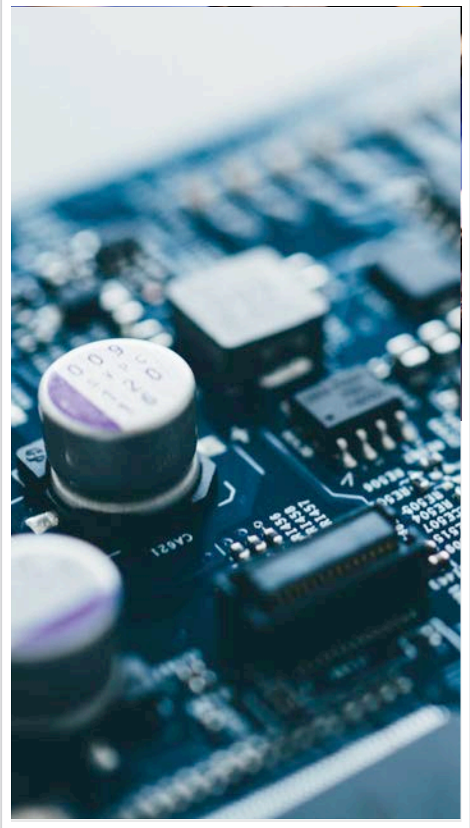
SPECIALTY COATING SYSTEMS™
A KISCO Company

Conformal Coatings 101

A Quick Guide to Acrylic, Silicone, Epoxy, Urethane and Parylene Conformal Coatings

Conformal coatings are generally thin, nonconductive, dielectric layers that are used to protect devices and components from damage due to contamination, salt spray, moisture, fungus, dust and corrosion. While conformal coatings were first used to protect military and aerospace applications, their use has expanded over the last 5 decades to include medical devices, consumer electronics, transportation electronics and more. In recent years, the development of new materials and coating processes has enabled an even larger variety of items to be coated in production facilities around the world.

There are several types of conformal coatings, including acrylics, silicones, epoxies, urethanes and Parylenes; each coating family provides its own set of unique properties and characteristics. A chart of common conformal coating properties is included on page 3 for reference.



***Conformal coatings** are often used to seal printed circuit boards against the damaging effects of moisture.*

Acrylic Conformal Coatings

Acrylic resin (AR), a commonly used conformal coating, is formed by the dissolution of acrylic polymers in a solvent. When the coatings are applied, the solvent gradually dissipates, leaving the protective polymer layer behind. Applied at a thickness ranging from 0.001 to 0.005 inches, acrylics can be deposited using various methods to protect a wide range of applications. One common application is the use of acrylic conformal coatings to seal printed circuit boards against the damaging effects of moisture.

Advantages and Considerations of Acrylics

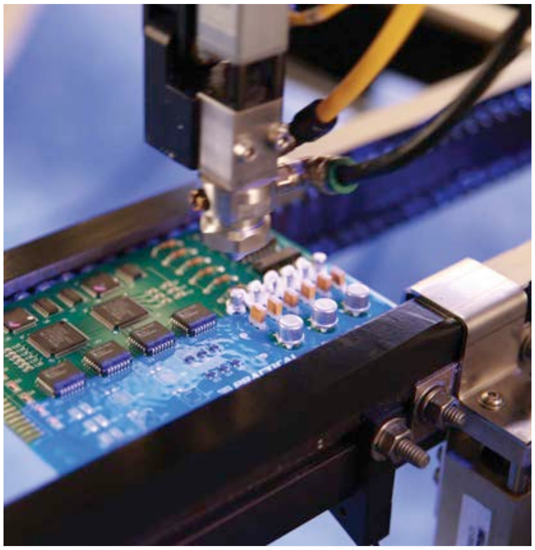
- Acrylics provide an effective barrier to moisture and humidity, improving the performance of electronic components in wet and humid environments. Acrylics can also prevent the growth of fungus.
- Acrylics can be applied by brush, spray or dip. While dipping and brushing are best for small applications, spraying is the quickest way to coat a large number of items in a batch.

- While acrylics can take up to 24 hours to cure in air, the curing process does not lead to shrinkage or heat emission. A cure oven may be used to expedite the cure time to as little as 30 minutes.
- Acrylics can be easily removed for component rework and repair using chemicals such as xylene or isopropyl alcohol. The drawback to this, however, is that the coatings do not provide strong chemical resistance properties.
- Acrylic conformal coatings are generally a low cost coating solution.

