UV Coatings for Automotive Interior Applications

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For many years, automotive manufacturers have turned to traditional thermal coatings to appoint their interior trims. With increased desire for higher quality, more durable appearances, OEM are upgrading performance testing, especially for interior automotive coatings. With harsher requirements across properties such as chemical resistance, abrasion resistance, and weathering, UV curable coatings are becoming more suited for these types of automotive interiors.

This paper will address the current coating methods on plastic interior automotive trim components. Also included are the typical performance and processing requirements, challenges involved in developing UV coatings for these applications, and explanation of the processing of the coatings, and a list of advantages that UV curable technology offers this market.

Current Coating Methods

Throughout the history of automotive interiors, conventionally cured coatings, such as one or two component polyurethane systems, have been able to meet automotive OEM requirements for interior trim coatings. As was stated earlier, harsher chemicals are being used and OEMs are testing more compounds such as sunscreens and bug sprays that are posing problems for traditional thermal coatings. These compounds are causing loss of adhesion and bubbling on the surface of automotive interiors. Although these coatings are usually less expensive per gallon, they require a large production floor footprint and a lot of energy to power the lines. Customers want to go greener and be more environmentally friendly in their production facilities as well which can also be detrimental for the argument to continue the use of conventional coatings.

Typical Performance Requirements

Performance targets for the interior automotive market are getting more and more stringent with each new design year. Whether it's the console lid, door panel surround, or instrument panel, OEMs are demanding more scratch, chemical, and stain resistance from their coating suppliers. Even if the coating is for decorative purposes only, it needs to be durable enough to last until the life of the product is over. Although the specific test specifications are different for every OEM, generally, scratch and abrasion resistance, chemical and stain resistance, and interior weathering and thermal cycling are all a concern.

Scratch and Abrasion Resistance

Scratch resistance can be tested by using a Taber abrader. One example, from OEM spec A, calls for 250 g load on CS10 wheels and 100 cycles. In order to pass this specification, the coating cannot show any signs of wearthrough after testing. The panels were also evaluated by looking at pre- and post-testing gloss readings, also known as gloss retention. Because of higher cross-link density, it is more like for UV coatings to more consistently pass this requirement than thermal coatings.

Another type of testing for interior automotive coatings is for repeated abrasion resistance. The test is called Crock-Mar Abrasion and is the repeated rubbing of a cloth over the top of the coated piece. There are different types of Crock-Mar testing done today. Sometimes, it is just done using dry cloth and other times, there is a grit applied to the cloth, such as Bon Ami cleaner. Other times, there are chemicals applied to the cloth to try and weaken the coating, such as ethanol, leather cleaner, or dish detergent. The data that was collected during scratch and abrasion evaluation is shown below in Table 1.

Evaluation Test	Thermal Coating 1	UV Coating 1
Taber Abrasion (100 cycles, 250 g load)	Pass Grade 5/Gloss Ret. = 77.6%	Pass Grade 5/Gloss Ret. = 84.9%
Crock Mar (Dry Cloth)	Pass Grade 4	Pass Grade 5
Crock Mar (Ethanol)	Pass Grade 4	Pass Grade 5
Crock Mar (Leather Cleaner)	Pass Grade 3	Pass Grade 5
Crock Mar (Dish Detergent)	Pass Grade 3	Pass Grade 5

Table 1. Scratch and Abrasion Resistance Test Data

Chemical and Stain Resistance

Everything from lotions and sunscreens to bugsprays and automotive cleaners have chemical compounds in them. These compounds are becoming more and more complex and damaging to automotive interiors, especially in high touch areas such as radio bezels and arm rests on door panels. It is increasingly important to be resistant to these harsher compounds and UV coatings are a good solution to this problem. Once again, because of the inherent high-cross link density of UV coatings, they are more likely to pass these tests than thermal coatings. A few examples of chemical and stain resistance tests that a coating may have to pass are: engine oil, grease, soy sauce, glass cleaner (such as Windex), gasoline, and acids or bases such as sulfuric acid or sodium hydroxide. The data from chemical and stain resistance tests are shown below in Table 2.

