Achieve Better Process Controls with Light-Cure Technology

DYMAX®

In manufacturing, process controls are used to ensure that products are made to the highest standard possible. When effective procedures are laid out for each step in the manufacturing process, it's much easier to reduce the risk of damage, failure, and loss. Employees are able to understand what to do, when to do it, and how to do it well.

Good process controls help a company turn out the best version of its product and have fewer headaches along the way. But some technologies lend themselves to smoother processes than others.

Light-curable materials in the manufacturing process actually allow for better process controls than other adhesive options. What exactly are the benefits of using them, and what do those process controls look like?

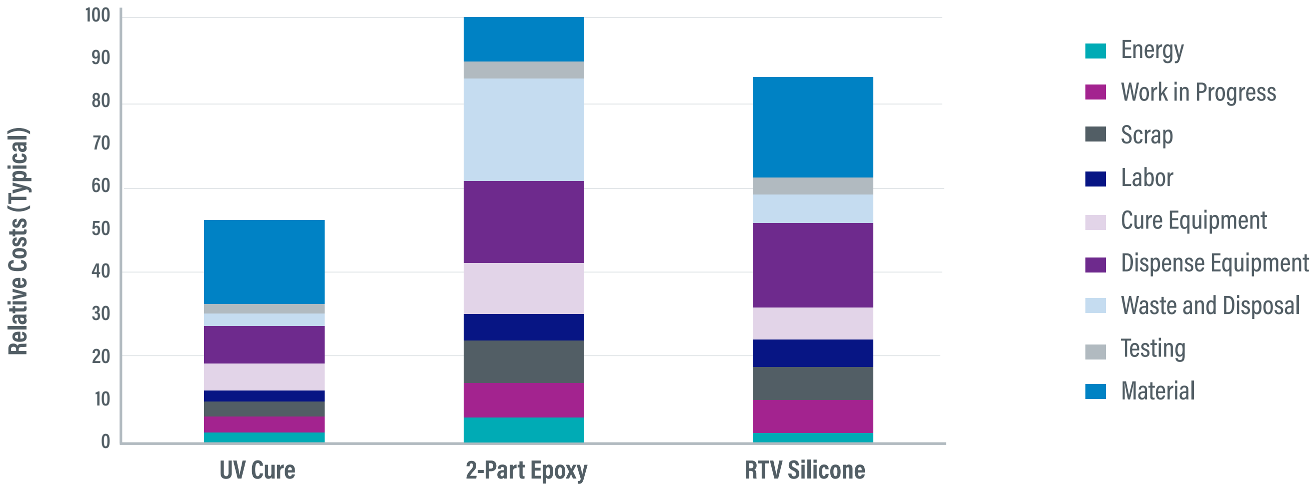
Benefits of Light-Curable Materials

Light-Curable Materials (LCMs) are used across many industries, including automotive, medical, optical, and electronics. These materials are typically composed of oligomers (medium-length polymer chains), monomers, additives, and photoinitiators, in formulations that can be tailored to suit specific applications. A photoinitiator is a chemical that fragments into free radicals when exposed to light, so when the photoinitiator in an LCM is exposed to a light-energy source of the correct spectral output, the curing process begins. Once light is introduced, it excites and fragments the photoinitiators, resulting in the generation of free radicals. These free radicals begin to attach themselves to the acrylates that make up the LCM, resulting in polymeric chain radicals. This process is repeated until all radicals are attached, resulting in polymer termination (cured material).

Light-curable materials that cure in this way can improve efficiency at the manufacturing level. Two-part epoxies are common, but they take longer to apply, and once they have been applied, the parts may need to sit in an oven or in ambient temperatures for an ex tended length of time. LCMs have the advantage of curing on demand, often within seconds, so the part is available immediately for the next step in the manufacturing process. With in-line assembly and inspection, the use of LCMs increases throughput dramatically.

Besides time, valuable floor space is saved when the need for large curing ovens or racking areas is eliminated. Energy savings are realized in the absence of oven heat generation, and lower labor costs are achieved as a result of the on-demand nature of curing with light. Additionally, with no solvents, light curing is a "green" chemistry, friendly for both workers and the environment. With all its benefits combined, light-curing technology provides an average 30% reduction in manufacturing costs. So what's the best way to use these materials in manufacturing? What do the process controls look like? There are several important steps that make the process go smoothly.

Comparative Assembly Costs



Know Your Substrate

Before choosing the material that's right for your application, you'll need to consider the surfaces that will be receiving the LCM. For success with light-curable materials, the substrate must allow light to pass through so that the chemistry will react properly. You'll test this by measuring the light transmittance of the substrate. Similarly, you must be aware of the way the parts will be configured and where the adhesive, coating, gasket, or masking resin will be applied. Can light get to the LCM? For parts with "shadowed areas" that prohibit a sufficient amount of light to pass through, secondary cure products are available.

Also, pay attention to any changes in the grade or surface of the substrate that could affect adhesion, durability, and other aspects of performance.

Other questions to consider when setting up a light curing process are how much adhesive strength will be necessary for the end-use application, and what type of testing will be used. Will it endure tensile, peel, or sheer stresses?

