

Conformal Coating

Why, What, When, and How

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Why?

Conformal coating is applied to circuit cards to provide a dielectric layer on an electronic board. This layer functions as a membrane between the board and the environment. With this coating in place, the circuit card can withstand more moisture by increasing the surface resistance or surface insulation resistance (SIR). With a higher SIR board, the risk of problems such as cross talk, electrical leakage, intermittent signal losses, and shorting is reduced.

This reduction in moisture will also help to reduce metallic growth called dendrites and corrosion or oxidation. Conformal coating will also serve to shield a circuit card from dust, dirt and pollutants that can carry moisture and may be acidic or alkaline.

There are several types of conformal coating materials and the selection of one for your application must consider several variables.

In today's manufacturing environment with no-clean fluxes being used for many products, there are concerns about applying conformal coating over the flux residues. In fact, many of the suppliers don't recommend this step, stating that residues can reduce adhesion, potentially resulting in delamination, and that it creates micro-condensation conditions; which can be more detrimental than no conformal coating

The application where the coating will be used should also be considered. For example:

The automotive industry specifies conformal coatings to protect circuitry from gasoline vapor, salt spray and brake fluid. The use of electronic systems in vehicles is growing rapidly, and as such, the use of conformal coatings is becoming vital to ensure long term reliability. Conformal coatings are used in applications both under the hood (e.g. engine management systems), and in passenger compartments (e.g. onboard computers).

The aerospace industry with its high reliability requirements is also a viable application for conformal coatings. The environmental requirements of the aerospace industry where rapid compression and decompression can affect the performance of circuitry, necessitates the use of conformal coatings. The coatings are used in both pressurized and depressurized areas.

Both fresh and salt water environments will attack electronic circuitry. Conformal coatings are ideal for the protection of equipment used for these applications, which can range from under the dash of high performance boats, to exterior equipment used on larger maritime systems.

Similarly, in the medical industry there are numerous areas where a conformal coating will be required for environmental protection: Tool protection while in storage to prevent corrosion; pacemakers, where it is vital to ensure continuous performance and even food carts in hospitals.

Applicable Documents

The industry has several documents that address the use of conformal coatings.

- o ANSI/IPC-A-610 Acceptability of Electronic Assemblies
- o MIL-I-46058 Insulating Compound, Electrical (for coating printed circuit assemblies)
- o IPC-HDBK- 830 Guideline for Design, Selection, and Application of Conformal Coatings
- o NASA-STD-8739.1 Workmanship Standard for Staking and Conformal Coating of PWB and Electronic Assembly.
- o Conformal Coating Handbook of Material Vendor

- o Internal documents:
 - o Acceptance criteria for Conformal Coating
 - o Conformal Coating processing
 - o Qualification of Conformal Coat Board
 - o Conformal Coating process flow
 - o Conformal Coating rework procedure

What?

The ideal conformal coating will have performance requirements that include good electrical characteristics, low moisture permeability, good chemical resistance and mechanical integrity. It must adhere to the printed wiring board and mix of component surfaces.

There are several choices of both conventional and new materials available for use as conformal coatings. Understanding your end use application is vital in making the appropriate selection. For example, an acrylic coating might not be the ideal choice for an automotive application, due to the high temperatures involved and exposure to moisture or petroleum residues. A better choice would be a silicone coating, which has a usable operating range of -55°C to $+200^{\circ}\text{C}$ and offers resistance to high humidity environments. A UV cured coating may not be the best option if the assembly being coated has high-profile components. A possible result is that shadowing can leave uncured coating which compromises the reliability of the PWB.

What are the types of materials that are viable as conformal coating and what are their respective pros and cons?

