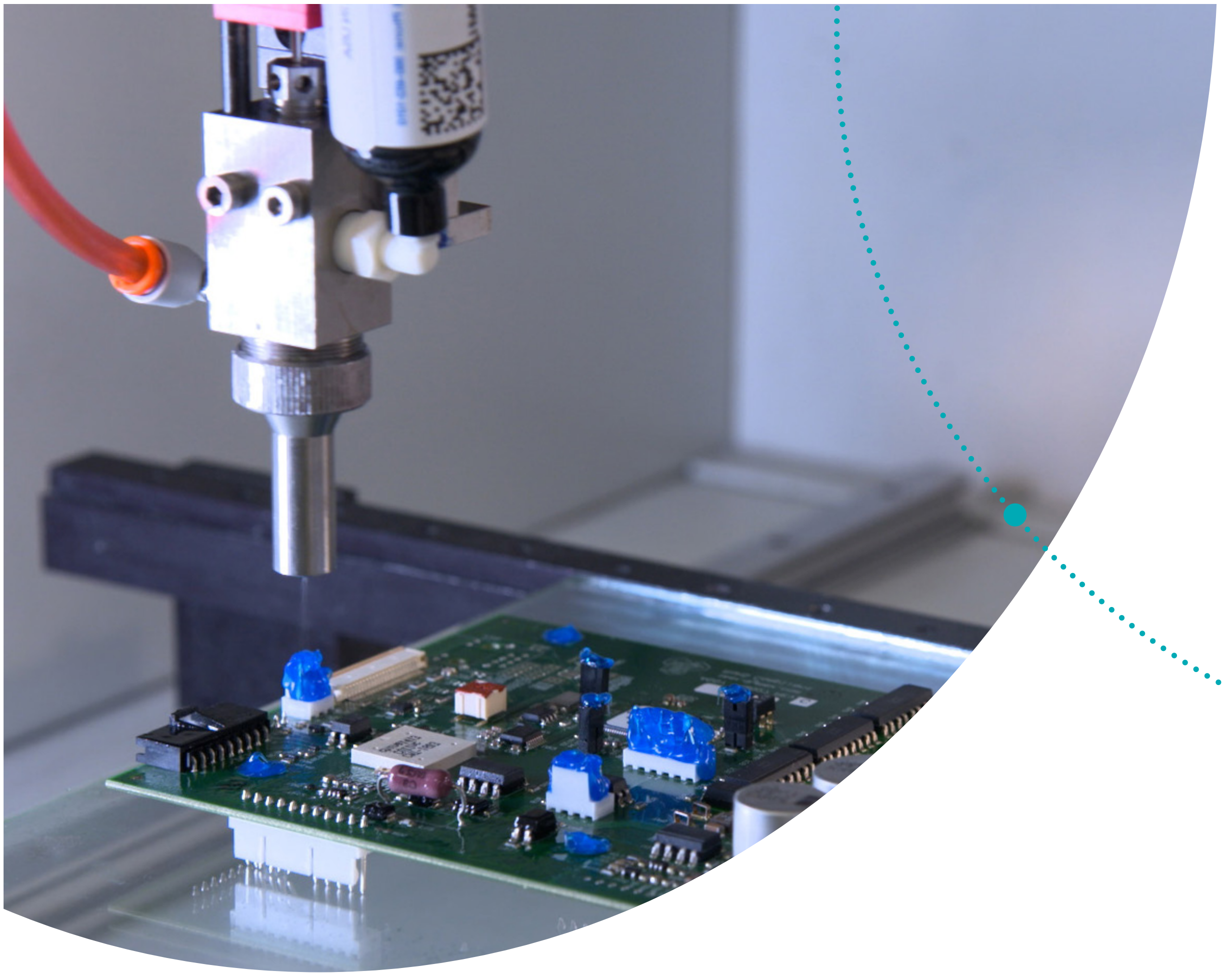

Increase PCB Performance and Productivity with UV Light-Curable Conformal Coatings and Maskants

