

UV Curable Coatings: Another Option for Decorating Glass

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Glass is not a new material; it has been made for thousands of years. Despite this, or maybe because of this, it is becoming an increasingly popular choice for consumer product containers, from beverages and food to perfume. Consumers perceive glass as being a pure choice, without the worry of the BPAs often found in plastic packaging. When handled properly, it is infinitely recyclable. Glass is also nonreactive and is considered a Generally Recognized as Safe (GRAS) substance, so it will not affect the taste, scent, or other qualities of the product inside. Although there are many reasons for consumers to choose glass, companies still look for ways to make their glass containers stand out from the crowd? A UV coating in a unique color or finish that does not detract from the overall performance of the glass container can achieve this by giving options that may not be possible or easily accomplished with other forms of decoration.

This paper will address some of the current decorating methods for glass containers. The paper will also discuss typical performance and processing requirements, some of the challenges involved in developing UV coatings in certain situations, an explanation of the processing of the coatings in various applications, and a list of advantages that UV curable technology offers these markets.

Current Decorating Methods on Glass Containers

Glass can be molded in some colors by the addition of metal ions to the glass mixture. Examples include the use of chromium to obtain green glass or cobalt, resulting in blue. Thermal or ceramic based coatings can be utilized to obtain these colors as well. A popular look in glass decorating is a frosted appearance. The frosted look is typically achieved by the process of acid etching. Acid etching is the process in which a container is submerged in a strong acid (most commonly hydrofluoric acid) that reacts with the surface of the glass, creating a permanent frosted appearance. Parts of the container can be masked off in order to create designs in the frost. Screen printing is used on glass containers in the same way it is on plastic; it can act as a label to add information and graphics to the container. A type of screen printing that is unique to glass containers is Applied Ceramic Labeling (ACL) where ceramic inks are printed onto the container and then heated to high temperatures to fuse the inks with the glass bottle. Labels are also applied to glass containers. Pressure sensitive labels and cut-and-stack labeling both utilize adhesives to adhere a plastic or paper label to the container.¹

Typical Performance Requirements

Performance targets in the containers market, whether cosmetics and personal care or food and beverage, tend to be very customer specific and can vary with end use. Even if a coating is meant to be for decorative purposes only, it still needs to be durable enough to last until the consumer purchases the product or until the life of the product is over. For the cosmetics market, scratch resistance, humidity, or a heated water soak, and product resistance (perfume, lotion, etc.) are the typical testing requirements. There is usually a customer driven variation within these test methods. Humidity and water soak testing is usually short term, ranging from 1 hour to 24 hours. Temperatures can vary, but a typical condition might call for 40-50°C (104-122°F). For high end products, more severe specifications may require a crosshatch adhesion test to be performed after humidity or water soak, and the parts are always visually inspected for hazing or blistering. Product resistance depends upon what type of product the container is being filled with. A typical test for a perfume bottle may involve spraying the perfume on the part and sealing it in a bag for 24 hours to look for surface defects such as haze or blistering. A lotion test might be performed in a similar way, or it might involve applying lotion to the decorated surface and

performing a specified number of double rubs, normally 50-100. Alcohols and other solvents are also used in a similar manner to test for proper cure and chemical resistance of the coating. Scratch and abrasion testing can be performed to ensure the coating will stand up to handling and abuse. Since coatings have to be at least as durable as the container or the package they protect, there are also test methods to replicate real world situations. Conditions that are simulated include abuse from filling and labeling lines, packaging, and the rubbing and vibrations that occur during shipping on trucks.

Processing Requirements

As mentioned previously, a good UV basecoat/topcoat will be able to pass a variety of testing for a multitude of end uses. This will enable the finisher to efficiently move from one project to the next with a high degree of confidence. To further enable the smooth transition from project to project, the coating also needs to have a wide processing window. Customer processing capabilities can vary, but typically a fast throughput and low energy requirements are a must. Often a first step in coating glass with a UV curable coating is flame treatment, followed by spray application of a primer. Typical processing parameters of the UV coating can be: a flash temperature of 100-140°F, from 30 seconds to 3 minutes (convection or IR oven) with a UV cure of 1000-3000 mJ/cm² depending upon the color and pigment loading in the coating. The UV coating should be able to fit into any combination of these parameters and still maintain performance properties. A lack of preventive maintenance on lamps at the finisher can also lead to lower cure energies later on than when a project was first started, so a wide processing window can help compensate for this as well. There may also be special circumstances, such as highly pigmented systems, when it would not be feasible for a coating to cure at the low end of the window, but overall the coating should be processable under sometimes less than optimal conditions.