Silicone

Silicone conformal coatings are most widely used in high temperature environments due to their innate ability to withstand prolonged exposure to higher temperatures than most other conformal coating chemistries. This attribute has made them the primary choice for under hood automotive

applications. They are also capable of being applied in thicker films making them useful as a vibration dampening / isolation tool if the coated assembly is to be placed in a high vibration environment. Rework of Silicone coated assemblies can sometimes be difficult due to their chemical resistance and the fact that, unlike Acrylics and Polyurethanes, they do not vaporize with the application of heat.

Polyurethane

Polyurethane formulations provide excellent humidity resistance and far greater chemical resistance than Acrylic coatings. They require very lengthy cure cycles to achieve full or optimum cure. Removal of Polyurethane coatings can be difficult due to their very high resistance to solvents. For single-components, the preferred method of removal is via burn through for spot repair, while the use of specially formulated strippers enables the user to completely remove the coating from an entire PCB assembly for more wide-ranging rework concerns.

Epoxy

Epoxy coatings are very hard, usually opaque, and good at resisting the effects of moisture and solvents. Epoxy is usually available as a two part thermosetting mixture and shrinks during curing leaving a hard difficult to repair film. It possesses excellent chemical and abrasion resistance but can cause stress on components during thermal extremes. Epoxy is quite easy to apply but nearly impossible to remove without damaging the components.

Acrylic

Acrylic conformal coatings are perhaps the most popular of all conformal coating materials due to their ease of application, removal and forgiving nature. Acrylics dry rapidly, reaching optimum physical properties in minutes, are fungus resistant and provide long pot life. Additionally, acrylics give off little or no heat during cure eliminating potential damage to heat-sensitive components. They do not shrink during cure and have good humidity resistance and exhibit low glass transition temperatures. The material also has a continuous operation range of -65°C to $+125^{\circ}\text{C}$.

Acrylic coatings typically consist of a solution of a thermoplastic acrylic polymer dissolved in a blend of organic solvents which dries by simple solvent evaporation. This means that acrylic coatings will soften at high temperatures and also that they are easily removed to effect board repair. The solvents involved are flammable and this type of coating is coming under pressure because of increasingly restrictive environmental legislation concerning the release of emissions of solvents into the atmosphere. Moisture resistance of this type of coating is good but resistance to organic solvents is relatively poor.

Paralyne

There is a unique type of coating process called Paralyne, originally created by Union Carbide. Di-p-xylylene is pyrolyzed at a temperature approximating 650°C in a high vacuum environment causing the monomer to polymerize on all PWB and component surfaces present in the high vacuum environment giving a very even pinhole free coating.

This process will effectively coat assemblies containing high profile components easily, whereas the more conventional processes previously mentioned would experience significant thinning of the coating on components due to surface tension.

A unique difference with the parylene process is that it also coats the underside of low profile components due to the thin application of the coating. Because of the requirement to use a vacuum chamber for this process it is inherently more expensive than the alternate methods.

Table 1 summarizes the properties and comments about each of these conformal coatings.

Table 1 - Summary of Conventional Materials

	Properties	Comments
Epoxy	Good adhesion Excellent chemical resistance Acceptable moisture barrier	Difficult to rework Needs compliant buffer Not widely used
Urethane	Good adhesion High chemical resistance Acceptable moisture barrier	Difficult to rework Widely used Low cost
Acrylic	Acceptable adhesion Poor chemical resistance High moisture resistance	Easy to rework Widely used Moderate cost
Silicone	Poor adhesion Low chemical resistance Excellent moisture resistance	Possibility of rework Moderate usage High cost
Parylene	Excellent adhesion Excellent chemical resistance Excellent moisture resistance	Impossible to rework Rarely used Extremely high cost

New Materials

There are several new materials entering the market that are intended to introduce new chemistries and formulations to enhance the utilization of conformal coatings.

Certonal FC-742 is a low viscosity surface modifier fluorochemical polymer coating that provides acceptable environmental properties for high reliability applications. The low surface energy films from the coating offer excellent repellency to hydrocarbon oils, silicone oils, synthetic fluids, and aqueous solutions. The manufacturer states that the material, can be used as an anti-migration barrier to prevent lubricants from migrating from critical wear components in gyroscopes, precision bearings, MEMS spindles, and other similar mechanical, critical wear devices.

