Protecting Printed Circuit Boards
The Benefits of Conformal Coatings on Electronic Devices

Manuel Dominguez, Engineering Sales Representative - Ellsworth Adhesives

Consumers expect their electronics to take a lot of abuse, yet device durability is ultimately about how well internal electronics have been protected. Destructive factors include moisture, vapor, corrosive solutions, sand and dust, as well as mechanical and thermal stress from vibration, impact and temperature extremes. Engineered solutions for these common hazards routinely implement conformal coatings to protect the sensitive printed circuit boards (PCBs) that are inside devices.

Protection for PCBs has evolved beyond the wax coatings and gasketing methods once used. Potting isn’t always practical, as it requires a significant quantity of adhesive and may not be optimal for thermal management. Encapsulants are for individual components, but PCBs often need complete protection. Epoxies are falling out of favor because thermal expansion mismatches can easily damage fragile board components. Overmoldings typically have high viscosities and dispensing requires high pressures that could damage the sensitive PCB.

Since PCBs are small, delicate instruments, thin layers of acrylic-, polyurethane-, or silicone-based coatings are applied to the PCB’s topography to provide dielectric insulation, security against hostile environments and chemicals, defense against mechanical stresses, and a basis to prevent interference from radio frequency or electromagnetic sources.
PCB Problems

Considering the billions of PCBs in use globally, many of them face highly adverse conditions. Some of them operate in conditions where humans can’t, such as in the arctic or in outer space, and therefore require exceptional protection from all types of risks. Conformal coatings are the go-to solution as they’re versatile, robust, and easy to apply.

Dielectric conformal coatings are useful when electrical shorts are a concern, such as when high-voltage components are in close proximity but need to be insulated, or when conductive contaminants may enter the PCB envelope. Conformal dielectric materials also mitigate the formation of tin whiskers and prevent whiskers from reaching nearby components, which has become increasingly important with the elimination of lead-tin solders. Components can also be protected from potential electrostatic discharges.

Dielectric insulating conformal coatings can avert false contacts, such as when PCBs are exposed to humidity or moisture and conductors have an increased risk of oxidation. False contacts can also be created by desoldering or by tiny fractures that result from mechanical stress. PCBs are prone to heat issues due to their dense componentry; this is especially true for LEDs. Conformal coatings cannot be filled with conductive materials, such as metal powders, but thin layers of dielectric conformal coatings allow the board to exhaust heat without creating thermally induced malfunctions.

An adverse operating environment is an incessant risk for many PCBs, especially those that operate outdoors in applications such as vehicles and infrastructure. PCBs in marine electronics need specific protection from corrosive salt water. Those found in aircraft, military hardware, and autos need exceptional dependability. Equipment placed outside, such as broadcast antennas or traffic sensors, aren’t sheltered from weather conditions that include oppressive heat, biting cold, snow and ice, storms, and everything in between. Leading PCB OEMs seek coatings that adapt to any environmental condition.

Other PCBs may be exposed to chemicals or mechanical stress. Sensors in storage tanks need inert coatings to remain effective. The same is true for electronics used in factory environments where chemicals are prevalent. Vibration is a common mechanical stress that is often unavoidable on certain machinery. Other, more violent trauma, such as drops or impacts, place durability demands on PCBs that are solved with a conformal coating.

Conformal coatings remain a solution for isolating radio antennas. Most modern cell phones have at least two antennas that are insulated from each other with copper or laminate shielding. The conformal coating prevents the shielding from contacting the PCB itself and does so without compromising effectiveness.
Chemistries
There are four principle conformal coatings materials that are effective for PCB protection: acrylic, urethane, silicone and UV-curing coatings. Each has inherent advantages and disadvantages, but how the conformal coating will be dispensed is also a necessary consideration.

Acrylic conformal coatings are the most popular, in large part because they’re relatively inexpensive. They are quite resilient and protective, especially against moisture and debris. Acrylics are also easy to apply as they require no mixing and cure relatively quickly. Acrylic is vulnerable to some solvents and chemicals, which makes it easy to remove and repair, but also makes it ineffective against chemical threats. Volatile organic compounds (VOCs) are released as the acrylic cures, which means additional ventilation equipment and personnel protection is required.

Polyurethane is also a common conformal coating material as it offers exceptional chemical and abrasion resistance, and because of this, conformal coatings are often the choice for automotive, marine, and industrial control uses. Polyurethane conformal coatings cure from exposure to heat or moisture, and have long curing times that can be helpful for reworks when necessary, but can also create production bottlenecks. Since they are chemically resistant, it is almost impossible to repair polyurethane conformal coatings once they are cured. They may be offered as a one- or two-part solution, the latter requiring thorough mixing before application.