Applications for Acrylics

Acrylics remain one of the most commonly used coatings for printed circuit boards; their moisture and fungus resistance makes them an extremely effective choice for components that are likely to get wet. Acrylics are also a preferred coating for applications where board rework is commonly required.

Silicone Conformal Coatings



Silicone resin (SR) conformal coatings use similar chemicals to the silicone found in common kitchen/bath caulking materials, kitchen equipment and implantable prostheses. Silicones offer a range of benefits including moisture barrier properties, protection against temperature extremes and flexibility.

Advantages and Considerations of Silicones

- Silicones can withstand temperatures as high as 200°C, special formulations can withstand temperatures as high as 600°C.
- Silicones are considered an excellent insulator due to their dielectric strengths, and silicone-coated items experience a high degree of protection against moisture, humidity, corrosion and UV radiation. Silicones also have a high wetting rate due to their low surface energy.
- Silicone coatings can be applied by dip, brush or spray and can cure – in air – in as little as one hour.
- Due to their low resistance to solvents, silicone coatings are easy to remove, allowing for the rework of electronic components.
- Thick applications of the coating can provide vibration-absorption and serve as a thermal insulator for coated items; however, due to their soft nature, silicones can also be easily damaged.
- Silicones are often applied in relatively thick layers, which limits their suitability for applications that have tight coating tolerances and/or are unable to support the coating weight.

Applications for Silicones

For high temperature applications and/or those that require high levels of moisture protection, silicone coatings should be considered. In addition, their ability to serve as a shock absorber is a beneficial property to many applications.

CONFORMAL COATING PROPERTIES

		Method	Parylene N	ParyFree®	Parylene C	Parylene HT®	Acrylic (AR)[a,b]	Epoxy (ER)[a,b]	Polyurethane (UR)[a,b]	Silicone (SR)[a,b]
Dielectric Strength V/mil		1	7,000	6,900	5,600	5,400	3,500	2,200	3,500	2,000
Dielectric Constant	**60 Hz** **1 KHz** **1 MHz**	2	2.65 2.65 2.65	2.38 2.37 2.35	3.15 3.10 2.95	2.21 2.20 2.17	– – 2.7 – 3.2	3.3 – 4.6 – 3.1 – 4.2	4.1 – 3.8 – 4.4	3.1 – 4.2 – 3.1 – 4.0
Dissipation Factor	**60 Hz** **1 KHz** **1 MHz**	2	0.0002 0.0002 0.0006	0.00001 0.0009 0.0007	0.020 0.019 0.013	<0.0002 0.0020 0.0010	0.04 – 0.06 – 0.02 – 0.03	0.008 – 0.011 – 0.004 – 0.006	0.038 – 0.039 – 0.068 – 0.074	0.011 – 0.02 – 0.003 – 0.006
Water Vapor Transmission Rate (g•mm)/(m^2•day)		3, 4, 5, 6	0.59	0.09	0.08	0.22	13.9[c]	0.94[c]	0.93 – 3.4[c]	1.7 – 47.5[c]
Water Absorption (% after 24 hours)		7	<0.1	<0.1	<0.1	<0.01	0.3	0.05 – 0.10	0.6 – 0.8	0.1
Service Temperature	**Continuous** **Short-Term**	8	60°C 80°C	60°C 80°C	80°C 100°C	350°C 450°C	82°C –	177°C –	121°C –	260°C –
UV Stability		9	≤100 hrs	≤100 hrs	≤100 hrs	≥2,000 hrs	–	–	–	–
Coefficient of Friction	**Static** **Dynamic**	10	0.25 0.25	0.23 0.23	0.29 0.29	0.15 0.13	– –	– –	– –	– –
Tensile Strength (psi)		11	7,000	9,600	10,000	7,500	7,000 – 11,000	4,000 – 13,000	175 – 10,000	350 – 1,000
Penetration Ability[d]			40 x dia.	10 x dia.	5 x dia.	50 x dia.	Spray or Brush	Spray or Brush	Spray or Brush	Spray or Brush
Rockwell Hardness		12	R85	R136	R80	R122	M68 – M105	M80 – M110	68A – 80D (Shore)	40A – 45A (Shore)
USP Class VI Polymer			Yes	Not Yet Available	Yes	Yes	Varies	Varies	Varies	Varies
Biocompatibility[e]			ISO 10993	Not Yet Available	ISO 10993	ISO 10993	Varies	Varies	Varies	Varies

a. *Handbook of Plastics, Elastomers, and Composites*, Chapter 6, "Plastics in Coatings and Finishes," 4th Edition, McGraw Hill, Inc., New York, 2002.
b. *Conformal Coating Handbook*, Humiseal Division, Chase Corporation, Pennsylvania, 2004.
c. *Coating Materials for Electronic Applications*, Licari, J.J., Noyes Publications, New Jersey, 2003.
d. Depth into tubing and crevices.
e. Contact SCS Marketing for specific results.