Written by Virginia Hogan and Christopher Morrissey

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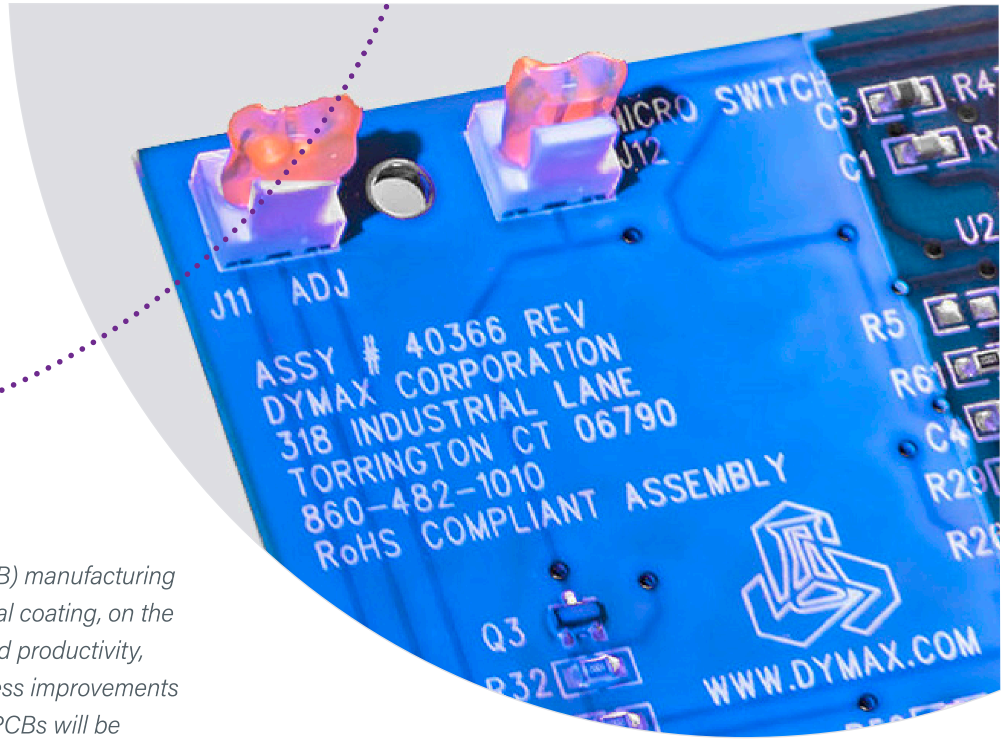


A key part of the printed circuit board (PCB) manufacturing process is the surface coating, or conformal coating, on the PCB and how it improves performance and productivity, while also taking advantage of other process improvements such as board masking. Ultimately, these PCBs will be key contributors to the critical performance in automotive, electrical components, instrumentation, appliances, consumer electronics, and other market applications.

Introduction

Today's challenging economic conditions require manufacturers to continually seek ways to improve productivity, reduce costs, and improve product performance without sacrificing product quality. How can these initiatives translate to a company's bottom line?

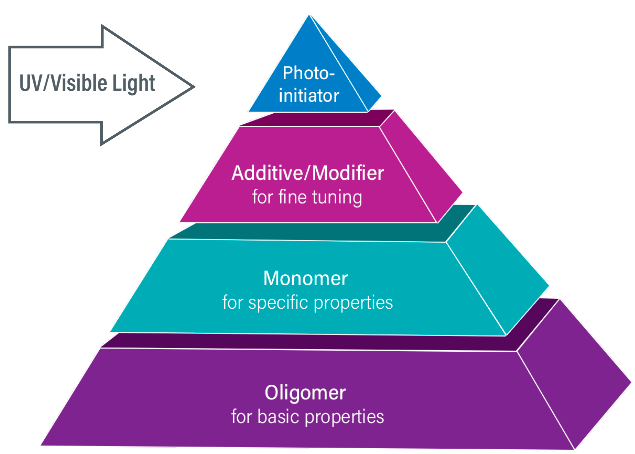
Manufacturing efficiency improvement starts with an objective that is typically converted into a process improvement. The improvement is driven by cost, time, volume, design changes, and the like, or it can be driven by market needs or internal goals and objectives. Addressing the complete manufacturing process can yield significant improvements from established norms. A key part of the printed circuit board (PCB) manufacturing process is the surface coating, or conformal coating, of the PCB and how it can improve performance and productivity while taking advantage of other process improvements such as board masking. Some products, such as conformal coatings, will stay on the board as a necessary performance enhancement. Some, such as maskants, will be temporary manufacturing aids.

