The Basics of Conformal Coating

www.paryleneconformalcoating.com

Introduction

Modern electronics manufacturers need devices that can withstand heat, cold, rain, snow, vibration, fungus, oxidation, and corrosion through decades of operation.

- Automotive and aircraft companies need circuit boards that perform for years inside cars, trucks, school buses, construction equipment, commercial aircraft, and even fighter jets.
- Defense manufacturers need systems that can operate in tanks, rocket boosters, and satellites—just to name a few.
- Medical device manufacturers need coatings that allow their devices to function for years inside the body.
- Cell phone and tablet manufacturers need circuitry that can withstand everyday vibration, moisture, and drops.
- Makers of wearable fitness trackers need devices that won’t fail in the rain, sun, snow, or during intense exercise sessions.

The Problem

Unprotected circuit boards and electronics will not survive these harsh environments.

Conformal Coatings Protect Devices from

Harsh Environments

Conformal coatings create a protective, non-conductive dielectric layer that's added to a circuit board or electronic device. There are five primary coating types, each with dozens of variations, meaning there are literally hundreds of conformal coatings to choose from.

Costs for different coatings vary wildly depending on the material type. Parylene dimer, for example, can cost anywhere from $100 to $10,000+ per pound, depending on the type and quality.

The application process, batch size, and the shipping and transport costs can also dramatically influence your overall cost. To choose the right protection, engineers should answer these questions:

- Is conformal coating the right choice to protect my device?
- What conformal coatings are available?
- Which coatings are cost effective for my situation?
- Is it better to outsource, or should we handle conformal coating in-house?

The Challenge

Electronics manufacturers rarely have the expertise to know exactly which coating is right for their device.

4 Steps to Help You Choose the

Right Protection

Here are four steps to help you choose the right protection for your device:

1. Define Clear Performance Requirements

It’s critical that you clearly define the performance requirements for your device. What temperature range will it face? Will it have to withstand moisture? What about vibration?

2. Understand the Advantages of Conformal Coatings When Compared to Alternatives

Alternative methods of protection such as “potting” can provide some of the protective properties of conformal coatings. But they also come with some significant drawbacks.

3. Learn the Five Types of Conformal Coatings

There are five main types of conformal coatings, each with its advantages and shortcomings. We’ll describe these later in this white paper.

4. Find a Company That Provides All Five Coatings

Companies that provide one coating option sometimes have an “every problem looks like a nail to a hammer” approach. It’s better to work with a provider that offers all five coatings. They’ll be able to help you choose the right protection for your needs. They’ll also be able to support you whether you want to outsource the work or keep everything in-house.

The Differences Between

Coating and Potting

Conformal coatings are a protective, non-conductive dielectric layer that are added to a circuit board or electronic device.

The coating “conforms” to the object being coated (often referred to as the “substrate”), allowing protection without significant additions to the weight or thickness of the device.

Potting (also called embedment) is also designed to protect a device from the surrounding environment. But instead of adding a coating, potting uses a “pot” or shell to encase the board or device.

The potting process begins when the substrate is placed inside the pot. A liquid compound is then poured into the pot, filling it and covering the device completely. The liquid hardens, encasing the device inside it. The pot and the hardened compound surrounding the device become part of the final product.

Potting is a common technique used to protect printed circuit boards (PCBs), especially in high-volume production facilities.

Similarities Between Potting and Conformal Coating

Potting and conformal coating have similar goals:

- Prevent the substrate from failing in harsh environments or from vibrations or other potentially-damaging uses.
- Increase the electrical performance of a circuit board through shielding.

Both methods can be effective when used in the right situation.

When Should I Use Potting?

Potting is the clear choice for impact resistance.

If your device needs to withstand potential impact damage or rough mechanical abrasion, potting will provide the best level of protection. Potting is also a good candidate if you need:

- Significant vibration dampening
- Heat dissipation
- Privacy and security

By using colored potting compound, potting can obscure the circuit board or device. This can provide protection against someone else reverse engineering your product.

Potting's biggest drawback is that it creates an extremely thick block compared to conformal coating methods. For this reason, potting is not a good choice if your device has thickness or weight restrictions.

When Should I Use Conformal Coating?

Conformal coating is extremely thin, making it an excellent choice for many circuit boards and devices, especially those with strict weight or thickness restrictions.

Circuit boards in mobile devices, for example, are often placed in extremely small spaces. In situations like these, conformal coating is an ideal option.

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 0.00197 in.

Which Is Better?