With plastics, will mold release agents be used in the molding process? Are plasticizers like DEHP used? These products will come to the surface during curing and negatively impact adhesion, so it's important to note these details when selecting the LCM.

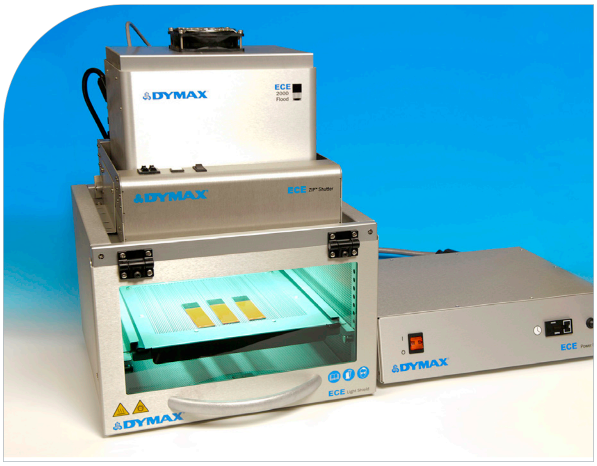
Finally, what kind of surface does the substrate have? Is it rough, does it have a smooth, mirror-like surface, or is it something in between? The adhesive needs to wet the substrate's surface, and should have lower surface energy than the substrate. If the substrate is very smooth, there are ways to prep the surface to improve adhesion, including primers, chemical etches, and corona, plasma, and flame treatments.

Setting Up a Light Cure Process

When you're ready to set up the light cure process itself, you'll start by choosing the LCM that will meet all of your performance requirements. What kind of light initiates curing? What is the viscosity of the material? Should it be rigid or soft when it cures? How well will it stick to your particular substrates? Does your substrate block light? What cure time will meet your production requirements?

You'll also need to choose the optimal dispensing system, which has its own criteria and is a critical part of the process. There are questions that will help determine the best dispensing system for the job. For instance, what type of dispense application does this call for — dot, potting, coating, bead, or sealant? Will the LCM be applied by a person or a machine? Will it be dispensed from something small, like a syringe, or something larger, like a pail? Would a pressure pot work for your selected material, or would a ram pump produce better results, as in the case of a more viscous LCM?

Then you need to decide what light source configuration will be best for your required cure time and for the configuration of the parts in question. Would a spot lamp be better, or a flood lamp, or perhaps a conveyor setup? Should you choose a wand-mounted or cabinet-mounted light source?

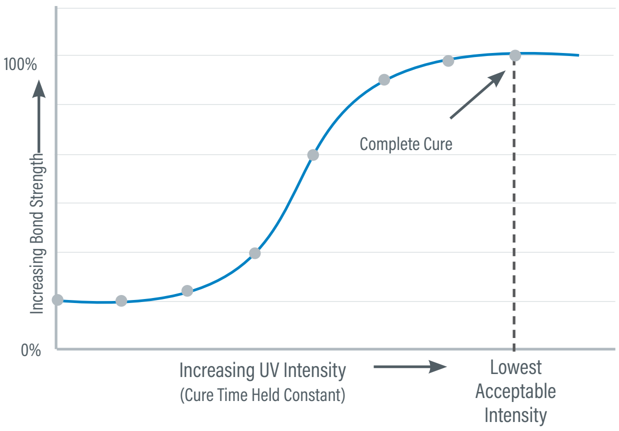


With those answers in mind, choose a curing lamp that has the appropriate intensity, wavelength, and design to meet the required cure time for your process. Remember, standard fluorescent and incandescent lighting can initiate curing of some light-cure materials if they're exposed long enough, so special "yellow lighting" is available for use in these areas to prevent premature polymerization.

A radiometer plays a critical role in successful light curing. You'll use the radiometer to ensure the curing unit is operating at the lowest acceptable intensity (the intensity at which the LCM fully cures) and meets all the curing performance requirements of your application. To find that number, start testing at the recommended intensity for the material you've chosen, and continue testing with lower intensities until there's a failure. From there, you can determine your minimum required intensity and safe margin of error.

Different radiometers are available for different purposes, depending on the type of equipment and the wavelength of light used. Recalibrate the radiometers in accordance with the manufacturer's suggested schedule to ensure they are giving accurate readings, and keep the sensor windows clean.

Figure 2. UV Curing Profile (Cure Time Held Constant)



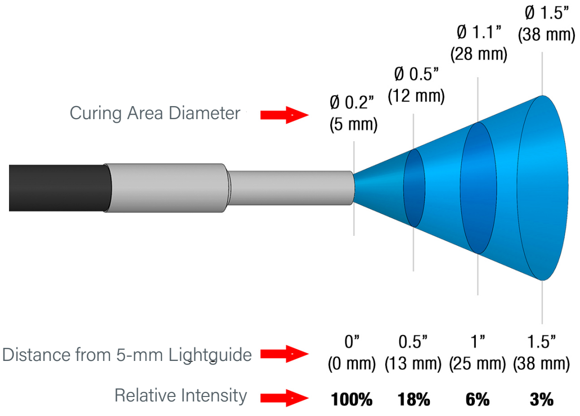
Effects of Under- and Over-Curing

When a LCM is underexposed to light, it will not cure completely, which can result in part failure at an inopportune time. Though it might seem safer to simply expose it to as much light as possible, there are negative consequences that can come from overexposure. A small amount of extra light exposure typically causes no problems, but significant overexposure may degrade the cured material as well as some substrates, particularly plastics, that can be degraded not only by overexposure to light, but also by too much heat absorption.

