Leading the Way With Dual Cure Technology

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Abstract

Dual cure coatings address the need for superior performance in interior automotive applications. By providing exceptional scratch and chemical resistance, as well as shadow cure capabilities, dual cure coatings fill in the performance gaps afforded by an all-thermal or all-UV approach. These coatings present finishers with a wide range of processing options. Dual cure technology provides both physical and intangible benefits that are essential in today's results driven world.

Introduction

UV coatings have long been bane of many automotive interior finishers. Many interior parts have intricate geometries that do not allow for light to completely reach all the nooks and crannies. The result can be an uncured or tacky finish. These factors can lead to various performance issues, as well as an overwhelming smell due to uncured resins outgassing. Thermal coatings are the clear winner because of the wide processability. To eliminate the shortcomings of a strictly UV or thermal system, dual cure technology relies on a multitude of cure mechanisms for enhanced performance. This flexibility widens the processing window and delivers fully cured coatings with high adaptability.

Formulation

As the term "dual cure" implies, this technology is an amalgamation of UV and thermal resins. UV acrylate monomers and oligomers, photoinitiators, thermal acrylic resins, and solvents comprise the base system. Formulations can also include other performance enhancing resins and additives. Combinations of these raw materials results in a system that has adhesion to a wide range of substrates while providing impeccable surface hardness for scratch and abrasion resistance. Dual cure systems are typically 2K due to stability issues. Packaging a dual cure coating as a 1K system can create difficulties with the variety of cure mechanisms already in play.

Performance Enhancements

The screening matrix for dual cure coatings typically falls into four categories: adhesion, scratch, chemical resistance, and weathering. Many thermal coatings have an inherent "self-healing" mechanism wherein scuffs and abrasions at the surface typically disappear due to the flexibility of the resins. While initially beneficial from a scratch standpoint, the lower crosslink density makes the coating susceptible to moisture and chemical penetration. The result can be a lifting or wrinkling of the paint. The high crosslink density of UV coatings makes them seemingly impervious to surface abrasions, but this comes at the cost of reduced weatherability and the inability to adhere to certain substrates.

Dual cure coatings offer a great compromise to all the above listed attributes (Figure 1). Sunscreen, oils from air fresheners, drink spills, and other common residues transferred to high touch interior automotive surfaces have a hard time penetrating the highly crosslinked surface. Surfaces display no wrinkling with minimal discoloration and ghosting (the outline left from the air freshener). Salt and other common abrasives that find their way inside a car do next to nothing to scuff the surface. Due to the nature of the technology, dual cure coatings do not sacrifice weathering performance.

		General Scratch			VW Microscratch		Ford Microscratch			Martindale	Linear Abrasion
Basecoat	Topcoat	1mm 5-Finger 6, 8, 10N	7mm 5-Finger 8, 10, 12N	10N Erichsen	20 ° - Initial Gloss Retention	20 ° - 24 h Gloss Retention	20 ° - Initial Gloss Retention	20 ° - 24 h Gloss Retention	20 ° - 7 Day Gloss Retention	20 ° Gloss Retention	Appearance
Thermal BC	Thermal TC	Fail - 6N	Fail - 8N	Pass	35.66	56.18	35.66	56.18	53.06	43.56	Pass
Thermal BC	UV TC	Fail - 6N	Pass	Pass	81.63	75.76	81.63	75.76	84.60	91.51	Pass
None	Tinted Dual Cure	Pass	Pass	Pass	97.36	97.82	97.36	97.82	97.67	99.08	Pass

		Air Freshener		VW Sunscreen			VW Handcream			Chrysler Suntan		GM Sunscreen/DEET	
Basecoat	Topcoat	Appearance	6N 5-Finger	Appearance	10N Erichsen	1mm Adhesion	Appearance	10N Erichsen	1mm Adhesion	Appearance	6N 5-Finger	Appearance	6N 5-Finger
Thermal BC	Thermal TC	Fail	Fail	Fail	Pass	Pass	Fail	Pass	Pass	Fail	Pass	Fail	Pass
Thermal BC	UV TC	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
None	Tinted Dual Cure	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

		Ford Xenon - 2406.4 kjs		
Basecoat	Topcoat	Appearance	Post Water Soak Appearance	Post Water Soak Adhesion
Thermal BC	Thermal TC	Pass	Pass	Pass
None	Tinted Dual Cure	Pass	Pass	Pass

Figure 1 – Dual cure coatings outperform thermal basecoat/clearcoats in scratch and chemical testing. It also outperforms UV topcoats in microscratch and 5-finger scratch testing. The thermal basecoat/topcoat combination is a 2K, solventborne urethane-based system. The UV topcoat is also a solventborne urethane-based system.

Processing

Dual cure coatings only have two processing requirements: an oven for the thermal cure and UV lamps for acrylate cure. These conditions make it easy for finishers to develop new paint lines as well as retrofit existing lines. Dual cure coatings are commonly processed using one of the two basic formats: pre-bake followed by UV cure or UV cure followed by post bake (Figure 2). A paint line set up for thermal technology typically has a spray booth with guns for primers, basecoats, and clearcoats, followed by a convection or IR oven. Adding a bank of UV lamps at the end of the oven is the only thing needed to ensure complete dual cure. This adaptability allows finishers to create new lines with smaller footprints or modify existing lines to ensure full capacity. Lines set up for UV cure followed by a post bake offer multiple benefits. The short flash followed by a UV cure creates a tack free surface that results in less scrap due to reduced dirt accumulation during a long bake process. This set up also allows for a shorter processing time, reducing cost to the finisher.