Advantages of UV Coatings

As seen from the various testing requirements, decorations for containers must endure many different conditions while still retaining their aesthetic qualities. UV coatings can not only pass these conditions, but also protect other forms of decoration. UV coatings provide environmental and processing benefits as well by allowing faster throughput, less downtime, and safety benefits over other forms of decorating.

Decorative and Functional Advantages

An optimally formulated UV coating can be used under many different conditions. Most manufacturers or decorators of glass packaging need to process a wide variety of shapes and sizes and the properly formulated UV coating should be able to be applied to most with little change to the formula. A UV coating can also be used over hot stamping, screen printing and vacuum metallizing. Therefore, it should have good adhesion and protect these other types of decorations. If vacuum metallization is being utilized, the same coating can be used as a base and top coats, which makes it possible to use one spray line for basecoating and topcoating. Depending upon the product inside the container, protection from UV radiation may be needed to ensure product purity. A UV curable coating can provide this protection by the use of UV absorbers. This allows the product inside the container to stay pure longer, but permits a wider variety of substrate colors.

The UV coating should provide decorative properties as well as functional ones. To make the container stand out a variety of looks may be needed, and in an ideal situation a similar coating can be modified either by the formulator or by the finisher to achieve these looks. An example of an appearance that can be achieved with UV coatings is color. Pigments or dyes are added to the coating in differing amounts to create a variety of colors of different tint strengths. Metallic flakes and pearls can be added, alone or with colors to add more depth and a luxe appearance to the container. Frosted or

matte looks are also popular, especially in the beverage industry. Matting agents can also be added to the UV coating, alone or with pigments, to achieve a frost appearance. It is preferable for the coating to be able to accommodate all of these changes without extensive reformulation. Addition of color or other additives should not affect performance properties of the UV coatings.

Advantages in processing

Some of the UV curable coatings greatest advantages over other methods of decorating come in the processing. Finishers that use UV curable coatings to decorate can have a faster throughput, smaller footprint, and more options in the substrates they use in comparison with conventional coatings. A conventional or a ceramic coating may have a very long cure time and require very high temperatures. Some conventional or ceramic coatings require curing temperatures from a couple hundred degrees to upwards of 1,000° F and the bake times can vary. To reach these temperatures the part must be heated for several minutes or more and then allowed to cool down, which leads to a long processing time and requires a large footprint for the coating equipment. Solvent-borne UV coatings call for little to no heating, depending upon the solids content (a 100% non-volatile material coating would need no flash for solvent evacuation). The UV cure occurs within seconds. The overall processing time for the UV coating is usually less than 5 minutes total. In comparison, the processing time for a conventional or ceramic coating may range from 15 minutes to several hours if a long cool down period is needed.

Figure 1 illustrates potential time savings possible when using UV curable coatings. A UV line drastically reduces throughput time, and since parts are on the line for a shorter time, the line does not need to be nearly as long. This allows for a smaller machine footprint in the production area. Containers coated with UV curable coatings do not need any post cure time before packing, and are ready to go as soon as they come out of the UV cure zone.

Pigmented UV coatings also offer an advantage over molding parts in color. To change out colors by changing the color of the un-molded substrate can take a significant amount of time and effort. Pigmented UV coatings can be changed out of the spray system quickly, allow for shorter downtime and give the ability to use the same color substrate for many different products. For example, instead of a transparent violet substrate being used and then switched out for a blue one of the same shape, only clear containers need to be made. The containers can then all be painted in the appropriate color with little time lost. Pigmented coatings may also give more color options than a container molded in color and can be combined with other decorating techniques such as vacuum metallizing for a unique appearance.

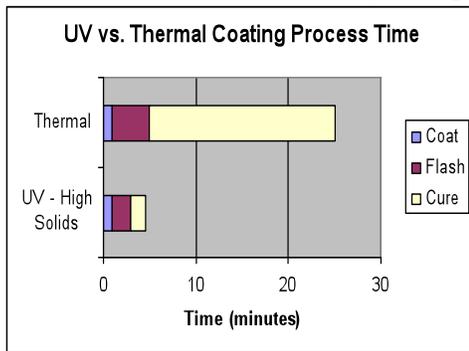


Figure 1: Comparison of general processing times for UV and thermal cure coatings