As with any engineering decision, the needs of your device will determine which protection is best. Both potting and conformal coating provide a degree of dielectric protection, and both can protect against:

- Corrosion
- Salt
- Acids
- Bases
- Most solvents

Potting is a popular choice because it is fast and easy to apply on assembly lines or in high-volume production environments.

A device that has been potted, however, is much more difficult to work with than a device that has been coated. Potted devices are extremely difficult to rework, since removing the potting often destroys the circuit board or device underneath.

Because they are so thin, conformal coatings are the clear choice when tolerances are tight. The invisibility of the coatings also makes them the right choice when an item needs to be visible. Potting a device with an indicator light, for example, defeats the purpose of having the light in the first place.

How to Choose

Before you make a final decision, we recommend consulting with a team of experts.

Both potting and conformal coating are complex processes with a number of variables that will determine effectiveness, cost, and turnaround time. Consulting a team of experts will help you choose the right protection for your project, budget, and timeline.

The 5 Types of Conformal Coatings and Their

Benefits and Drawbacks

There are five types conformal coating.

Four of the five—acrylic, epoxy, polyurethane, and silicone—are applied by either brushing, spraying, or dipping the coating on the substrate, then letting it dry. The fifth coating type—Parylene—is applied using a unique vapor-phase polymerization process.

Each type of coating has it's own benefits.

1. Acrylic Resin (Type AR)

Acrylic conformal coatings are fungus resistant and can easily be applied. They dry to the touch at room temperature in minutes and have excellent electrical and physical properties. Acrylic coatings are typically applied at 0.002 to 0.005 inches thick. Most variations cure in as little as 30 minutes, making them a great choice when you need a short turnaround time.

Most popular acrylic coatings are not good choices for high-temperature environments. They can usually only withstand temperatures of up to 125 degrees Celsius.

2. Epoxy Resin (Type ER)

Epoxy conformal coatings are “two-component” compounds. They deliver a rugged coating with good resistance to damage from humidity, high abrasion, or chemicals.

Epoxy coatings are known for their extreme hardness, making them a good choice when you need toughness and durability.

Their extreme hardness means rework and repair are difficult. Extreme temperatures also tend to reduce the stress resistance properties of epoxy coatings.

3. Polyurethane Resin (Type UR)

Polyurethane (also called “urethane”) conformal coatings deliver excellent humidity and chemical resistance. Polyurethane is often the optimal choice for devices that will be exposed to chemical solvents. Its dielectric properties also promote miniaturization because it insulates signal traces from circuits that are close together.

Polyurethane provides humidity, abrasion, and chemical resistance. It retains high dielectric properties over time and is one of only a few methods to prevent against tin whisker growth.

Polyurethane’s resistance to solvents means it can be difficult to remove or rework. It also doesn’t do well in high-vibration or high-heat environments.

4. Silicone (Type SR)

Silicone conformal coatings perform well in high-temperature environments, even up to 200 degrees Celsius. That makes silicone a popular choice for automotive applications. It also has a resistance to humidity and corrosion and can be applied in thicker layers than other coatings, promoting vibration damping.

Silicone is less resistant to abrasion and solvents than other coatings. It also requires more care to apply correctly.

5. Parylene (Type XY)

Parylene is often considered the “gold standard” of conformal coatings. Unlike the other coatings, Parylene conformal coatings are applied using a unique vapor phase polymerization process.

Parylene’s application begins with a raw parylene dimer. The dimer is placed in a loading boat inside a vaporizer.

The powdery dimer is heated to 100-150 degrees Celsius, converting it from a solid into a gas. The gas is then heated to 680 degrees Celsius. At the higher temperature, the parylene gas splits from a polymer into a monomer, causing a single molecule vapor to be formed.

The gas is pulled through a vacuum into an attached coating chamber, where it evenly coats the surface of the circuit board or device placed there by the operator.

Parylene-coated surfaces are exceptionally resilient, withstanding extremes in temperature and physical stress. The unique coating process makes Parylene coating the thinnest coating available, and it ensures a pinhole free application.

Parylene can be applied to virtually any surface and objects of any shape, including glass, metal, paper, resin, plastics, ceramics, ferrite, and silicon. Parylene is also completely inert, making it an excellent choice for implants and biomedical devices.

Rework is difficult with Parylene due to its unique application process. Operators must also ensure the object to be coated is completely clean and that any areas not to be coated are meticulously masked.

