significant level of fire-retardancy are required and coatings with flame retardant properties have been developed.
Two main classes of “flame-safe” coatings can be distinguished. The first class generally referred to as flame retardant coatings, concerns coatings that delay ignition and hinder flame spread. The second class concerns coatings that combine the properties of the first class with protection of the substrate by formation of an insulation layer during its combustion. Such systems are also referred to as intumescent coatings.

In conventional plastics, additives such as chlorinated/brominated aromatics, antimony halides, organophosphorus compounds or combinations thereof are commonly used to impart flame retardancy. However, the additive approach suffers from several drawbacks, like low compatibility with the polymer matrix, negative impact on the physical and mechanical properties of the material and additive loss by migration. In the case of UV-curable coating, pigmented additives will reduce the UV reactivity of the resin and additive migration leads to a blooming of the surface. In addition flame retardant clear coats giving a nice appearance of the wood are not achievable with additives. Finally, halogen based fire retardant systems show undesirable negative side effects so that an urgent need is now to be satisfied for halogen free fire retardant systems.
In order to avoid such drawbacks, binders with phosphorus-containing flame retardant functionality, covalently bound to the polymer backbone were developed. The main benefits of this new chemistry are its non-toxicity, the superior clarity of the cured films, the environmental compliance (solvent free) and the properties achieved with thin films.

Flame Retardant Binders and Starting Point Formulations

Two new phosphorus containing polyester acrylate binders Raylok™ 1721and Raylok™ 1722 were developed to formulate FR adhesion primer and FR sealer. Their characteristics are outlined in table 4.

Table 4: characteristics of the phosphorus-based FR binders

Raylok™ 1721 Binder for FR adhesion primer
Difunctional water soluble phosphorus polyester acrylate, 75% solid content
Höppler viscosity (25°C): 3300 mPa.s
Contains 5% phosphorus on solid
pH=6.5-7.5

Raylok™ 1722 Binder for FR sealer
Difunctional phosphorus polyester acrylate
Höppler viscosity (60°C): 7100 mPa.s
Contains 5% phosphorus on solid

Starting point formulations for primer and sealer are outlined in table 5. The amount of reactive diluent and photoinitiator system in the sealer should not exceed 20% in order to maintain a sufficient concentration in phosphorus to get the required flame-retardant performance.

Table 5: starting point formulations for FR primer and FR sealer

Formulation for FR primer	
Raylok™ 1721	96
Photoinitiator	4
Brookfield viscosity(20°C):3300 mPa.s	

Formulation for FR sealer	
Raylok™ 1722	80
Photoinitiator	5
Aminoacrylate	5
Difunctional reactive diluent	10
Talcum	5
Crystalline SiO_2	5
Brookfield viscosity(20°C):1200 mPa.s	

Flame Retardant Radiation Curable Coatings for Horizontal Application (Parquet Flooring)

An application process was specifically developed for parquet flooring application. This system meets the requirements of the parquet coating industry in terms of wood aspect, abrasion, scratch, chemical and solvent resistance combined with flame retardant properties in the radiant flooring panel test (ISO 9239-1) and ignitability test ISO 11925-2. The coated materials have a class B_{FL}* in the new harmonised European classification of construction materials (see figure 1) which is the highest class attainable for an organic material. Normally the different types of wood floorings without any kind of treatment are in the D_{FL} class of reaction to fire in this new Euroclass system.

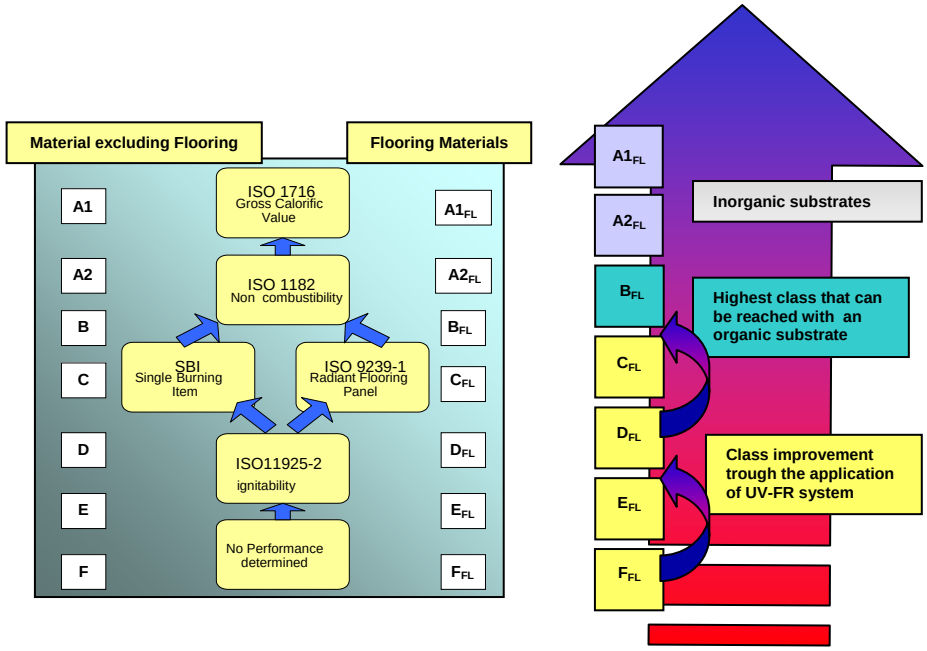

Figure 1: Euro-classification of construction materials for flame retardancy. Improvement of flame retardancy properties of coated parquet through the use of the UV-FR system (tested with Radiant Flooring Panel Test)

* from orientation test on MDF-beach veneer panels

The application system has a total coat weight of approximately 140 g/m^2 and includes (see figure 2):

- an adhesion primer based on Raylok^{TM} 1721 (water-based phosphorus containing polyester acrylate) applied at 15 g/m^2 wet
- a sealer based on Raylok^{TM} 1722 (UV 100% phosphorus containing polyester acrylate) applied in 2 or 3 coats with a total coat weight of 80 to 90 g/m^2. It should be applied with a heated smoothing roll-coater
- a classical abrasion resistant UV coating based on Raylok^{TM} 1124 applied in 2 coats with a total coat weight of 30 g/m^2
- a classical UV topcoat based on Ebecryl^{TM} 265 (8 g/m^2)

The high thickness of the phosphorus-based sealer is necessary to get the concentration in phosphorus needed to provide the flame-retardant performance of the system.