UV curable coatings can also be more environmentally friendly, which is becoming increasingly more important as more customers are asking for “green” alternatives to existing technologies. UV

coatings can be made with low or zero volatile organic compounds (VOC) and hazardous air pollutants (HAP). Some areas have tight restrictions on allowable VOC emissions and UV curable coatings can help companies meet these restrictions in their manufacturing process. Since a UV line is usually smaller and does not require heating a large oven, UV coatings can offer energy savings as well. This can turn into cost savings for the finisher, also an important feature in tough economic times. Use of UV coatings also offers environmental and safety advantages over the acid etch process. To produce the desired frosted appearance, acid etching utilizes corrosive acids such as hydrofluoric acid. Hydrofluoric acid can be extremely dangerous to handle due to the fact that it penetrates tissue very easily and even limited exposure can be harmful or fatal.² Thus, acid etching needs to be performed with care. While not as permanent as acid etching, UV coatings can mimic the frosted appearance and provide a much safer alternative.

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Formulation Challenges

There are some challenges involved with making UV curable coatings that meet all performance, aesthetic and processing standards of the containers and closures market. Many of these challenges can be met by proper raw material choices and a thorough understanding of processing conditions that may be encountered. One problem that may arise is adhesion to certain substrates. Glass can be a difficult surface for UV curable coatings to adhere without the loss of all performance properties. To obtain proper adhesion to these surfaces the coating needs to have a low rate of shrinkage and low crosslink density. These properties can adversely affect scratch, chemical and moisture resistance. A balance between being hard enough to pass the testing, but flexible and soft enough to have good adhesion is necessary. Glass can provide another level of complexity due to the use of cold end coatings on the glass bottle. A cold end coating is applied during the glass manufacturing process to protect the glass from scratching during filling and handling and to add lubricity. Typically this coating is a polyethylene wax. It is helpful to know whether or not this coating is present on the container before coating formulation begins.¹

The nature of glass can make it difficult for an organic coating to achieve a good mechanical or chemical bond and the possible presence of the polyethylene layer can complicate this further. Because of this, some sort of pretreatment and a primer step is usually needed to obtain optimum adhesion and performance characteristics. A typical scenario would include a flame treatment with a silane primer spray application following. The choice of silane for the primer, however, has to go hand in hand with the chemistry of the coating. The backbone of the coating, whether it is a urethane, epoxy or some other chemistry needs to be taken into consideration when developing the correct primer to work with the coating system. Table 1 shows the performance differences with different silane choices. The silanes were mixed into an IPA and water blend and applied after a flame treatment step.

Table 1: Results of a room temperature water soak in percentage adhesion retained using three different primer chemistries.

Coating	Silane in Primer	Initial Adhesion	Post 2 hr. 25°C Water Soak	30 Minute Recovery
UV-1	No Primer	100%	0%	0%
UV-1	Primer A	100%	90%	100%
UV-1	Primer B	100%	0%	0%
UV-1	Primer C	100%	5%	60%

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Another difficulty arises when working with heavily pigmented UV systems. If a coating has high loads of pigment, matting agents, or UV absorbers it will typically require more energy to cure. However, most finishers want to cure with the minimal amount of energy. A proper blend of through- and surface-cure photoinitiators will allow the coating to cure optimally, though perhaps not with as low a cure as a clear or lightly pigmented coating. The use of additive bulbs, such as iron or gallium, may also be helpful in achieving a greater depth of cure in situations when the coating is nearly opaque.

Typical Application Scenarios

Application of the UV coating will depend on other decorating methods used. In a typical scenario, the substrate is molded and either sent out for decorating or done in-house. The substrate may be pretreated if necessary, usually by a flame treating process that is followed by the application of a silane primer. If the container is to be screen printed or hot stamped, that step is normally performed at this point. The first layer of UV coating is then spray applied and the solvents are flashed off for 0.5-3 minutes in an IR or convection oven at anywhere from 100-140°F. The UV coating is then cured. Curing can vary depending on the pigment or additive loading but will typically be between 1000-3000 mJ/cm² of total UV exposure. Vacuum metallizing is performed at this point if needed. If the part is metallized, a UV topcoat will be applied after, using the same or similar parameters as the basecoat. This is just a general view of the application; cure and flash schedules will vary depending upon the finisher's capabilities and performance requirements of the coating.

Conclusion

A UV coating system can add great value to a glass container in many different ways. The coating can be decorative and provide a unique finish to make the container stand out to the consumer. The coating can also be functional and protective to ensure the container retains its beauty through 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 container decorating.

References

1. <http://gpi.org/glassresources/education/>
2. See <http://www.cdc.gov/niosh/ipcsneng> for safety information on hydrofluoric acid.