How to Prepare Your Device for
Conformal Coating Success

Once you've decided to use conformal coating for your device, a question that often comes up is:

- *Does my product need to be cleaned before conformal coating?*

The short answer is: yes. Your device absolutely needs to be cleaned. But there's also a broader question we recommend you ask:

- *What's everything I need to know to prepare my device for conformal coating success?*

6 Essentials for Conformal Coating Success

Understanding a few fundamentals about conformal coating will help you be successful. Here are a few of the major topics you should be familiar with:

1. Common Contaminants: Ionic vs. Non-Ionic

Your device might become contaminated for a variety of reasons. The manufacturing process, transport, handling, and storage can all introduce different types of contaminants. There are two broad categories of contaminants, each with a different impact on the conformal coating process.

Ionic contaminates break down into separate molecules inside the coating itself. This process can make the coating into a conductor, potentially creating a massive short-circuit between every element beneath it. Ionic contaminants can also lead to corrosion or small vertical defects in the coating known as dendrites.

Non-ionic contaminants won't short your circuit boards, but they will prevent your coating from adhering to the substrate beneath.

2. Where Contaminants Come From

Many ionic contaminants come from the manufacturing process, but sweat from workers can also cause ionic contamination.

Non-ionic contaminants are usually organic materials such as grease, oil, or hand lotion. Rosin and silicone can also act as non-ionic contaminants.

3. Cleaning Techniques

Ionic contaminants are often removed with water. Care must be taken to use pure water during the cleaning process. Impure water will make the problem worse by depositing ionic compounds such as salt onto the substrate after the water evaporates.

Non-ionic contaminants can be removed using solvents or surfactants. A thorough cleaning is usually good enough to eliminate these types of contaminants.

4. Testing for Contamination

To identify ionic contaminants, we use the Resistivity of Solvent Extract (ROSE) method. The ROSE method begins by measuring how conductive a solution is. Then the solution is used to wash the substrate being tested.

After the wash, the solution is tested again for contamination. If the solution’s conductivity goes up, it’s a sign the board is contaminated with ionic substances.

To identify non-ionic contaminants, we can use a residue test with special glass slides coated with aluminum. The test begins by rinsing the substrate with a solution containing acetonitrile onto the aluminum-coated slides. When the solvent evaporates, the substrate is rinsed onto the slide again. This cycle is repeated (usually six times), and then a technician inspects the slides for residue.

If anything appears, it’s a sign of non-ionic contamination. If nothing appears, the technician will then inspect the slide under a microscope. If nothing appears under the microscope, the final step is to inspect the slides using a special spectroscopic process that uses infrared light to identify any remaining residue on the slide.

5. Consequences of Poor Preparation of a Device Before Conformal Coating

If your device isn't clean before coating, severe degradation of insulation resistance and dielectric strength can be the result.

In addition, labor—not materials—is often the biggest factor that determines the cost of conformal coating. And nothing takes more labor than rework.

6. Who “Owns” Responsibility for Conformal Coating Preparation

When choosing what company to work with for conformal coating, be sure to ask who's responsible for preparing your device for coating.

The five types of conformal coating all have unique preparation procedures. A good conformal coating partner will help you perform much of the preparation work that needs to be done prior to coating.

If you plan to perform conformal coating in-house, we still recommend working with a conformal coating company.

You'll need employees who are highly skilled at applying conformal coatings. A conformal coating partner with deep knowledge of the different coating types will be able to train and equip your engineering team to be successful.

Other Than Cleaning, What Other Preparation Work Needs to Be Done?

There are two common preparation steps in addition to cleaning you'll need to think about: masking and pre-coating.

1. Masking

Most conformal coating projects require at least a bit of masking. Devices often have areas that need to remain uncoated. Examples include connection points that will connect a circuit board to the rest of a device.

2. A-174 Silane Pre-coating

When using Parylene coating, it might be necessary to "pre-coat" the device using A-174 Silane. This will help the Parylene coating "stick" to the item being coated, helping to ensure the protection you need for the device.

How Can I Be Sure My Device Are Properly Cleaned and Prepared for Conformal Coating?

A good conformal coating provider will know how to prepare your device for coating. However, some providers are more experienced than others.

Make sure you're working with a company that knows how to prepare your device for coating. Here are a few questions to ask:

- Does the company have technicians who are experienced preparing products for the type of coating you want to use?
- Have they supplied clients from a wide variety of industries?
- Do they have a track record of satisfied clients?

These are usually good signs that a company can meet your conformal coating needs.

Conformal Coating

Adhesion Testing

You've done your research, chosen a conformal coating provider, and coated your device. Now you want to know if the coating properly adhered.

If you search Google for "conformal coating adhesion test," the results will show a number of documented tests and standards. These include tests from the International Standards Board (ISO) and the American Society for Testing and Materials (ASTM).

