

Protecting Automotive Electronics with Conformal Coatings



Once a lagging market segment, automotive electronics has gained significant importance in recent years as the industry, the culture, and consumer expectations have changed. Safety and regulatory requirements for vehicles have increased, manufacturers have new warranty requirements, and what used to be "luxury" features are now expected to come standard with a new car. Features like lane keeping, rear-facing cameras, automated parking, and other types of assisted driving are becoming commonplace as manufacturers look toward a self-driving car. Full "infotainment" systems, with software for navigation, playing music, communication, and a number of less-typical apps, are gaining market traction as well.

Essentially, every new vehicle on the market is expected to be safe, comfortable, and reliable. Those characteristics depend greatly on the quality of the electronics used. Airbag controls, fuel injection systems, suspension control, automatic transmissions, modules for power windows and doors, engine control modules, and climate controls are a tiny fraction of the current electronic systems found in the average new car. Use of electronics is even higher in hybrid vehicles. And besides the increase in electronic content per vehicle, there has also been an increase in overall vehicle sales, particularly in the Americas and Asia.

The quality and reliability of the electronics in automobiles affects consumer decisions. A vehicle manufacturer with a reputation for electronics that fail more quickly will face difficulty in the market, honor more warranties, and issue more recalls.

This means there is a need to create not just well-tested software, but also ruggedized hardware. A car is a harsh environment for a printed circuit board, depending on the location of the board, how much use the vehicle gets, and the sort of environment to which it is exposed. The fragile electronic components and the paths between them must be protected in order to function reliably.

A board can be exposed, designed in its own enclosure, or potted in a suitable resin. Enclosing or potting takes up space and artificially limits the space available for the electronics. Potting entire printed circuit boards (PCBs) also adds weight, yet vehicle designers are increasingly interested in removing every unnecessary ounce from a car. There is, however, an alternate solution.

Using Conformal Coatings

Conformal coatings are polymers that can be applied in thin layers to printed circuit boards (PCBs) to protect and electrically insulate the components from environmental stresses. They can be sprayed, brushed, flow coated, or dispensed by robots, as needed, and take up very little additional space. A typical thickness would be from .002" to .005" with thicker coatings applied as needed. Conformal coatings allow for smaller, lighter assemblies as no additional enclosures are necessary, making it possible to fit more PCBs in the same space. Additionally, their ability to insulate can improve performance and permit a significant reduction in the space needed between conductors on a board.

Despite their thin coating application, they are very effective. Conformal coatings protect boards from mechanical and thermal stresses, humidity, corrosives, contaminants like salt and dirt, noxious gases, fungi, and other environmental factors that PCBs in vehicles are likely to encounter.

Tin whisker growth occurs on PCB components over time, and it is spurred by mechanical and thermal stresses, which are especially common in automotive settings. Conformal coatings can slow this growth, preventing arcing and short circuits.

Coatings also increase mechanical support for components and improve the fatigue life of solder joints.

In the automotive realm, PCBs are placed wherever they fit best for a given vehicle system — which can be practically anywhere in a car. Sensors and circuit boards are found in places that can be exposed to everything from brake fluid to gasoline fumes, salt spray, and all the heat and vibration associated with an internal combustion engine. The right kind of conformal coating will offer protection and not add additional inefficiency to the manufacturing process.

Benefits of Light-Curable Coatings

Various types of conformal coatings are available, including solvent-based, silicone, two-part epoxies, and urethane acrylates. Light-cure coatings offer several advantages over other systems.

Light-cure conformal coatings cure on demand, in seconds, and are easier to automate as a total process than other types of coating. There is no need to stack and temporarily protect the boards and then have them undergo additional cure. Besides saving time, light cure technology also saves space on the manufacturing floor and increases efficiency overall. There is no need for mixing, as with two-part epoxies; no need for explosion-proofing, as with solvent-based coatings; and typically fewer steps and fewer operators are required for each processing step. In addition, no extra shipping charges are required as may be the case with hazardous materials. Light-curable materials can be both silicone-free and solvent-free.

The curing mechanism is fairly simple. When light that produces energy of the correct spectral output comes in contact with a light-curable material (LCM), the photoinitiators in the material fragment to form free radicals, beginning the curing process. The free radicals begin to form polymer chains with the acrylates that

comprise the LCM until all of the available radicals have attached and become a solid polymer. Then the end of the curing process, called termination, has occurred and the LCM has polymerized, or cured.