The UV Curing Process

The typical ultraviolet (UV) curing process focuses on the 315 to 405-nanometer (nm) electromagnetic light spectrum. Theproper light-curable material capability at wavelength, along with the proper curing intensity, are essential components of the curing process.

UV-light-curable materials are typically made up of basic components, as illustrated in the pyramid shown in Figure 1. On the bottom is the oligomer, which brings the basic properties such as chemical resistance or heat resistance. Next is the monomer, which is used to add

Figure 1. UV-light-curable materials are typically made up of basic components that stack into a pyramid



specific properties such as elongation, flexibility, increased adhesion, and lower shrinkage. The additive is the fine-tuning for color, fluorescence, or surface tackiness, and finally, the photo initiator (PI) package enables the material to cure. All of these elements together are the formulation for the light-curable material. But they need the proper energy to initiate the curing process.

The PI package is designed around the spectral output of the curing equipment — this will vary. Formulations are designed with a specific type of curing mechanism in mind. For example, a broad-spectrum curing unit has a spectral output from 315 to just over 400 nm into the visible range. The PI package will be optimized to match the same range. Conversely, for LED curing, the wavelength is very narrow or specific like 385 nm. Optimizing a formulation for LED curing means that the PI package needs to match the same wavelength to initiate and complete the curing process.

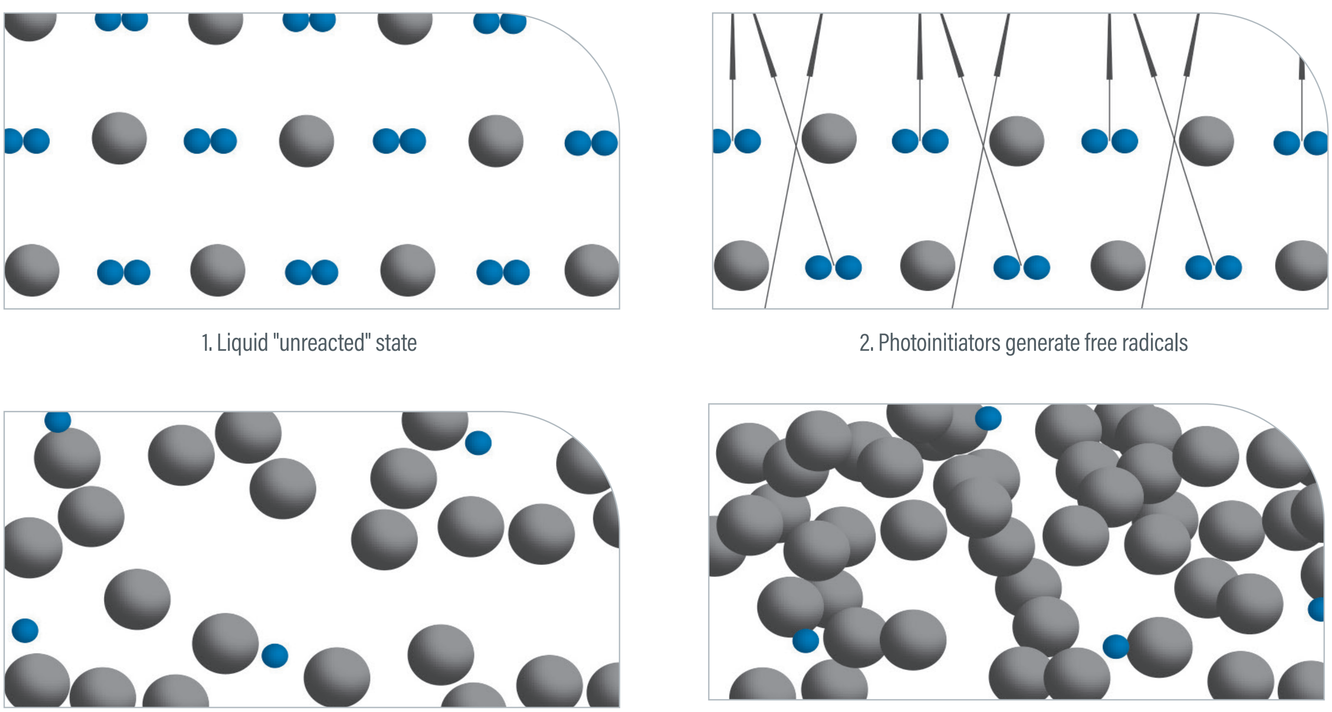
Figure 2 illustrates the light-curing process. In box 1, the light-curable material is in an unreacted state. In box 2, the curing process begins. This happens when the PI in the material is exposed to the energy source of the proper spectral output. It excites and fragments the PIs, resulting in generation of free radicals. In box 3, the free radicals actually begin to attach themselves to the acrylates that make up the light-curable material, resulting in polymeric chain radicals. The process is repeated until all the radicals are attached and there is polymer termination, i.e., a cured material as shown in box 4.