The 3M Novec series of materials also offers excellent hydrophobic and oleophobic properties. It is also a low viscosity, low surface tension solution of a fluorochemical acrylic polymer carried in a hydrofluoroether solvent. 3M focuses this material on its application to epoxy laminates where it provides excellent repellency, against liquids, water, hydrocarbons, silicones and photoresists.

Another technology of interest is the Ross NanoTechnology superhydrophobic material called "Never Wet." Currently this material is used to coat mechanical components, but due to its 165 degree wetting angle it appears to offer excellent possibilities for being a conformal coating material. It provides a barrier to penetration of materials such as water, oils from industrial sites, and acid rain. It is interesting to note that due to the high wetting angle of the material aqueous solutions of acids, alkalis and salts similarly bead up on the surface like water does.

How

Conformal coatings are typically applied to circuit boards by either dipping or spraying, to achieve a thickness of 20-50 microns (1-2 mils depending on technology) , although conventional silicone and other specialty coatings can be applied at up to 4 mils. For small volume production or prototyping of a product, coatings may be applied by simple brushing as this is not a production process.

By preventing contamination of the PWB surface, the coating helps to prevent corrosion of conductors and solder joints and also reduce dendritic growth between conductors. It is also a mechanism for minimizing the risk of problems due to the growth of tin whiskers.

Coating Application Techniques

The conformal coating material can be applied by brushing, spraying or dipping. Or, due to the increasing complexities of electronic circuit board assemblies being designed and with the 'process window' becoming smaller and smaller, by selectively coating via robot.

Brush coating

The coating material is flowed onto the board and is suitable for very low volume application, finishing and repair. The result is typically inferior cosmetically and can be subject to many defects such as bubbles, or missed coverage. The coating also tends to be significantly thicker and unless skilled operators applied the coating, highly subjective in quality.

Spray application coating

Conformal coatings can be applied with a spray aerosol or dedicated spray booth with spray gun and is suitable for low and medium volume processing. The quality of the coverage can be superior to all other methods when a trained skilled operator performs the process, as long as the circuit board is clean and the coating has no adhesion issues.

Conformal coating dipping

This coating is a highly repeatable process. The coating will penetrate everywhere, including under devices, and therefore any masking to protect certain components (e.g connectors) from the coating must be perfect to prevent leakage. Therefore, many PCBs are completely unsuitable for dipping due to design. The issue of thinner coating around sharp edges can be a problem especially in a highly condensing atmosphere. This issue with complete coverage can be eliminated by either double dipping the PCB or using several thin layers of atomized spraying to achieve good coverage without exceeding coating thickness recommendations.

Typical robotic processes

This approach involves a controlled needle and atomized spray applicator that can move above the circuit board and dispense / spray the coating material in pre-programmed selective areas. This method is highly effective at large volumes as long as the PCBs are designed for the method. However, there are limitations in the robotic approach—like all the other processes, such as potential capillary effects around low profile connectors which "suck" up the coating accidentally.

Table 2 summarizes the differences between the dip and selective coating processes.

Table 2 – Comparison of Dip and Selective Coating Processes

Dip - Process	Selective Coating
- Simple to apply	- Excellent consistency in thickness
- Undefined thickness	- Controllable process
- Uncontrolled process	- Programmable Coating
- Masking	- Requirement for Aircraft & Military application on computing Boards

Inspection

Inspection of the coating is easily accomplished using “Black Light” to expose the surface to be inspected. The conformal coating will fluoresce (See Figure 1). Areas that are coated will look like snow on the surface of the PWB, while uncoated areas look dark. This allows touch up to be performed to assure full coverage of the product.



Figure 1 – Conformal Coating under UV light.