Evaluation Test	Thermal Coating 1	UV Coating 1
Engine Oil Chemical Resistance	Fail Grade 3	Pass Grade 5
Soy Sauce Chemical Resistance	Pass Grade 4	Pass Grade 5
Glass Cleaner Chemical Resistance	Pass Grade 4	Pass Grade 5
Sodium Hydroxide Staining Resistance	DE = 0.83	DE = 0.10

Table 2. Chemical and Stain Resistance Test Data

Weathering and Thermal Cycling Resistance

Even though the coatings for automotive interiors aren't directly exposed to destructive UV rays from the sun, weathering resistance is still an important concern. Over the average life of a car, an interior coating can face many different conditions and a lot of kJ of energy to break down the coating. This is why weathering is an important test for OEM. Although there are many different specs, a common one seems to be 1250 kJ. At the end of the test, the coating can exhibit no cracks or other signs of catastrophic failure.

The other side of this is thermal cycling testing. Just in one year, a coating can experience many different environments on the inside of a car. During the summer, it might see very humid, high temperatures. During the spring and fall, lower humidity but higher temperatures on sunny days. Even in wintertime, on sunny days, it may see elevated temperatures depending on the location of the vehicle. Cold temperatures and temperature swings throughout the days can create problems too. A common test for thermal cycling is 0096Z-SEC-Thermal Cycle. The results for thermal and UV coatings in thermal cycling and weathering are shown below in Table 3.

Evaluation Test	Thermal Coating 1	UV Coating 1
Appearance	Pass Grade 5	Pass Grade 5
Delta E	.20	.05
Adhesion	25/100	100/100

Table 3. Weathering and Thermal Cycling Resistance Data

Processing Requirements

Automotive interior parts are currently coated by spraying and that's how the UV coating would be applied as well. Just like the thermal coatings, the UV coatings are formulated with the proper rheology to be able to flow over all of the contours of the most intricate interior parts evenly and without sags forming in the coatings to give a beautiful, glass-like appearance with even film builds. UV coatings are generally solvent-borne which enables the good flow. This would require a short flash through a convection oven, generally five minutes or less at between 140-160 °F. Following the short flash, the parts would enter the UV cure oven where they would see 4000-6000 mJ/cm^2. After cure, the parts are immediately ready for packaging to travel to the next step in the automotive assembly process. Taber Abrasion was tested in a range from 2500 mJ/cm^2 to 5500 mJ/cm^2, and every combination passed the test with no wear through.

Advantages

As is evident by the various testing requirements, automotive interior coatings must be able to withstand many different conditions and environments while still maintaining their functional and aesthetic qualities. UV coatings can not only hold up to all of these requirements, but they can do it while protecting themselves as well as other decorative coatings in the interiors of cars and trucks. UV coatings can also provide environmental and processing benefits as well as faster throughput, higher production, less downtime, and other safety benefits over conventional thermal interior automotive coatings.

Decorative and Functional Advantages

A UV coating that has been formulated optimally would have adhesion to many different substrates or even other thermal coatings with little to no pretreatment. At an automotive interior coater for OEMs, there is the possibility of using many different substrates or wanting different colors to coat over yet still retain the benefits of the UV coating. An example of this would be a finisher that coats

PC/ABS door handles direct to substrate with no pretreatment. A customer may approach them with a project for a thermal colored basecoat such as silver or piano black but they would still want the scratch, chemical, and weathering benefits the UV coating would provide. The optimal coating would be able to go from one application, to the next, with ease and very few tweaks to the production line to make this plausible.

Advantages in Processing

Many of the advantages UV coatings have over other types of interior automotive coatings come during the processing of them. A lot of Tier suppliers that use UV curable coatings to appoint automotive interiors have a faster throughput, smaller footprint, and more options in the substrates they are able to use compared with conventional coatings. Many of the conventional coatings in use today, require a very long cure time compared with UV coatings, about 30 minutes usually. The cures also require high temperatures which mean large and long ovens. This equals a large production floor footprint and high energy bills to power all of the ovens. After the cure, the parts would need time to cool down and then a post cure before they can be packed to be shipped to the next area. Solvent-borne UV coatings require little to no heating, depending upon the solids contents (a 100% non-volatile material coating would require no flash for solvent evacuation). The UV coating cures within seconds. The overall processing time for a typical UV coating is usually less than 7 minutes altogether. Compared to the processing time for a conventional coating that can range from 15 minutes to hours depending on the cool down needed, the UV coating can drastically reduce throughput time and line length, since the parts are on the line for a much shorter amount of time. The figure below shows the potential time savings possible when using UV curable coatings.

