Innovations in Dual Cure Technology

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Abstract

Dual cure is an emerging technology that bridges the strengths of typical thermal and UV systems. It provides the superior scratch and chemical resistance hallmark to UV coatings while allowing for shadow curing via thermal reactions. This feature has made dual cure an attractive option for automotive interior applications. Its processing flexibility also allows finishers to adapt and retrofit lines without having to build from scratch.

Introduction

Many finishers have shied away from UV coatings for automotive interiors for a variety of reasons. Foremost amongst the concerns is the ability for the paint to fully cure in the absence of UV light. Low molecular weight monomers could potentially be left uncured, thus causing problems including tacky parts on handling and outgassing. These valid concerns leave thermal coatings as an easy choice from a processing standpoint. However, new developments in dual cure technology address many of these worries. Formulations are now able to use a multitude of resins and resin technologies to cure all materials within the coating for worry free processing.

Formulation

As the term "dual cure" implies, this technology is an amalgamation of UV and thermal resins. UV acrylate monomers and oligomers, photoinitiators, acrylic resins, and solvents comprise the base system. Formulations can also include other property modifying 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.

Performance Enhancements

The screening matrix for dual cure coatings typically falls into four categories: adhesion, scratch, chemical resistance, and weathering. Thermal coatings can have "self-healing" properties in which scuffs and abrasions to the surface eventually disappear due to the flexibility of the resins. While this is a beneficial characteristic from a scratch perspective, it leaves the coating vulnerable to attack from various chemical agents. UV coatings usually have a highly crosslinked surface that demonstrates excellent toughness for scratch but leaves it brittle and susceptible to adhesion and weathering issues.

Dual cure coatings can check all these boxes (Figure 1). A densely crosslinked surface prevents attack from chemicals and moisture, holds up to abrasions, and offers better adhesion and protection from UV degradation. The coating holds up exceptionally well to harsh chemicals in air fresheners and sunscreens. Surfaces display no wrinkling with minimal discoloration and ghosting. Crock testing has negligible effects on the surface, and five finger scratching shows slight indentation with no exposure of the substrate.

		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% Gloss Retent.	20% Gloss Retent.	20% Gloss Retent.	Post Gloss 24 hrs	24 Hrs. % Retention	Post Gloss 7 day	7 day % Retention	% Gloss Retent.	Appearance
Thermal BC	Thermal topcoat 1	Fail - 6N	Fail - 8N	Pass	35.66	56.18	35.66	50.10	56.18	47.31	53.06	43.56	Pass
Thermal BC	Thermal topcoat 2	Fail - 6N	Fail - 8N	Pass	41.69	83.38	41.69	73.73	83.38	66.27	74.94	57.18	Pass
Thermal BC	UV topcoat 1	Fail - 6N	Pass	Pass	85.72	91.01	85.72	79.66	91.01	85.46	97.64	91.43	Pass
Thermal BC	UV topcoat 2	Fail - 6N	Pass	Pass	70.21	76.49	70.21	68.23	76.49	71.64	80.32	97.12	Pass
Thermal BC	UV topcoat 3	Fail - 6N	Pass	Pass	81.63	75.76	81.63	66.97	75.76	74.79	84.60	91.51	Pass
Thermal BC	Dual Cure topcoat	Pass	Pass	Pass	93.37	93.04	93.37	82.43	93.04	89.61	100.00	98.54	Pass
none	Dual Cure tinted topcoat	Pass	Pass	Pass	97.36	97.82	97.36	85.10	97.82	84.87	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 Adh.	Appearance	10N Erichsen	1mm Adh.	Appearance	6N 5-Finger	Appearance	6N 5-Finger
Thermal BC	Thermal topcoat 1	Fail	Fail	Fail	Pass	Pass	Fail	Pass	Pass	Fail	Pass	Fail	Pass
Thermal BC	Thermal topcoat 2	Fail	Fail	Fail	Pass	Pass	Fail	Pass	Pass	Fail	Pass	Fail	Pass
Thermal BC	UV topcoat 1	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Thermal BC	UV topcoat 2	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Thermal BC	UV topcoat 3	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Thermal BC	Dual Cure topcoat	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
none	Dual Cure tinted topcoat	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