Problems like cracking, physical distortion, changes in color, chalking, or a change in a physical property can occur. The degree to which the material or substrate degrades in this situation depends on factors like the intensity of the lamp, the wavelengths that are transmitted, the temperature in the area (which can be minimized by a cooling fan in the curing area), exposure time to the light, the properties of the substrate, and the material formulation.

However, if the curing process is properly controlled, significant overexposure is very unlikely. Those who use LCMs should test and validate their assembled devices at both the high and low extremes of their light curing process.

Curing Area/Intensity vs. Distance
Using a 5-mm Lightguide



Ensuring Success

There are a few other keys to success in the light-curing process. First, make sure the parts are clean before attempting to apply the LCM as any surface contamination may interfere with the adhesion process and negatively affect the resulting strength of the bond.

Carefully monitor your light cure process by using a radiometer every day to ensure you are running at or above your lowest acceptable intensity. If you're running below, change the bulb.

All lamps degrade over time, and not all lamps degrade after the same amount of time. Degradation rates vary among bulbs, curing types, and operating environments, which is why it's so important to test them regularly. No assumptions can be made safely.

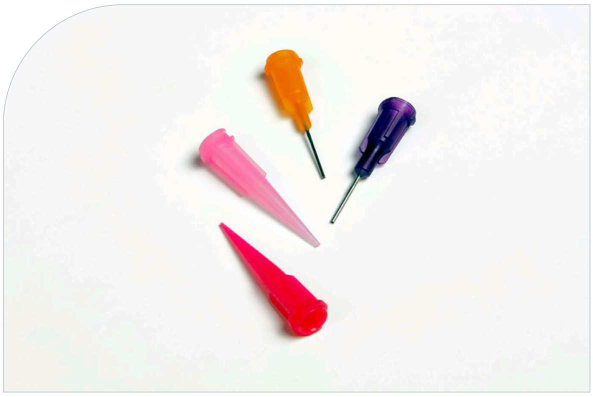
Additionally, note that some resins may be inhibited by oxygen molecules during cure, which results in a tacky surface — an undesirable outcome. Solutions include using higher-intensity light, using a curing energy source that includes delivery of shortwave energy (short wavelengths give a better surface cure, while long wavelengths give better depth of cure), eliminating "squeeze-out" of the adhesive by preventing excess, or using a nitrogen or argon gas blanket to block that oxygen.

Process Controls for Dispensing

The dispensing system, while sometimes an afterthought, is just as important as the LCM and curing system. There are different types, including syringes, pressure pots, and ram pumps. After choosing the best system for your application, what details should you consider when setting it up? Always pay attention to the recommendations and warnings that come with your particular type of dispensing system as well as those that are common across the board.

For instance, all components of any valve system that will come in contact with the light cure material must be opaque to visible light, and must be compatible with the material. Incompatible metals, like brass, may cause the material to gel or harden in the system. This most commonly occurs when incompatible fittings are used. Additionally, incompatible plastics can break down and fail when they come in contact with the light cure material, potentially causing a fluid line rupture.

The way the material transfers from the needle to the part, including the distance and angle of the needle, plays a major role in the repeatability of the system. Make fine adjustments to the size of the deposit with time, not with pressure, and always en- sure the dispense cycle is complete before lifting the tip. Pres- sure adjustments in the dispensing system may be necessary at times in order to accommodate temperature-caused changes in viscosity.



When selecting a dispense tip, use taper tips whenever possible unless you're working with a low-viscosity material. Always use the shortest length you possibly can.

Be careful of the possibility of curing through a plastic tip, and use extra shielding if needed. Use proper vacuum suck-back as needed to prevent material from remaining on the tip of a syringe. Note that if too much vacuum suck-back is used — or if the fittings in the system are not tight — air bubbles can form in the material.

For pressure pots, where the material is pulled instead of pushed out, choose the shortest tubing possible from the pressure pot to the valve, and minimize fittings and bends to help maintain consistent pressure. Use the lowest air pressure needed to sufficiently feed the valve, and don't keep it pressurized when it's not being used (like overnight or on weekends). Additionally, it is not recommend to pour the material into pressure pots, which can introduce contamination and air bubbles.

Storage, Shelf Life, and Disposal

When storing LCMs, it is necessary to protect them from light. If kept in their original packaging at typical room temperature, they should last for 3 to 12 months from the date of shipment, depending on the type of material and the storage environment. To properly dispose of used LCM containers and used bulbs, check your local and state regulatory guidelines.

With the right system for the job, good processes, and regular maintenance, the use of light curable materials facilitates an efficient manufacturing experience. Light-curable materials and associated equipment manufactured by Dymax are selected and optimized for many applications in various industries worldwide.

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