

# Conformal Coating Defects

Why They Happen & How to Prevent Them



[www.paryleneconformalcoating.com](http://www.paryleneconformalcoating.com)

# Introduction

Conformal Coatings are polymeric materials used to protect circuitry, parts, and related components. They are most commonly used to protect printed circuit boards (PCBs) and electronic devices.

However, conformal coatings can be applied to a wide variety of materials, including metal, plastic, silicone, ceramics, glass, and even paper. We use the term "substrate" to refer to an object or material that's been coated with a conformal coating.

## Conformal Coating Costs

The price for conformal coating varies depending on the material being used and the preparation required. Raw parylene dimer, for example, can cost between \$100 and \$10,000+ per pound.

In many cases, however, the biggest cost of conformal coating is manual labor. Tasks such as cleaning, masking, and inspection take time and must be completed by a well-trained technician.

This is important for conformal coatings, because repairing or reworking a failed coating is often a costly process.

## The Problem

**Unexpected rework or repair can add significant cost and delays to a conformal coating project.**

## The Cost of Conformal Coating

# Defects and Repair

The cost to repair a defective or failed conformal coating depends on the method required to remove and repair the material.

Some materials can be removed with solvents, then reapplied. Others must be burned away or mechanically removed using grinding or microabrasion techniques.

Coatings made of acrylic, for example, are relatively easy to remove using chemical solvents. Parylene and epoxy coatings, on the other hand, are difficult to remove. They usually require mechanical or microabrasion methods.

The type of defect impacts the amount of repair required as well. Conformal coatings can fail for a variety of reasons. We'll look at the major ones in this white paper.

Regardless of the type of defect, however, the more labor required to fix the problem, the higher the cost of repair. In every case, the best way to keep your costs in line is to avoid these defects in the first place.

## The Challenge

**To prevent unexpected repairs, you need to know how to prevent the common causes of conformal coating defects.**

### 6 Common Causes of Conformal Coating

# Defects and Rework

Here are the six most common causes of conformal coating defects we see, along with recommendations for how to avoid them:

## 1. Capillary Flow

Capillary flow is a type of coating migration that happens when a liquid conformal coating pulls away or “flows” from one area of the substrate to another. This usually happens during the drying and curing process, resulting in a patchy, uneven finish. Some areas of the substrate may even be left completely uncoated.

The most common causes for capillary flow are:

- Low viscosity of the coating material
- High surface tension of the coating material
- Too much coating material applied to the substrate
- Low surface energy of the substrate

To avoid these problems:

- Make absolutely sure the substrate is clean before applying coating
- Reduce the use of thinners to increase viscosity
- Reduce the coating thickness
- Try using a solvent-based coating instead of a water-based coating
- Heat the board prior to coating to help it dry more quickly

## **2. Cracking**

Cracking happens when a smooth surface of coating fractures into sections. The cracks between the sections leave the area below exposed to potential contaminants.

Common causes for cracking are:

- High temperature during curing
- Coating cured too quickly
- Coating was applied too thick
- Operating temperature too high or too low for coating specifications

To prevent cracking:

- Lower the cure temperature
- Allow additional drying time at room temperature
- Apply the coating to specified thickness levels
- Choose a coating with a wider effective temperature range
- Choose a more flexible coating

## **3. De-Wetting**

De-wetting occurs when a liquid conformal coating will not evenly coat the surface. De-wetting usually happens because of a nonionic contamination, often from the manufacturing, transport, or handling process.

The best way to prevent de-wetting is to ensure the substrate material is completely clean prior to applying conformal coating.

## **4. Delamination**

Delamination happens when a conformal coating lifts away from the substrate, leaving the area below it exposed. Delamination is most often caused by:

- Contaminants on the surface of the substrate
- Lack of compatibility between the coating and the substrate material
- Moisture
- Improper curing of the conformal coating

To help prevent delamination:

- Reduce the coating's thickness
- Reduce force drying
- Clean the board thoroughly prior to coating it
- Choose a different coating material
- Apply a "primer" material known to bond well with the substrate and the material you're using for your conformal coating

## **5. Orange Peel**

Orange peel happens when the coating is uneven and textured, often appearing dull, very similar to the skin of an orange. It is caused by:

- Improper application of coating materials
- Not enough coating applied
- Not enough time curing

To mitigate the effect of orange peel:

