

# UV Curable Coatings for Containers and Closures

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A container gives the consumer one of their first impressions of a product, whether it is perfume, makeup, or a beverage at a convenience store. Whether the purpose is to draw a customer to a new product, or bring them back to one that already exists, the container needs to be decorative as well as functional to put the product's best face forward and to differentiate it from the competition. UV curable coatings have been adding value to plastic and glass containers and closures for over 20 years by not only enhancing the appearance of the product, but also bestowing practical properties. With growing concerns about "greener" technologies and a need for processing speed and flexibility in the manufacturing of these products, UV curable technologies remain and may be even more relevant today for these markets than when they were first introduced.

This paper will address the current decorating processes on plastic and glass containers and closures for the cosmetics, beverage and food markets. Also included are typical performance and processing requirements, challenges involved in developing UV coatings on these substrates, 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 Plastic Containers**

Current decorating on cosmetics, beverage or food containers and closures can differ depending upon the substrate. Typical plastic substrates used for the cosmetics and food and beverage industries are ABS, PET, HDPE, PC/ABS, and polypropylene. Depending upon the look needed, a variety of decorating methods can be used. Some of the plastics can be molded in a multitude of colors or textures to provide looks that can range from glossy to matte. Hot stamping, where a heated die or roller and foil are used to add an aluminum-like finish, is often used for lettering and other graphics. Screen printing, or silk screening, is used to add graphics, logos and lettering to the packaging. This can be done with UV, water-, or solvent-based inks. Vacuum metallizing and sputtering are two metallizing techniques used to lay down a very thin layer of metal (usually aluminum) over the plastic to give a bright and shiny appearance to the part. A basecoat is often used to cover any defects in the molding of the substrate and allows a smooth surface for the metal to lie down upon. Since the metal layer is very thin (approximately 600-1,000 angstroms), a topcoat is applied over the metallized layer to protect it from scratching or oxidizing and to provide chemical resistance. This topcoat can also be used to impart color or a lower gloss look to the aluminum. Figure 1 illustrates the vacuum metallizing "sandwich" of basecoat, metal and topcoat. Conventional (thermal-cure) coatings and UV coatings can be used alone or in conjunction with any of the other methods to give a variety of appearances and properties.

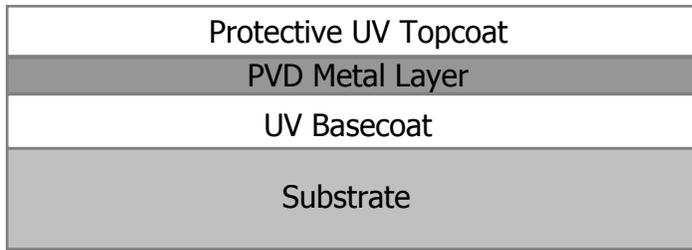


Figure 1: The vacuum metallizing “sandwich” of substrate, basecoat, metallization layer, and protective topcoat.

### Current Decorating Methods on Glass Containers

There is some overlap of decorating techniques used on plastic containers and glass containers, but the end goal is the same: enhance the look of the container while retaining functional qualities. 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. 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 on 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.<sup>1</sup>

### Typical Performance Requirements

Performance targets in the packaging market, whether cosmetics and personal care or food and beverage, tend to be very customer specific and can vary with substrate and 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, on glass and plastic, 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. Scratch resistance testing can range from Taber testing to methods that are meant to replicate the inside of a woman’s purse. Often, this test is performed by putting several parts or, in more harsh methods, parts and hardware into a can or drum and shaking or rolling for a specified amount of time. The parts are then inspected for scratches, marring, or other defects. Humidity and water soak testing is often short term, ranging from 1 hour to 24 hours. Temperatures can vary, but a typical situation might call for 40-50°C (104-122°F). For high end, more severe specifications a crosshatch adhesion test is 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 (or another product) 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. Since coatings have to be at least as durable as the container or the package that 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 on a multitude of substrates. 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 greatly in this market, but typically a fast throughput and low energy requirements are a must. Since many of the plastic substrates used are heat sensitive, a low flash time and temperature are usually a necessity. Typical processing parameters might be a flash temperature of 100-140°F, from 30 seconds to 3 minutes (convection or IR oven) with a cure of 1000-3000 mJ/cm<sup>2</sup>. The UV coating should be able to fit into any combination of these parameters and still maintain performance properties. An ability to fit into a wide processing window also allows the formulator to use the same or a similar formula for several different projects. A lack of preventative 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 are special circumstances, such as a highly pigmented system, when it would be unfeasible for a coating to cure at the low end of the window, but overall a coating should be processable under sometimes less than optimal conditions.