Silicone-based conformal coatings are often the preferred choice when the PCB will be exposed to extreme temperatures, from -40° C to 160° C. Silicones also have good solvent resistance that makes them difficult to repair and remove. They are cured by heat, moisture, or ultraviolet (UV) lamps. Although silicone coatings are impermeable to liquid water, vapors can still penetrate. Thus PCBs must be thoroughly cleaned to prevent vapor from being drawn through the conformal coating.

UV-curing conformal coatings are typically made of urethane-acrylic hybrids or specialty silicones. UV-curing compounds are preferable when rapid processing is a concern. After exposure to a UV lamp, the conformal coating cures in 15 to 20 seconds; UV lamps are also more energy efficient and adaptable than other curing technologies. Large components may require a secondary curing mechanism if the light is unable to reach all of the conformal coating. These coatings offer quality abrasion and temperature resistance, while solvent resistance is determined by

Conformal Coating Comparison Chart

<table>
<thead>
<tr>
<th>Type</th>
<th>Moisture Protection</th>
<th>Debris Protection</th>
<th>Chemical Protection</th>
<th>Ease of Application</th>
<th>Ease of Removal/Repair</th>
<th>Cure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Urethane</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Silicone</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+/-</td>
</tr>
<tr>
<td>UV Curing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

UV-curing conformal coating with a Dymax BlueWave
the choice of conformal coating material. Despite their higher initial cost, UV-curing conformal coatings improve productivity due to higher efficiency and quicker throughput.

Dispensing and Application
Processing volume, factory floor space, manual versus automated application, and capital investment are all important factors when it comes to selecting the method in which to apply conformal coatings.

The simplest means to apply a conformal coating is manually with a brush. It is low cost and easy to change between compounds. Depending on the operator’s skill, little or no masking needs to occur over connectors or sensitive components, and repairs and touch-ups are easily completed. However this method is usually sufficient only for small production volumes. Brush application is slow and it can be difficult to control the conformal coating thickness. It is also taxing on labor as it requires a skillful operator as well as an individual to manage quality control.

Dipping PCBs is a solution that coats all board surfaces simultaneously. It is a simple process that can coat many pieces at once and does not depend on operator proficiency. However, dipping can require significant masking and the conformal coating has a tendency to run off edges or corners. Dipping is typically used for heat- or UV-curing materials. An open conformal coating reservoir is susceptible to contaminants. Dipped conformal coatings also have occasional problems maintaining a uniform viscosity.

Spraying conformal coatings is often the best option when manufacturers require rapid throughput and high product volumes—it can be accomplished manually or robotically. Manual PCB spraying requires a skilled operator, but needs less masking than the dipping process. The low investment required for manual spraying equipment and easy conformal coating changes make this an attractive solution. Spray nozzles support a variety of application resolutions and patterns, and there are no edge coverage issues. However, manual spraying can be a slow process as the operator must maneuver the PCB or equipment while also applying the conformal coating. Certain compound viscosities are incompatible with spraying equipment, and the conformal coating spray emitting from a nozzle may not be uniform. Due to all of these factors, manually sprayed components often need multiple applications.
Automated conformal coating spraying is the apex of conformal coating technology. It is excellent for high-volume, high-precision applications. It requires little masking as a multi-axis robotic arm or table ensures controllable and repeatable processing. Automated sprayers also can spray around components. Such systems may have significant capital expenses and maintenance needs, but this is the optimal system for speed and efficiency.

When selecting a conformal coating, there are four simple questions begin with:

1. What will the PCB need to protect against?
2. What is the volume being produced
3. Is rework required?
4. Are industry qualifications required (UL, MIL, IPC, IEC, etc.)?

If these, or other questions are difficult to answer, Ellsworth Adhesives is available to assist with any and all conformal coating and PCB applications. Finding the best chemistry and application combination produces reliable devices, lowers costs, creates efficiencies and creates a loyal customer base.
Ellsworth Adhesives is a solutions provider for all applications or manufacturing processes that utilize adhesives, sealants, encapsulants, lubricants, tapes and related equipment from major manufacturers.

Ellsworth Adhesives’ specialty chemical knowledge spans across multiple industries. A global network of Engineering Sales Representatives is available to assist with the integration of adhesives through the complete production process. ISO 9001:2008 and AS9120A certified.