- Reduce the viscosity of the coating
- Apply the coating to the recommended thickness
- Increase the "flash-off time" for the solvents to evaporate before turning up the temperature to speed the curing process

## **6. Bubbles, Pinholes, and Foam**

Bubbles happen when pockets of air become trapped under a layer of conformal coating. Pinholes occur when a bubble bursts through the coating layer. Foam is a form of extreme bubbling. Common causes of bubbles and foam:

- Coating applied too thick
- The coating is too viscous
- The coating is applied with incorrect equipment settings or pressure

To help prevent these problems:

- Ensure the coating is applied only to recommended thickness
- Apply several thin coats, allowing bubbles to dissipate between layers
- Use a lower viscosity version of the conformal coating
- If brush coating, blend the coating so it flows easily into all areas of the substrate.

## How to Avoid

# Bubbles and Foam

Bubbles and foam are two of the leading causes of failure during conformal coating inspections. Because of this, it's worth looking at these defects more closely.

Bubbles cause voids in the coating, leaving areas of the substrate exposed to potential contaminants. Knowing this, a question we often hear is:

- *How do I prevent bubbles from forming in my conformal coating?*

The answer is: Understand how and why bubbles form in the first place. Then you can take steps to prevent them.

## 5 Common Causes of Bubbles in Conformal Coating (and Their Remedies)

Here are the five most common causes of bubbles in conformal coating, along with their remedies:

### **Cause #1: Wet Surface Skins Over**

When applying a wet conformal coating, the surface of the coating can skin over, trapping solvents under the surface, which can bubble or burst out.

The remedy: When applying the conformal coating, ensure the wet film surface is not too thick. This is particularly important when spray coating. It is better to apply multiple thin layers than one thick layer.

### **Cause #2: Coating too Thick or too Viscous**

If the coating is applied too thick or too viscous, any bubbles that are created can become trapped in the coating before they settle out.

The remedy: Apply thinner individual layers, and allow a flash-off time between coats to let any excess coating evaporate.

### **Cause #3: Air Trapped Under Components**

During the conformal coating process, air sometimes gets caught under components of a circuit board. When this happens, air can seep out during the drying and curing process and cause bubbles.

The remedy: To avoid air entrapment under circuit board components:

- Dip the circuit board or device slower into the coating dip tank.
- Add a dwell time to allow penetration of the coating around and beneath components.
- Use a lower viscosity version of the conformal coating to underfill components more effectively.

### **Cause #4: Pressure Pots**

Pressure pots with conformal coating inside can absorb air, which can cause champagne bubbles.

The remedy: When using pressure pots with conformal coating inside, try to avoid leaving the pots pressurized for long periods of time. You should avoid running the pressure pots more than 50% full and letting them stand. This will minimize the champagne effect in the coating.

### **Cause #5: Coating is too Viscous**

Brush coating with too viscous a material or working the coating can cause bubbles.

The remedy: When brush coating try to blend the coating so it flows easily and “flow” the material onto the PCB. Do not “work” the coating into the PCB as it creates bubbles.

## **What if My Conformal Coating Is**

# **Applied too Thick?**

Coating thickness is critical to the proper functioning of your printed wiring assembly, circuit board, or electronic device.

If a coating is too thin, proper coverage is impossible. But, if your coating is too thick, it may create excessive stress on solder joints and components (particularly glass-bodied components).

What's more, controlling coating thickness is of special importance with rigid coating materials such as epoxy. Excessively thick conformal coatings can cause residual stress that can damage the electronic device that's been coated.

If your coating is too thick, you'll need to remove and reapply the coating or grind it down. The specific method you use will depend on the coating you're working with.

Before we look at removal methods, here's a cheat sheet showing recommended thickness for the five major types of conformal coating.

Type	Full Name	Thickness When Applied
Type AR	Acrylic Resin	0.00118 to 0.00512 in.
Type ER	Epoxy Resin	0.00118 to 0.00512 in.
Type UR	Polyurethane Resin	0.00118 to 0.00512 in.
Type SR	Silicone Resin	0.00197 to 0.00827 in.
Type XY	Parylene Resin	0.000394 to 0.00192 in.

## Conformal Coating

# Removal Methods

If your coating has been applied too thick or there is a defect that requires removal of the coating, there are three broad categories of removal techniques:

- Thermal removal
- Chemical removal
- Mechanical removal

## 1. Thermal Removal

Thermal removal methods use a soldering iron to heat and remove the coating.