		Ford Xenon - 2406.4 kjs		
Basecoat	Topcoat	Appearance	Post Watersoak Appearance	Post Watersoak Adhesion
Thermal BC	Thermal topcoat 1	Pass	Pass	Fail
Thermal BC	Dual Cure topcoat	Pass	Pass	Pass
none	Dual Cure tinted topcoat	Pass	Pass	Pass

Figure 1

Processing

Just as there are multiple ways to formulate a dual cure coating, there are also numerous ways in which it can be processed. Dual cure coatings only have two processing requirements: an oven for the thermal cure and UV lamps for acrylate cure. This allows finishers the ability to retrofit existing paint lines without the necessity of building new ones. Dual cure coatings are commonly processed using one of two basic formats: pre-bake followed by UV cure and 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 cure. This adaptability allows finishers to create new lines with smaller footprints or modify existing lines to ensure full capacity.

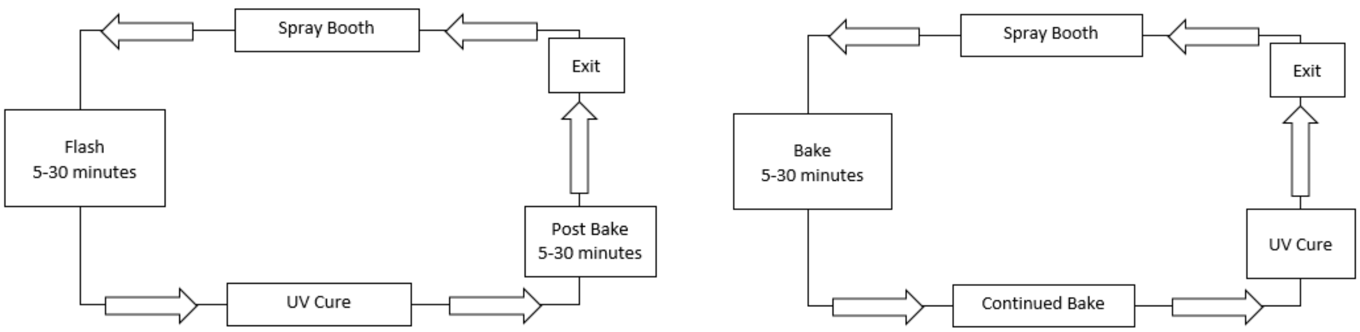

Figure 2

Considerations

One of the biggest obstacles with dual cure 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.

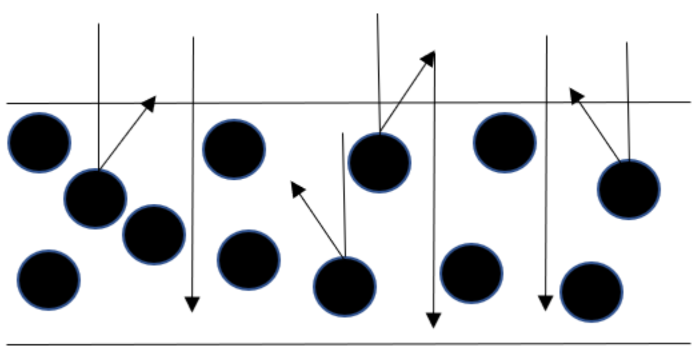

Figure 3

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. Formulation and processing must be carefully balanced to provide ample thermal and UV cure

Conclusion

Advances in dual cure technology have opened the doors to coatings that provide superior scratch, chemical, and moisture resistance in high traffic locations while allowing for full curing of pigmented systems. This one-two punch offers a wide range of processing that can conform to most paint lines. These developments will continue to push towards smaller line footprints, lower energy and material outputs, and ultimately enhanced performance at lower costs.