Incorporation of light-curable materials can provide significant benefits over conventional solvated materials. Light-curable materials offer advantages over other technologies, including lower operating costs driven by lower labor needs, lower energy demand, and higher throughput. These materials are 100% solids, or solvent-free products, and they can also increase production capacity due to fast cure times and small production footprint.

Light-Curable Conformal Coatings

Conformal coatings are available in a variety of solventbased as well as 100% solids forms. A key advantage of UV light-curable conformal coatings and maskants is the ability to use a green (100% solids) material — UV-curable urethane acrylates are a perfect example (Figure 3). Conformal coatings are thin,

Figure 2. The four steps of the light-curing process



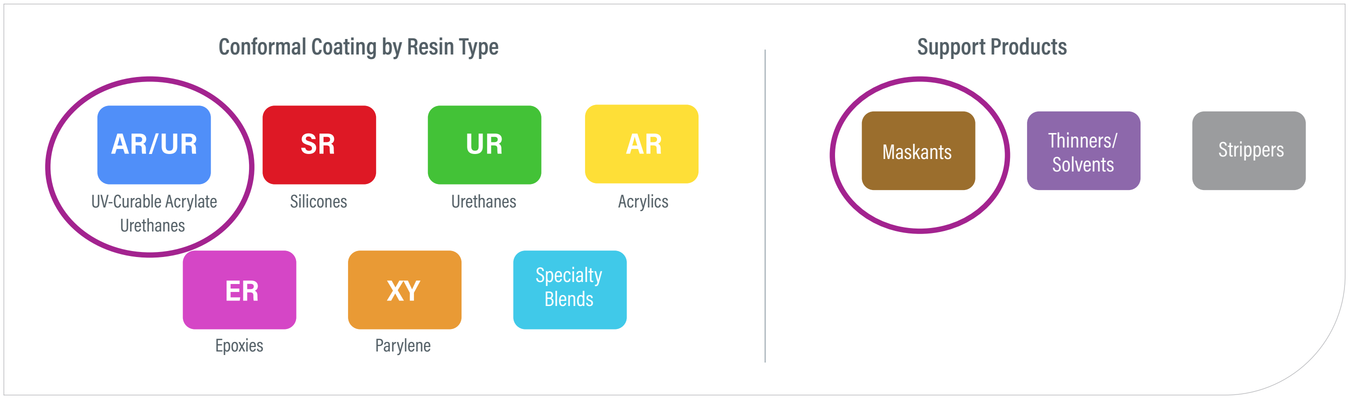
1. Liquid "unreacted" state

2. Photoinitiators generate free radicals

3. Polymer propagation

4. Polymer termination

Figure 3. A key advantage to UV-light-curable conformal coatings and maskants is the ability to use a green (100% solids) material — UV-curable urethane acrylates are a perfect example