Parylene Test Methods:

1. ASTM D149
2. ASTM D150
3. ASTM E96 (at 90% RH, 37°C) (Parylene N only)
4. ASTM F1249 (at 100% RH, 37°C) (ParyFree only)
5. ASTM F1249 (at 90% RH, 37°C) (Parylene C only)
6. ASTM F1249 (at 100% RH, 38°C) (Parylene HT only)
7. ASTM D570
8. TGA/FTIR, DSC and thermal endurance testing
9. ASTM G154
10. ASTM D1894
11. ASTM D882
12. ASTM D785

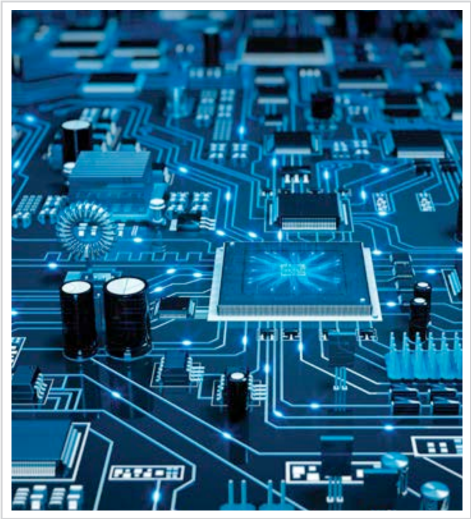
Urethane Conformal Coatings

Urethane resin (UR) conformal coatings are an excellent option for many conformal coating applications because of their broad range of capabilities. In exchange for relatively long cure times, the coating offers a low cost solution for protection against abrasion, moisture, solvents and more.

Advantages and Considerations of Urethanes

- Urethanes are one of the hardest conformal coatings available, protecting substrates and components against abrasion and other types of direct mechanical wear.
- The coatings provide resistance to moisture, humidity and harsh chemicals and are excellent dielectric barriers, maintaining their insulating properties over long periods of time. Urethanes do not, however, withstand high temperatures as they commonly break down at temperatures above 125°C.

- Like acrylics and silicones, urethanes can be applied by spray, dip or brush; they can also be applied by automated equipment.
- Urethanes are one of the slowest conformal coatings to cure – taking as long as 30 days to completely cure in air. The curing time can be reduced with the use of heat, but the curing process for urethanes is still lengthier than other coating materials.
- Unlike many conformal coatings, certain types of urethane coatings can limit the formation of tin whiskers when applied at thicknesses of 2 mils or greater.



Applications for Urethanes

Urethanes remain one of the most popular coatings for circuit boards as they provide robust chemical, electric and moisture protection and enable greater levels of miniaturization by insulating circuit board traces from each other. Additionally, urethanes are an excellent choice for electronics due to their ability to inhibit tin whisker formation.

Epoxy Conformal Coatings

Much like epoxies that can be purchased commercially as adhesives, epoxy resin (ER) conformal coatings come in both one and two part formulations. Like other liquid coatings, their application process is relatively straightforward; however, they are nearly impossible to remove for board rework.

Advantages and Considerations of Epoxies

- A key benefit to epoxy coatings is their strength, making them one of the most abrasion resistant conformal coatings available. The coatings are so strong that when combined with a colorant, epoxies can be used to both seal off and "hide" underlying components, protecting the application from being reverse-engineered.
- Epoxies can withstand higher temperatures, with a maximum temperature rating of around 150°C, and are effective insulators against electricity and RF. The coatings also provide resistance to moisture and solvents.
- Epoxy coatings can be applied by spray, dip or brush, and two-part epoxies begin curing as soon as they are mixed together. Due to their tendency to shrink while curing, which may cause damage to underlying components, it's best to cure epoxies under a UV light or in low temperatures to prevent component damage.
- Unfortunately, epoxies do not lend themselves to rework. Attempts to remove the coating by mechanical, chemical or thermal means often results in damage to the underlying board or components.