Because most conformal coatings require a very high temperature and long exposure times, the thermal removal process can cause discoloration, leave residue, and

adversely affect solder joints and other materials and components used in the fabrication of assemblies.

If you decide to use the thermal removal process, it must be monitored to ensure excessive temperatures do not cause delamination or other damage to the underlying device.

Extreme caution must be taken when burning off conformal coatings; some coatings emit toxic vapors which are hazardous.

## **2. Chemical Removal**

Chemical methods are the most popular method for removing conformal coatings. As long as the solvents used do not adversely affect the printed wiring board or components, and there are no environmental issues, this technique works well.

However, there is no one perfect solvent for all applications. In some cases it may be difficult to find a suitable solvent.

The following sections discuss the chemical removal methods for various types of coating:

### **A. How to Remove Urethane**

There are several solvents you can use to remove urethane conformal coatings. These solvents include:

- Methanol base/alkaline activator solvents, which provide a range in the dissolution power and selectivity
- Ethylene glycol ether base/alkaline activator solvents, which are relatively fast and less selective than methanol/alkaline solvents

### **B. How to Remove Silicone**

Methylene chloride based solvents are very effective in removing silicone conformal coatings. Several other hydrocarbon-based solvents are also used as alternatives.

While not as fast as the methylene chloride, the hydrocarbon-based solvents are more selective. When not contaminated by water, hydrocarbon solvents will not attack epoxy-glass printed circuit boards (PCBs), components, metals and plastics.

### **C. How to Remove Acrylic**

In the past, acrylic coatings were removed using highly volatile and flammable solvents such as methylene chloride, trichloroethane or ketones.

A relatively safe alternative has been developed based on butyrolactone. It can be used for the removal of most acrylic coatings.

## **D. How to Remove Epoxy**

The complete removal of epoxy coatings for repair is nearly impossible by chemical means. The solvent can't discriminate between the epoxy coating, the underlying printed circuit board, and any epoxy-coated or potted components.

However, if done carefully, spot removal may be accomplished by the application of methylene chloride and an acid activator with a cotton tipped swab.

## **3. Mechanical Removal Methods**

Epoxy and parylene coatings are resistant to both thermal and chemical removal techniques. In most cases to remove these types of coatings, you must use mechanical or microabrasion techniques.

Mechanical removal techniques require precise manual labor from a highly-experienced technician. He or she must grind down the coating to remove it, without damaging the circuit board or device underneath.

## **9 Questions to Ask a Conformal Coating Provider**

How can you tell if a potential conformal coating provider has the credentials and expertise necessary to avoid costly defects with your product?

The first step is to make sure the provider you're considering has expertise working with all five major types of conformal coating:

- Acrylic
- Urethane
- Silicone
- Epoxy
- Parylene

A company with this type of broad experience will be able to help you find the right coating solution for your device, not just the coating solution they prefer.

## **The 9 Questions to Ask a Coating Provider**

Step two is asking the provider a series of basic questions about their process. This will give you a good idea of whether the company has the right expertise for your project.

Here are the nine questions we recommend you ask:

### **1. What Is Your Process for Preventing Ionic and Nonionic Contaminants?**

Ionic contaminants can't be seen visually, but they can turn the coating layer from non-conductive into a massive short-circuit that connects all the components underneath it.

Ionic contaminants can also cause corrosion or dendrites, small metal outgrowths from a circuit component that can damage the conformal coating and cause short circuits.

Nonionic contaminants sit on top of a device prior to coating and can usually be seen visually. If not removed, nonionic contaminants can prevent coatings from adhering to the substrate.

### **2. How Do You Clean Circuit Boards and Other Devices Prior to Conformal Coating?**

Water will remove most ionic contaminants, but the water must be pure. Otherwise it can leave behind salt and other compounds when it evaporates.

Your coating provider should also thoroughly clean your device using a solvent or a surfactant in order to remove nonionic contaminants.

### **3. After Cleaning, Do You Test the Device for Remaining Contaminants?**

At Diamond-MT, we use the Resistivity of Solvent Extract (ROSE) method, which works as follows:

- Measure the solution's conductivity
- Use the solution to wash the substrate being tested
- Measure the solution's conductivity post-wash

If the solution's conductivity goes up after the wash, it's a sign the device has an ionic contaminant.