protective polymeric coatings most often used to provide environmental protection without adding excessive cost or weight. Typically, they're applied at 50 to 225 microns thick, and they conform to the board, allowing for protection and coverage that ultimately extends the life of the PCB.

They can be applied in a variety of ways including dipping, brushing, spraying, flow coating, etc., yet the most common application method is spraying. The coating can be applied over the complete board, or more efficiently, in a selective conformal coating process that applies the coating only where it is needed.

Shadow areas are the areas beneath components where a conformal coating may flow, and relative to light curing, may not be exposed to the curing light from above. If this is the case, it's important to have a secondary curing mechanism. This is often heat or a secondary moisture cure, which can cure in these shadow areas using just available ambient moisture. Both secondary heat cure and secondary moisture cure can eliminate concerns about uncured material on the PCB.

Once the coating is applied, typically by spray dispensing, curing depends on the shape and complexity of the board as well as the thickness of the conformal coating. UV cure typically is very fast and happens in seconds, unlike solvated chemistries, which take time to flash off solvents. The secondary cure depends on the cure type; however, because of the tack-free nature of UV cure, the secondary curing can happen while the boards are undergoing further processing.

When comparing UV-light-curable materials with secondary moisture cure to other chemistries, there are advantages that can lead to increased process efficiencies. The actual advantages depend on the particular material offered by each coating manufacturer, yet currently, commercial materials can offer: immediate tack-free curing in seconds; fast curing under ambient conditions in as little as two or three days; rework ability, which is of particular value for expensive PCBs; and avoidance of board or component damage from excessive heat or temperature processing. It's also common for light-curable materials to fluoresce a bright red or blue to help with board inspection. With respect to performance, light-curable conformal coatings are also robust enough to meet very demanding application requirements and existing conformal coating performance standards.

When it comes to performance testing, there is a series of other common tests against which light-curable materials have performed well, particularly compared to competing technologies. Tests such as flexibility, thermal shock and thermal cycling, temperature and humidity testing, as well as corrosion testing using salt spray or salt fog, and sublimated sulphur arecommonly required.

Light-Curing Maskants

When the PCB is designed, there are areas designated to be free of coatings including the pin connectors, through holes, or zones on the board itself (Figure 4). Maskants are used to protect these "keep-out" areas during the conformal coating process.

Tapes and dots are very common masking methods that don't require a curing step, but can be very labor intensive to apply, especially on highly populated boards where there is very little space between the connectors to achieve a good seal against the board. Tapes also create the challenge of removing the residue left after the coating has been applied and heat cured. This could potentially be a cause for not passing SIR testing of the boards.

Caps are another common masking option. There are standard caps available that may or may not fit certain connectors. Custom caps may be required to accommodate the exact height and shape of a connector. Caps are not effective on through holes or board-level keep-out areas. Caps have a limited use, as they lose shape and sealing ability after multiple uses, causing rework of the conformal coating.

Latex-based maskants are yet another option for protecting connectors and board surfaces. Latex-based maskants are 50% solid, so the solvent needs to be flashed off, the water heat cured, or the maskant air dried. Curing times range from 15 minutes of heat cure to eight hours for air-drying the maskant. Depending on the viscosity of the maskant, multiple applications and multiple cure cycles are required to achieve the full protection coverage. Some latex-based maskants have an ammonia content that may cause discoloration or corrosion of the copper pins.