Applications for Epoxies

Due to their hardness, epoxy coatings are an excellent choice to provide an extra layer of physical protection to components. Additionally, pigmentation of the coatings is an attractive option for some applications.

Parylene Conformal Coatings

Parylene conformal coatings offer a unique set of properties for a wide range of applications. The ultra-thin coatings are applied in a vacuum deposition process one molecule at a time; while their raw material costs are generally higher than liquid coatings, their protective benefits are often unmatched.

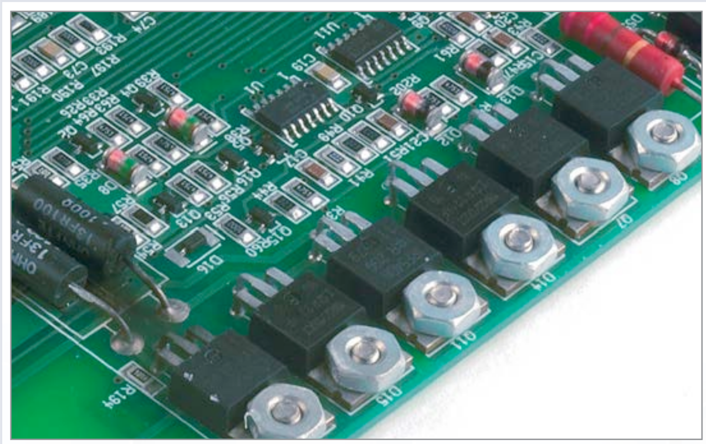
Advantages and Considerations of Parylenes

- Parylene coatings offer excellent resistance to moisture, chemicals, acids, bases and solvents. They also provide high dielectric strengths and low dielectric constants, making the coatings excellent electrical insulators. These properties and more are achieved with a remarkably thin coating – generally measured in the microns range.
- Several variants of Parylene are available, each offering their own unique set of properties. Parylene HT®, for example, provides thermal stability up to 350°C long-term, 450°C short-term.
- Parylenes are applied in a vapor deposition process in which parts to be coated remain at ambient temperatures throughout the entire coating process. No cure forces or stabilizers are used in the coating process.
- Because the coatings are applied as a gas, Parylenes penetrate crevices and under components, providing ultra-thin, perfectly conformal protection. The downside of such protection is that the coating is difficult to remove due to its impermeability to solvents and chemicals.
- Parylene coatings have also been shown to mitigate tin whisker growth.

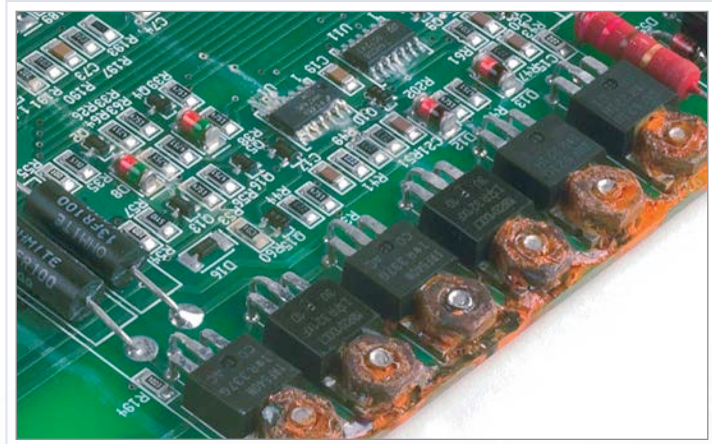
Applications for Parylenes

Parylene coatings provide best-in-class protection for a wide range of applications due to their ultra-thin nature and performance characteristics. Their high temperature stability allows for protection in harsh aerospace and defense applications, and their natural biocompatibility means that Parylene coatings are often the only choice for medical device protection.

Circuit boards after 144 hours of salt-fog exposure.



Coated with SCS Parylene HT®



Uncoated

Innovative Solutions from the Leader in Conformal Coatings

With 50 years of experience in engineering and applications, Specialty Coating Systems (SCS) is a world leader in conformal coating technologies. A direct descendant of the companies that originally developed Parylene, we leverage expertise on every project – from initial planning to process application.

SCS employs some of the world's foremost coating specialists, highly experienced sales engineers and expert manufacturing personnel, working in state-of-the-art coating facilities in 12 countries worldwide. Our extensive, proactive approach to production and quality requirements gives our customers peace of mind and minimizes the resources they need to meet even the most challenging requirements and specifications.

50 years

12 countries

3 continents

>1,000 employees

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