Choosing the Correct Coatings

End-use environment and qualification tests simulate the environment in which the PCBs and conformal coatings will eventually be used in a vehicle's lifetime. Expected temperature extremes, moisture, abrasion, salt-spray, vibration, chemicals, and other potential or likely hazards will affect what specific conformal coating is optimal for a particular application. It is also necessary to consider the required electrical property performance in order to ensure the electrical integrity of the assembly.

Most urethane acrylate light-cure conformal coatings work well in operational temperatures between -40°C (-40°F) and 150°C (302°F), though some can also be used at temperatures below -40°C . These coatings have good chemical and moisture resistant properties.

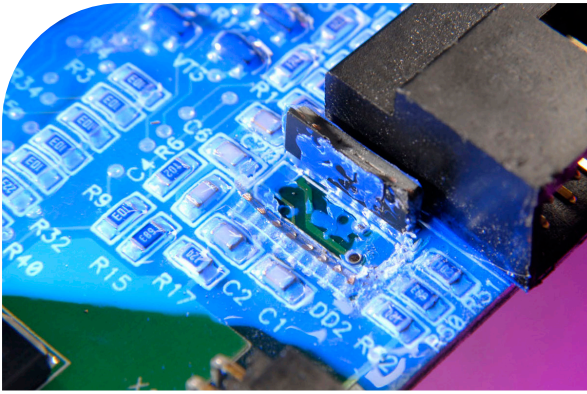
Overall, higher-durometer (harder) light-cure conformal coatings tend to have higher chemical and abrasion resistance, and are particularly beneficial if especially thin coatings are desired. Softer, lower-durometer conformal coatings reduce stress on components and offer the best thermal shock performance. For higher chemical resistance in softer coatings, a slightly thicker coating may be applied.

Destructive testing will be useful for determining what coating and application type are best for the boards being produced.

Shadowed Areas

Areas on PCBs that light cannot reach directly are called "shadowed areas." Light-cure coatings can either be prevented from entering those areas entirely, or cured with a secondary cure.

If the coatings do not flow into shadowed areas, then there is no need for a secondary cure. Low-offset, smaller, surface-mount components are significantly less likely to allow coatings to flow beneath them. Selective automated application of medium- to high-viscosity coatings is also an option.



Cured Dual-Cure Coating Under PCB Component

Dual-cure coatings that cure materials by using the ambient moisture in the air and secondary thermal cure materials that require heat curing are available as well, and can be used to cure material that flows into shadowed areas.

For areas not requiring a coating, selective coating processes can be used. Another option is to mask specific areas of a PCB to ensure the coatings don't flow into areas like connectors, through-holes, and other keep-out areas on the board. While various methods are available, some can be labor-intensive, so minimizing or eliminating the need to mask is desirable and using a secondary curing option, where suitable, may be most efficient.

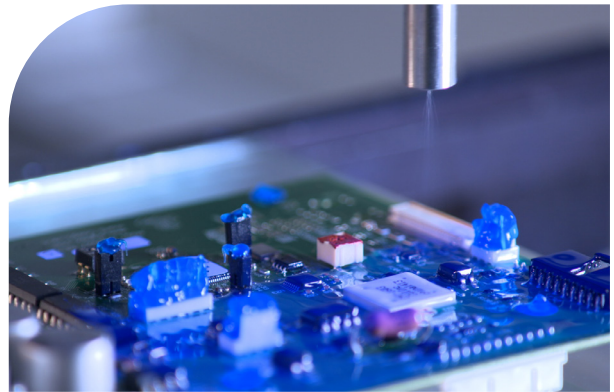
Application Processes

There are several common application methods for light-cure conformal coatings, including automated selective application, manual spray, jetting, and brushing. Dipping is rarely practical for light-cure conformal coatings, as it requires a more complex equipment setup because of the light sensitivity of the coating bath and it is more difficult to adequately control the coating thickness and uniformity of the coating.

Automated selective application uses robotics to apply coatings repeatedly and reliably to minimize time, material waste, and labor costs. Either atomized (spray) or non-atomized (brushing or jetting) techniques may be used this way. Non-atomized and atomized processes may also be used in tandem as needed for a particular board.

Successful automated selective application does depend on the capability of the robot and on the board layout. Manual spray is a common low-cost method, as many boards may be processed at the same time with only minimal required capital cost. However, it does require more labor input and care to achieve the desired coating thicknesses. Masking of keep-out areas is necessary, and the application may require multiple passes of the coating from different directions for a uniform result.

Brushing can also be done manually, and it is used more for touch-up work or small areas. Reliability and repeatability do depend highly on the operators.



Conformal Coating Sprayed on PCB

It is essential to choose the best dispensing system for the application. Many options are available, depending on what works best with the conformal coating that has been selected, and care should be taken to ensure that all parts of the system are compatible with each other. Special yellow lighting is available to prevent early curing from ambient light, though it is best if all the parts of a dispensing system are entirely opaque.