It can be deceiving. In a list of search results, it can appear as if these tests were designed for conformal coating.

That is not the case.

At present, there is no widely-accepted test for conformal coating adhesion.

Adhesion Needs Should Be Determined on a Case-by-Case Basis

Adhesion testing for conformal coating is best determined on a case-by-case basis by the parties involved in the process.

For example, one of our recent clients decided to use the ASTM D3359 scratch test as their standard, even though the test wasn't specifically designed for conformal coating.

ASTM D3359 is sometimes called, "The Tape Test." There are two variations: the X-Cut Tape Test and the Cross Hatch Tape Test.

For the X-Cut Tape Test, a technician will use a knife and a straightedge to make two cuts in the coating to form an “X.” Tape is then placed on the intersection of the two lines and then is rapidly removed. The center of the “X” is then inspected to see if tape caused any of the coating to pull away from the device.

The Cross-Hatch Tape Test is typically used in a laboratory environment. Instead of cutting an “X” into the coating, the technician cuts several parallel lines using either a cutting guide or a custom cross-hatch cutter.

Cross-hatch cutters will make cuts of exactly the same depth and separation. This creates a series of squares resembling a grid on top of the material.

Tape is then applied and then rapidly removed, followed by a close inspection of the coating to see if any squares pulled away with the tape.

In general, the ASTM D3359 test is a very high standard for conformal coating. But for this company, it provided an important reference point for their certification needs.

One mistake we sometimes see is choosing a standard that’s simply too rigorous for the conformal coating being used. When a test that’s too rigorous becomes part of the certified manufacturing process, a company might find itself forced to throw away or recoat entire batches of its devices later on.

We strongly recommend working with an experienced conformal coating expert to determine adhesion standards for your project.

Coating Tests Require a Test Coupon

All coating tests are destructive. They are not appropriate on a "live" product. Instead, you'll need to create a "test coupon" to use for any adhesion test you'd like to use.

The coupon will be coated at the same time as your devices, using the same coating materials and methods as you do with your actual products. Once the coating has dried, you'll be able to run the destructive adhesion test on the coupon, instead of your products.

Create a Representative Coupon

If you're going to run any kind of adhesion test, you need to create a test coupon that accurately represents the device that's being coated.

If you're coating a printed circuit board, for example, using a plain piece of FR-4 glass epoxy is not a representative coupon.

(FR-4 glass epoxy is the green “card” material on which most circuit boards are printed.)

The connections and the elements on the board are where adhesion problems are most likely to occur. Using a plain coupon without connections or electronic elements might produce a good test result, but it won’t tell you much about how well the coating adhered at the connection points for the board.

Adhesion Testing for Process Monitoring

Adhesion testing is an effective way to monitor your manufacturing process over time.

Some devices require rigorous process monitoring. The manufacturing process for medical and aerospace devices, for example, must often be certified and monitored.

The goal of process monitoring is to identify changes in performance between batches.

A company using the ASTM D3359 “cross-hatch” version of the test might normally see zero to one square removed by the tape. But if the tape suddenly pulls up seven squares, it’s a signal that you might have a problem with that batch of devices.

Every device has different requirements for adhesion performance, and in some situations, formal adhesion testing is not necessary.

If you have questions about process monitoring for your device, be sure to work with your coating provider to establish an adhesion test that’s suitable for your situation.

Adhesion Testing Is a Common Source of Confusion

We understand it is difficult to find information about adhesion testing for conformal coating. It’s not a topic that’s widely discussed online or in trade publications, and a Google search often returns results that describe formal adhesion tests that were not specifically designed for conformal coating.

The best advice we can give is to partner with a conformal coating provider that has a deep knowledge of all types of conformal coating. That’s the best way to ensure you get the right coating for your device, along with the best standards for adhesion and testing in your specific situation.

7 Key Points to Remember About

Conformal Coating

1. Rework, not materials, is often the most expensive element of conformal coating.
2. Every device should be tested for cleanliness prior to conformal coating.
3. If your device isn't clean before coating, severe degradation of insulation resistance and dielectric strength can be the result.
4. There are major 5 types of conformal coating, each with its own unique characteristics and benefits.
5. Each type of coating has a number of variations. There are literally hundreds of conformal coating options for you to choose from.
6. Parylene is considered “the gold standard” of conformal coating.
7. Choose a company that has expertise with all five major coatings. They’ll be able to help you find the right coating solution for your device, not just the coating solution they happen to prefer.

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!

Diamond MT
213 Chestnut Street
Johnstown, PA 15906
Phone: (814) 535-3505
Fax: (814) 535-2080