Dual cure coatings can be used as a tinted monocoat. A tinted monocoat system is slightly pigmented and is intended to be applied in a single layer. In conjunction with the color of the substrate, this adds a beautiful depth of appearance to the part. Due to the lower pigment loading, full opacity is not achievable with a monocoat.

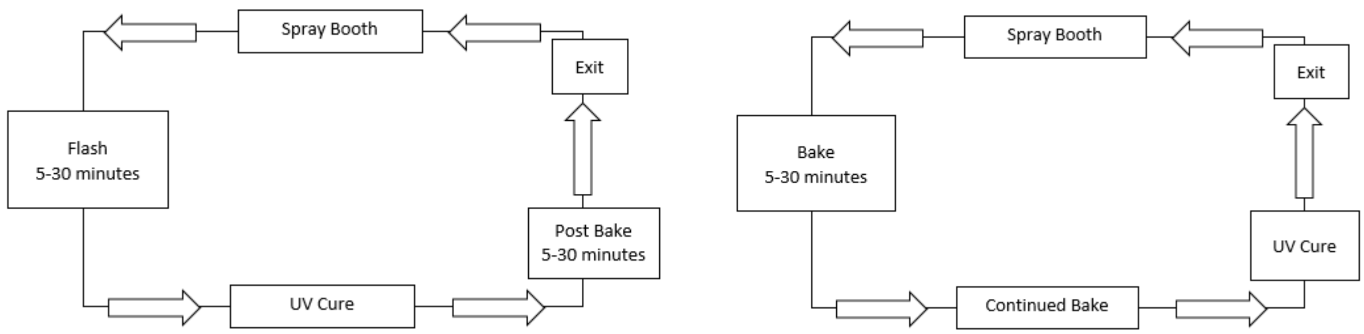

Figure 2 – Dual cure processing can follow two different paths. A short flash followed by UV cure allows for less dirt accumulation/scrap due to quick surface curing. It can then be followed by a post bake to continue curing thermally (image left). A current thermal line can be retrofitted to add UV lights to the end. The result is the finisher being able to run a variety of coatings without having to install a new line set up (image right).

Considerations

One of the biggest obstacles with dual cure monocoat technology is the limited color palate. Most UV systems are clear or lightly pigmented as tints can interfere with the cure. Pigments, pearls, and metallic flakes can all inhibit the cure by scattering UV radiation and preventing enough light waves from penetrating deep into the coating (Figure 3). The result of this is uncured acrylate near the substrate interface. The higher the film build of these pigmented coatings, the worse the cure.

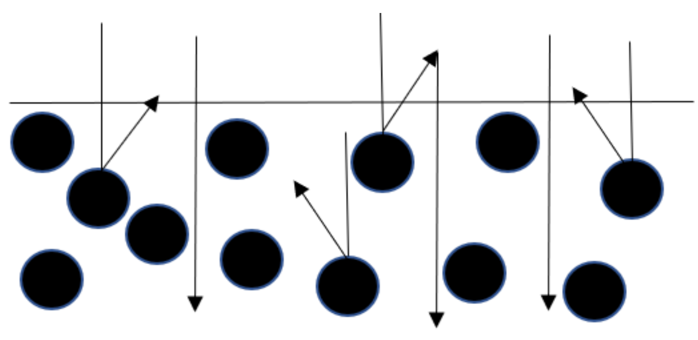

Figure 3 – Transmission of UV energy can be affected by pigmentation. This image shows the blocking and back-scattering of energy from the pigments. This can interfere with the cure in deeper layers of the coating.

In order to sidestep this hinderance, one of two methods can be applied. First, dual cure coatings can be formulated with photoinitiators that absorb in the 360-380 nanometer range. These so called “through-cure” photoinitiators are reactive with longer wavelengths of energy that are emitted from the UV lamps. The longer waves penetrate further into the coating and allow for a better cure close to the substrate.

The second method to overcoming cure related issues is to change the spectral output of the UV lamps. Standard UV paint lines are equipped with mercury bulbs (commonly referred to as H bulbs). H bulbs produce energy with shorter wavelengths and are suitable for curing thin and non-pigmented coatings. D bulbs (iron doped) and V bulbs (gallium doped) produce longer waves of energy that are particularly good at curing thick or pigmented coatings. To get a more complete cure, either D bulbs, V bulbs, or a combination of H, D, and V bulbs may be used. Providing the proper energy spectra is essential to achieving full cure.

Another potential challenge is the interference of multiple curing mechanisms. Depending on the processing, dual cure coatings may undergo a more thorough UV cure or thermal cure depending on when the coating receives heat or UV light. Either way, a reaction in favor of either mechanism may lock up unreacted materials in the other chain, essentially terminating any future chain propagation. This incomplete cure can lead performance issues. The residual materials can lead to outgassing (volatilization of unreacted components). It can also result in premature adhesion failures. Formulation and processing must be carefully balanced to provide ample thermal and UV cure.

Conclusion

Dual cure technology has unlocked the ability for UV cure mechanisms to become ubiquitous in automotive interior applications. The ability to be pigmented allows for flexibility in processing that encompasses most paint lines. The advantages of high scratch, chemical, and moisture resistance are innumerable. These developments will continue to push towards smaller line footprints, lower energy and material demands, and ultimately enhanced performance at lower costs.