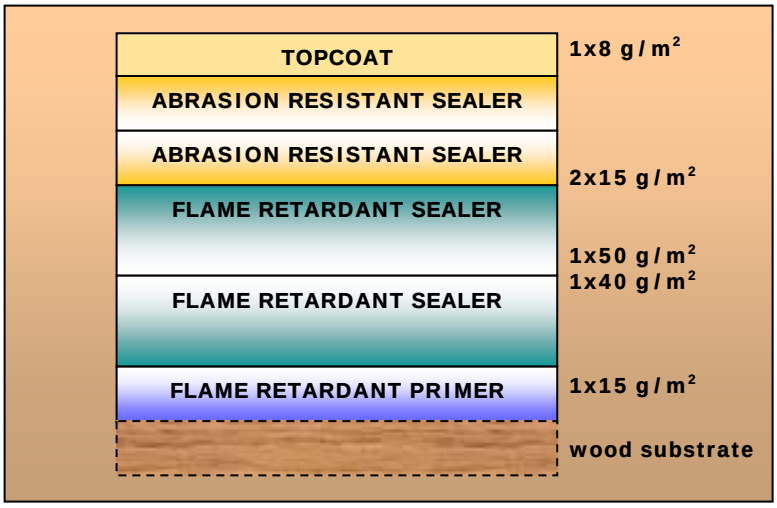

Figure 2: cross-section of the flame retardant multi-layers UV-curable system for parquet application

The UV curable flame retardant system was compared with a conventional solvent based industry standard for abrasion resistance, mechanical properties and flame-retardant performance and with a classical UV curable system for abrasion resistance and mechanical properties. The results are summarised in table 6 and clearly show the superior performances of the UV curable system.

Table 6: comparison of the performances of the UV curable flame retardant system with a solvent based flame retardant industry standard and a conventional UV curable system for parquet.

Methods	Properties	UV Curable flame retardant	Conventional UV curable system	Industry standard flame retardant
ASTM F510-93	Grit feeder abrasion (1 kg) weight loss after 4000 cycles	290 mg	260 mg	760 mg
ASTM D6040	CS 17 Taber abrasion (1 kg) weight loss after 3000 cycles	320 mg	300	750 mg
ASTM D2794	Impact resistance	+ (50 cm)	+	- (< 10 cm)
	Coin test	++	+/-	+/-
ISO 9239-1	Flame retardant	class B_{FL}	class C_{FL}	class C_{FL}
Total dry coat weight		160 g/m^2	60 g/m^2	225 g/m^2

Flame Retardant Radiation Curable Coatings for Vertical Application

An application process was developed to improve the fire resistance of MDF panels for vertical application (doors, partition wall). This system-applied on 4 mm thick MDF allows reaching class II in the Vertical Radiant Panel Test (CSE RF 3/77), see figure 3. Unprotect MDF gets class IV in this test.

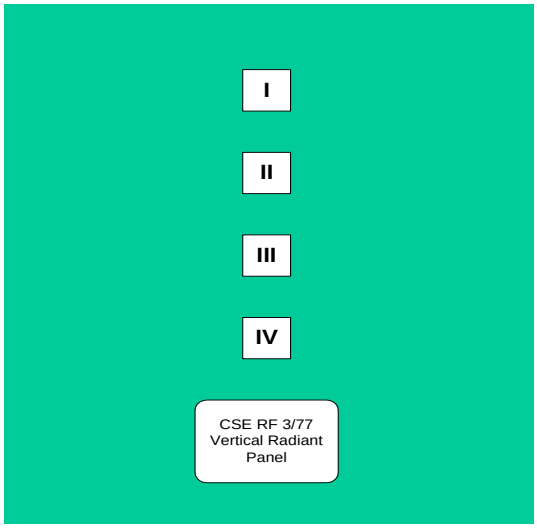

Figure 3: classification in the Vertical Radiant Panel Test

The application system has a total coat weight of approximately 120 g/m^2 and includes:

- an adhesion primer based on Raylok^{TM} 1721 (water-based phosphorus containing polyester acrylate) applied at 15 g/m^2 wet
- a sealer based on Raylok^{TM} 1722 (UV 100% phosphorus containing polyester acrylate) applied in 2 or 3 coats with a total coat weight of 80 to 90 g/m^2. It should be applied with a heated smoothing roll-coater
- a classical UV topcoat based on Ebecryl^{TM} 265 (8 g/m^2)

Conclusions

Over the years, radiation curing has become a successful technology in the wood coatings industry. Under environmental pressure and to take advantage of this unique curing mechanism, new chemistries like phosphorus containing acrylates have been developed to meet the new market requirements for flame-retardant coatings.

If these resin developments can be efficiently integrated with new developments in application and curing equipment and with new photoinitiators, pigments and additives, the future continues to look bright for radiation curing technology in the wood coatings area.

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