There are key differences between light-curable maskants and conventional masking options. First, the maskants conform to the simple configuration of a through hole, or complex connectors with formulations that are not slumping and will not migrate off the connectors onto the board. These formulations are compatible with copper and gold pins, eliminating corrosion or discoloration. Application of the maskants can be done by manual dispense processes, or for more precision applications, automated processes such as jetting or a multiple-axis valve system can be used. These formulations are developed to be a manufacturing aid with either UV conformal coatings or solvated conformal coatings.

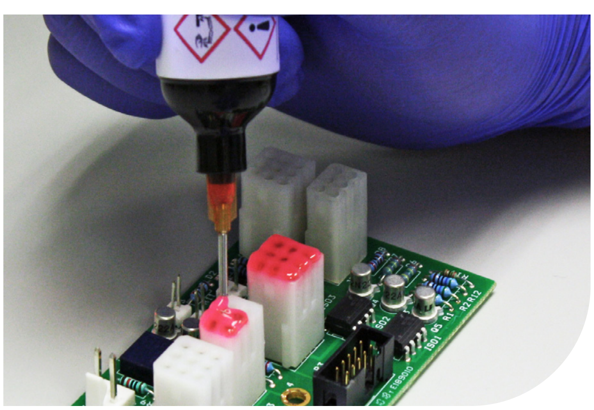
Unlike latex-based maskants, light-curable maskants cure on demand in seconds rather than hours, which means the boards are readily available for the conformal coating process — there is no need to rack the boards to wait for the maskant to cure. The light-curable resins are applied to the necessary thickness with one layer of coverage with one cure cycle. Additionally, these resins are formulated with fluorescing agents for inline placement inspection. When properly cured, the resins can easily be removed in one piece after the conformal coatings are tack-free. The one-piece removal leaves no residue on the connectors or keep-out areas, and passes SIR testing.

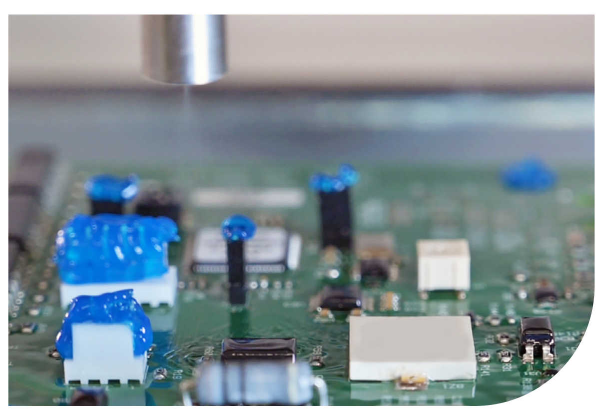
What benefits do these maskants bring to the manufacturing process? Light-curable maskants contribute to the reduction of total operating cost through efficiency of application and reductions in scrap and rework as a result of their reliability.

Light-curable masking resins are 100% solids and solvent free, reducing the environmental impact. Many available latex-based maskants are solvated or have an ammonia base that is harmful to the environment. Light-curable maskants are a greener option.

The time required to process light-curable maskants is significantly shorter than solvated or heat-cured masking resins. Time savings allow for increased throughput and reduced lead-time to the customer. Zero keep-out violations prevent rework of the coating and contribute to

Figure 4. When the PWB is designed, areas on the board designated to be free of coatings can include pin connectors, through holes, or zones on the board itself. Maskants are used to protect these "keep out" areas during the conformal coating process





increased throughput. Also, light-curing equipment has a smaller footprint than heat-curing ovens, freeing up floor space. Shorter cure cycles and the immediate availability of boards for conformal coating increases productivity — the resins are tackfree upon cure.

Conclusion

Whether a Fortune 500 company, a small startup, or somewhere in between, all companies strive to achieve an increase in profit levels. Conformal coatings and light-curable materials provide a solvent-free, greener solution; inline assembly and inspection; increased throughput with on-demand cure; and reduced floor space. All of these advantages contribute to process savings and reduced costs, resulting in increased profits.

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