### **Advantages of UV coatings**

As seen by the various testing requirements, decorations for packaging 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 packaging and container decorators receive many different substrates in-house, so an optimum coating would adhere to all the different types of packaging with no primer or little to no pretreatment. An example of this would be a finisher that decorates PET jars and polypropylene tubes and would ideally want to use the same protective coating for both. A UV coating can also be used over hot stamping, screen printing and vacuum metallizing and have good adhesion to 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. In the container and closures industries 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 be added to the UV coating, as well as color, to achieve a frost appearance. It is preferable to be able to make these changes to a formula without the extensive reformulation. Addition of color or other additives should not affect performance of UV coatings.

### Advantages in processing

Some of 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 ceramic coating may have a very long cure time and requires very high temperatures. Some conventional or ceramic coatings require from a couple hundred to upwards of 1,000° F and 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 2 illustrates the 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. Pigmented UV coatings also offer an advantage over molding parts in color, especially in glass. 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 the ability 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. Colored 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.

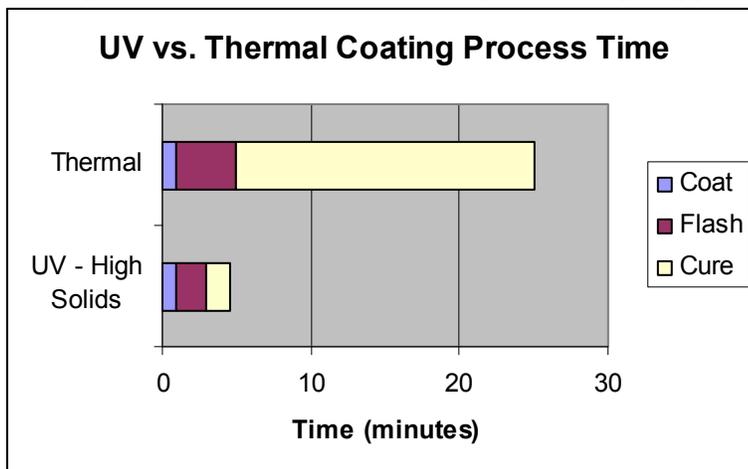


Figure 2: Comparison of general processing times for UV and thermal cure coatings

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 (VOCS) and hazardous air pollutants (HAPS). 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 in to 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.<sup>2</sup> 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 safer alternative.

## **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, metal and vacuum metallizing can be difficult surfaces for UV curable coatings to adhere while still retaining 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.<sup>1</sup>

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 a 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. topcoat.

A final challenge occurs when attempting to use the same coating as both a basecoat and topcoat for vacuum metallizing. As a basecoat, the coating must adhere to a variety of substrates, and also be able to accept the metallization layer without hazing or cracking from stress induced in the vacuum metallization process. As a topcoat the coating must adhere to the metallizing layer and be hard enough to provide the scratch and chemical resistance to the metal that it ordinarily would not have. Balancing all the properties of a basecoat and topcoat in one coating can be challenging, though appropriate raw material choices and processing parameters allow for an optimum metallic finish that is durable enough to last the life of the product.

## **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. 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 flashed off for 30s-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/cm<sup>2</sup>. 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 container in many different ways. The coating can be decorative and provide a unique finish to make the container stand out to the end 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. [www.gpi.org](http://www.gpi.org)
2. See <http://www.cdc.gov/niosh/ipcsneng> for safety information on hydrofluoric acid.