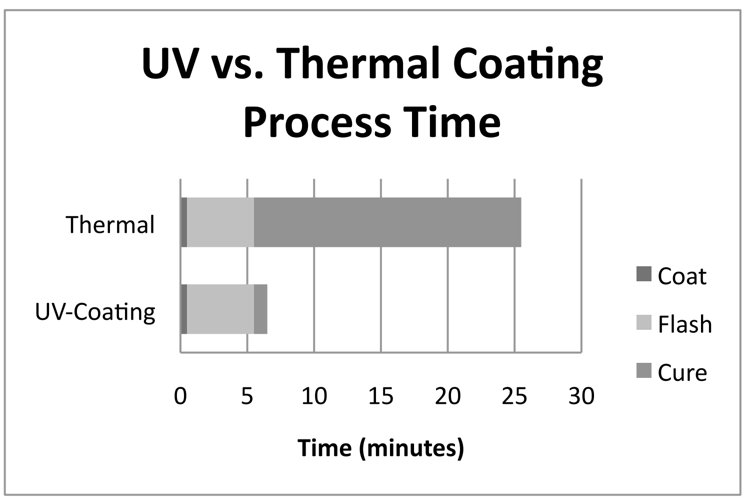

Figure 1. Comparison of general processing times for UV and thermal cure coatings

Formulation Challenges

There are some challenges involved with making UV curable coatings that meet all the performance, aesthetic, and processing standards required for the automotive interior coatings market. A majority of these challenges can be met by making proper raw material choices and an extensive understanding of processing conditions that may be encountered. One problem may be adhesion to certain substrates. Polypropylene, vacuum metalized, and previously coated substrates can be difficult surfaces for UV coatings to adhere to while still maintaining the performance qualities required. It is important to attempt to closely match the surface energies of the coatings with the substrate to achieve optimal substrate wetting which will increase the probability of adhesion. The coating also needs a low rate of shrinkage and a slightly lower crosslink density. This is difficult because these properties could also adversely affect scratch, chemical, and moisture resistance. The proper balance between all of these properties is necessary to successfully develop a UV coating that will meet all of a customer's performance needs.

Another problem arises when pigmenting UV clear coats. A coating that has a high pigment load, a lot of matting agents, or even UV absorbers, usually requires more energy to cure. A lot of tiers would like to cure with as little energy as possible though. This is where UV coatings come into play. Currently, we are using thermal basecoats to expand the reach and color palette to achieve the look the designers would like for new automotive interiors. Then by applying the UV topcoat over it, the performance requirements for the customers are met as well.

Typical Application Scenario

Application of the UV coating will generally depend on the substrate. In a typical scenario, the substrate is molded and either sent somewhere else for coating, or done in-house. The substrate is then prepared for coating by usually wiping away any dust and contamination with a quick wipe using a gentle solvent such as isopropyl alcohol and then blown off with de-ionized air. If the project is for a colored piece, the thermal basecoat would first be applied and then allowed to cool to about 80 °F and then blown off again and the UV coating is applied. The coated part would then pass through the flash oven for 3-5 minutes at 140-160 °F and then go directly into the UV cure oven. While in that oven, it would see 4000-6000 mJ/cm^2. After exiting the UV cure oven, the parts are ready for packaging and shipping. No post-cure is required. This is just a general view of the application of a UV coating; cure and flash schedules will vary depending upon the finisher's capabilities and specific performance requirements of the coating.

Conclusion

Based on the evidence above, a UV coating can provide great value and performance properties to an automotive interior trim part in many different ways. The coating can be very aesthetically pleasing and provide a different finish from a thermal coating. It can also be functional and protective to ensure the interior retains its finish throughout the life of the product. With these advantages as well as environmental and manufacturing benefits, UV coatings offer a flexible alternative to other curing technologies used for automotive interior decorating.