Coating the board to protect it is less effective if the board is contaminated and, in fact, the coating may seal in existing contaminants. Over time, such contaminants can react with even small amounts of moisture and lead to delamination in that area. These contaminants can also prevent proper adhesion of the coating to the board. Therefore, it is important to ensure the

board is clean before applying any conformal coating, typically by using a solvent or aqueous wash followed by the recommended drying cycle, and storage in an electrostatic discharge bag if storage is necessary.

Best practice is for boards to be handled with gloves so oils don't transfer from human hands to the PCBs.

If, for some reason, the boards cannot be cleaned, it is important to test that they will fulfill all end requirements at the existing level of contamination. Enhanced wetting light-cure conformal coatings have been engineered to limit the effects of board contaminants such as no-clean flux.

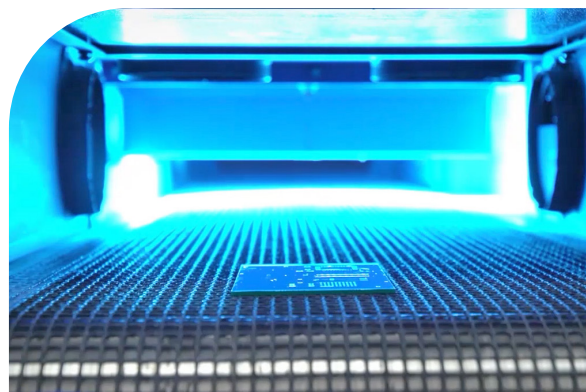
All industry-approved conformal coatings fluoresce when exposed to black light, which helps operators see whether the coating is applied completely and correctly. Newer 3D laser measurement systems are available now as well for high reliability applications.

Curing Processes

For complete and reliable cures of light-cure materials, it is important to select a light source with a spectral output that matches the absorption spectra of the photoinitiators in the LCM, with the optimal intensity for the application.

Typically, light-cure conformal coatings absorb light in the UVA and blue visible-light range, and many curing systems are available on the market for curing conformal coatings. The most common curing setups are automated conveyors and bench-top flood systems. Spot systems are available, but are recommended only for rework and for small curing areas. Again, it is important to ensure all parts of the system, including all equipment and the coating itself, are compatible with one another.

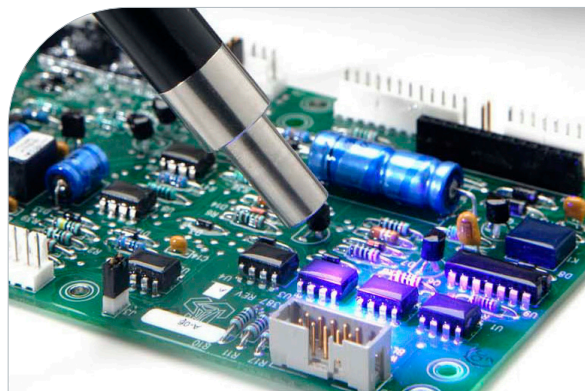
The intensity, measured in milliwatts per centimeter square (mW/cm^2), is the amount of energy at a given wavelength that reaches the coating surface. The amount of total energy that has arrived at a surface over a given time is known as the dose, measured in millijoules per centimeter square (mJ/cm^2). In brief, higher-intensity lamps cure faster, with all other variables held constant, but too much intensity can cause damage to the materials and parts. It is important to use the optimal intensity for the application.



Conformal Coating Curing in Conveyor System

As with any light-cure materials, it is critical to use a radiometer to ensure the light source is continuing to emit at sufficient intensity for complete and reliable cures of the conformal coatings.

Given the value of electronic components in modern cars, their relative fragility, and the harsh environment in which they are placed, as well as the increasing need to save space, conformal coatings are an ideal solution to the problem of optimized protection. Light-cure conformal coatings can be used to save time and space and to increase efficiency while effectively protecting PCBs in the automotive industry.



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Americas

USA | +1.860.482.1010 | info@dymax.com

Europe

Germany | +49 611.962.7900 | info_de@dymax.com
Ireland | +353 21.237.3016 | info_ie@dymax.com

Asia

Singapore | +65.67522887 | info_ap@dymax.com
Shanghai | +86.21.37285759 | dymaxasia@dymax.com
Shenzhen | +86.755.83485759 | dymaxasia@dymax.com
Hong Kong | +852.2460.7038 | dymaxasia@dymax.com
Korea | +82.31.608.3434 | info_kr@dymax.com

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