The Fast Guide to

Protecting COTS Electronics with Conformal Coatings

The Basics of Acrylic, Silicone, Urethane and Parylene Conformal Coatings

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Conformal Coatings for Protecting Essential COTS' Components

Commercial off-the-shelf (COTS) electronics are used frequently for military and aerospace applications. They need to provide unquestionable performance, operating without fail under often extreme, severe, and rugged circumstances for extended periods of time. Some COTS applications that demand solutions superior to normal use are:

- on-site, embedded battlefield weapons and systems,
- manned spaceflight electronics,
- satellite electronics, and
- radar/detection equipment.

A conformal coating provides an ultra-thin, consistent layer of insulation that conforms closely to the shape and contours of a circuit board, or similar COTS' device. A variety of conformal coatings are used to provide sufficient environmental protection during operation, to minimize degradation of performance factors. Their advantage is the ability to safeguard the function of COTS units with a fine layer of electrically non-conductive protective surfacing that does not interfere with sensitive systems performance. Conformal coatings for COTS components need to be:

- Flexible, to ensure low component stress during performance, and
- Easily repaired if the protective surface is corrupted while in use.

Typical methods for depositing conformal coatings on surfaces include dipping, spraying, hand brushing, and vacuum deposition. The prevalent coating types available for these purposes are acrylic, epoxy, parylene, silicone, urethane, and UV-cured materials. Parylene is used more frequently for COTS-specific equipment, because of its ability to effectively conform to their often minute surfaces.

America's National Aeronautics and Space Agency (NASA) uses COTS devices regularly, and has written several manuals concerning the benefits of their application to its interstellar vehicles and devices. NASA also created its 8739.1 Workmanship Standard for Polymeric Application on Electrical Assemblies - defining appropriate protection of COTS' equipment and similar applications - for aerospace and defense equipment where exceptional performance is required.

These are conditions where excessive moisture or dryness, extreme temperatures, high levels of vibration, wind, or lack of atmosphere are the rule. Conformal coatings generate an exceptional range of properties that support COTS' products. They add durability in avionic/military operating environments requiring dependable functionality through extreme conditions for an often extended duration.

Under NASA regulations, conformal coatings can be sprayed, brushed, or dipped onto COTS components; these methods can be used in combination, as well as individually, to assure coating-adherence. Further NASA stipulations demand that excessive filtering, oozing/dripping (material-runs), and material-bubbles in the coated-surface be eliminated or severely minimized during application. Where bubbles do occur, their tolerance may not exceed 0.76mm (0.03 inch) in any dimension; exposure of a bare conductor surface is similarly unacceptable, as are bubbles bridging connective component surfaces.

Because conformal coatings are electrically insulating, their long-term surface insulation resistance (SIR) makes them very suitable for COTS adaptations. Regarding the specific thickness of conformal coatings for COTS electronics, NASA-STD 8739.1 is very precise, categorizing coating-requirements by material, measured in millimeters (inches):

- Parylene: 0.013 – 0.051 (0.0005 to 0.002).
- Silicone: 0.051 – 0.203 (0.002 to 0.008).
- Acrylic/Urethane: 0.025 – 0.127 (0.001 to 0.005).

These levels of conformal coating for COTS circuits or components have been certified to ensure their reliable performance through frequently extreme, non-conventional operating conditions. The figures indicate that parylene requires the lowest level of coating to effectively conform to COTS electronics, significantly increasing its value for these uses where any added weight could cause performance issues.

Conformal Coatings Compared

Selection of conformal coating material depends on the environment that the parts will be subjected to, objects to be covered and the preferred method of coating application. In addition to the coating-thickness requirements mentioned above, each coating material exhibits the following characteristics:

- **Acrylic**: Can be applied quickly, decreasing production downtime; acrylic coatings protect COTS electronics from corrosion, dirt, dust, fungus, moisture, static discharge and thermal shocks. High dielectric qualities withstand voltage discharge. They can be applied by brush or spray, and are clear, quick-drying, salt-resistant, with a high fluorescent level; suitable for miniaturization and repair processes. Although they demonstrate only low-level abrasive/chemical resistance, acrylic coatings can be rather easily applied, cleaned and removed, enhancing their popularity. Some grades of acrylic (e.g., Humiseal 1B31) are suitable for such COTS applications as Mil-I-46058C IPC-CC-830B. Their cost is moderate. Their resistance to solvents is generally poor. Its operating temperature range is -65'C through +125'C, with a dielectric strength of V 300/Mil., a dielectric constant of 2.5, and a dissipation factor of 0.01. Spray application is the standard.
- **Silicone**: Exhibiting high dielectric strength and good moisture resistance, silicone protects and insulates COTS' electronic components and assemblies, guarding them from the negative effects of corrosion and thermal shock. It provides stable protection of COTS electronics across an extensive temperature range, -40'C through +200'C (-40'F through +392'F), far exceeding the working range of competitive conformal coatings in operational environments where exceptional temperature variation is an overriding factor. Silicone needs to be applied in thicker layers than acrylic, urethane or parylene, limiting its use for miniaturized applications; therefore, tight spatial clearances should be avoided. However, it is suitable for use for non-COTS electronics and electronic components and assemblies, such as those for generators, motors, relays, solenoid coils, and transformers, providing these products the same kind of reliable protection and insulation it does with its COTS-uses. Whatever its specific application, silicone is easy to work with, conformally covering surfaces

smoothly and drying quickly, usually in an hour or less. Relatively trouble-free product reworking is another advantage of silicones, minimizing the cost/time of labor for electrical assemblies that require further development following the coating process.

- **Urethane**: With exceptionally durable surfaces, very resistant to abrasion and other forms of mechanical wear and corrosion, urethane also demonstrates considerably lower reversion potential. Further advantages of urethane are its exceptional ability to resist moisture, while generating highly acceptable dielectric qualities. It stands up well to operating environments characterized by exposure to harsh chemicals, but those with high heat or levels of vibration should be avoided. NASA has reported that urethane coatings are especially effective combating the development of crystalline, electrically conductive structures of tin that may sometimes gestate on component surfaces whose final finish is composed of tin. Known as 'tin whiskers,' because of its hair-like appearance, this condition is particularly a problem for commonly-used electroplated tin finishes. Although whiskers seldom exceed several millimeters, they can contribute to electrical short-circuits for COTS and other electronic assembles; urethane provides the best known conformal coating for these surfaces.
- **Parylene**: Parylene is the name commonly used to represent a vapor-deposited conformal coatings descended from para-xylylene and its derivatives. There are three main variants of parylene used, Parylene C, N, or AF-4. Parylene has demonstrated a remarkable capacity for providing an exceptionally thin but resilient film surface-coating for an increasingly wide range of COTS products. While it can be more expensive than other conformal coatings, parylene also provides reliable and cost-effective protection for COTS' components, systems that must consistently perform in abrasive, unstable operational environments; its cost-effectiveness results from the range of protection not found with other conformal coatings. Parylene is especially adaptable to the coating requirements of printed circuit boards (PCBs), microchips, their sensors, related components and other electrical assemblies. Its non-conductive qualities usefully eliminate electrostatic, magnetic or radio frequency interference during operation, perhaps to a greater degree than acrylic, silicone and urethane. Parylene has a very low dissipation factor of 0.0027, a dielectric constant of 3.1 and a dielectric strength of 6900 V/Mil; its

temperature range is from -195'C through +125'C. It also demonstrates excellent resistance to acids, bases and solvents.

The Functional Advantage of Conformal Coating and COTS Electronics

Until further technologies are developed, conformal coatings remain the protective medium of choice for COTS electronics. Used selectively, according to their respective properties, coating substances like acrylic, silicone, urethane and parylene best meet the current demands of military and aerospace applications.

They provide solutions for operating conditions exceeding conventional use, assisting the performance of battlefield equipment, satellite/spaceflight electronics, radar/ detection equipment, and numerous similar products requiring specialized, exceptional performance.

With the explosive growth of the semiconductor industry, application of conformal coatings can be expected to grow well into the foreseeable future. Performance standards for conformal coatings will require monitoring and improvement as these many uses proliferate.

Parylene conformal coatings provide the most reliable level of uniform, device-security, ensuring reliable performance through a variety of high-stress situations and environments. It is particularly versatile for most COTS applications. It also has numerous uses for industrial, LED, MEMs, consumer, medical and automotive products.

What To Do Next

Call or email Sean Horn, Vice President of Diamond-MT, Inc. at (814) 535-3505 / shorn@diamond-mt.com and ask for a coating project application. Sean will be happy to discuss your specific requirements and deadlines, and discuss any aspect of conformal coating that may still be unclear. The Diamond-MT team looks forward to serving you as you tackle one of the important challenges for COTS technology.