In addition, we recommend asking about the defects we described earlier in this paper:

#### **4. How Do You Avoid Capillary Flow for the Conformal Coatings You Apply?**

Capillary flow is a type of coating migration that happens when a liquid conformal coating pulls away or “flows” from one area of the substrate to another.

#### **5. How Do You Prevent Cracking of Your Conformal Coating?**

Cracking happens when a smooth surface of coating fractures into sections. The cracks between the sections leave the area below exposed to potential contaminants.

#### **6. How Do You Prevent De-Wetting of Your Coatings?**

De-wetting occurs when a liquid conformal coating will not evenly coat the surface.

#### **7. How Do You Prevent Delamination?**

Delamination happens when a conformal coating lifts from the surface of the substrate, leaving the area below it exposed.

#### **8. How Do You Prevent Orange Peel?**

Orange peel happens when the coating is uneven and textured, often appearing dull—very similar to the skin of an orange.

#### **9. How Do You Prevent Bubbles, Pinholes, and Foam?**

Bubbles happen when pockets of air become trapped under a layer of conformal coating. Pinholes occur when a bubble bursts through the coating layer. Foam is a form of extreme bubbling.

## 7 Key Points to Remember About Conformal Coating Defects

# Coating Defects

1. Rework and repair can add significant cost and delays to conformal coating projects.
2. The best way to deal with defects is to understand why they happen and prevent them.
3. Conformal coating defects can happen for a variety of reasons.
4. Bubbles and foam are among the most common types of conformal coating defects.
5. Conformal coating that is applied too thick can cause stress on the underlying circuit board or electronic device.
6. To remove conformal coating from a device, you'll need to use chemical, thermal, or mechanical techniques.
7. Choose a company that has expertise with all five major coatings. Then ask a series of questions to ensure the company has the expertise to meet the requirements for your project.

# About Diamond MT



Diamond MT was founded in 2001 as a firm specializing in contract applications of conformal coatings for Department of Defense and Commercial Electronic Systems. Since our beginning, Diamond MT has established a reputation for providing the highest quality services in the industry. Our commitment to quality, integrity, and customer satisfaction combined with an unmatched expertise in applications and processes has provided every one of our customers with superior results.

Diamond MT operates out of a freestanding 12,000 square foot building in Johnstown, Pennsylvania, which is located 60 miles southeast of Pittsburgh. Diamond MT is located near three major interstates and is supported by the Cambria County Airport, which serves as a primary freight terminal for south central Pennsylvania. Diamond MT maintains a strict program per NSI ANSI Standard 20.20 for ESD protection. All work areas are safeguarded with the latest in protection devices including wrist straps, garments, and workstations.

Quality Assurance: Diamond MT's quality manual ensures every employee is focused on continuous improvement and service excellence. Our ESD safe facilities stretch over 12,000 square feet dedicated to your conformal coating requirements. We are continually researching and updating our equipment to make sure we are providing the best ESD protection available.

All employees have been trained in proper ESD procedures. We operate at a class 3 level to ensure the job is done right the first time and to the highest quality standards set forth in accordance with the MIL-STDs, IPC, J-STDs as well as having our biomedical and ITAR certification. Furthermore, all assemblies are tracked through every step of the process with documentation/serialization spreadsheets as well as each assembly going through a 100% visual inspection.

Diamond MT has a strong organization consisting of highly motivated personnel, modern facilities, and diverse capabilities. Diamond MT represents one of the most modern, well-equipped facilities in the region. Diamond MT offers a highly skilled workforce, rapid turnaround manufacturing and high reliability through an established quality program, along with experience of commercial manufacturing requirements, competitive pricing and on-time delivery.

Rapid Turnaround: Diamond MT understands that oftentimes conformal coating is overlooked because it's the last step in the process. We are committed to serving the industry with rapid turn times for parylene, (normally 10 business days) with expedited service in as little as 2-5 business days depending upon the complexity and quantity.

For liquid coatings, our normal turnaround time is five business days; again with expedited service in as little as 2-3 business day turns. We understand that there are times you'll need a project completed FASTER. We will accommodate your needs in a budget friendly manner. This service is offered on a FIFO basis.

To learn more about Diamond MT, please contact us today!

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