Assuring Parylene

Conformal Coating Adhesion

DIAMOND-MT

www.paryleneconformalcoating.com

Introduction

Parylene's ability to provide uniform, pin-hole free, dielectrical insulation and protection from contaminants and other potentially hazardous substances for an exceptional variety of electronic assemblies and components is well-documented. However, parylene conformal coatings are not infallible. Improper management of pre-treatment, application and drying processes can generate defects to the parylene films that negatively impact their adhesion to the substrates they're designed to protect. In particular,

- while treatments enacted prior to parylene's unique chemical vapor deposition (CVD) process can add substantially to coating adhesion,
- failure to execute them,
- or inappropriate administration of these pre-CVD procedures can lead to coating deficiencies,
- which compromise the films' adhesion and provoke delamination or similar erosion of the protective parylene film.

The following pages discuss reliable methods that promote good adhesion between the parylene film and the substrate. In doing so, they minimize the incidence of not only delamination and other defects that defeat the purpose of coating substances with parylene films.

Causes of Parylene Delamination

Delamination Problems of Parylene Conformal Coatings

Providing a uniform and pinhole-free substrate coating that is ultra-thin, lightweight and durable, parylene coatings completely conform to targeted components and assemblies. Parylene CVD generates a structurally continuous film that, with appropriate pre-treatment, penetrates deep within substrate surfaces, rather than simply attaching themselves to substrates as liquid-application coatings do. These provide effective, dielectrically efficient safeguards with coatings as thin as a fraction of a micrometer. Parylene is chemically and biologically inert and stable, an excellent barrier material to abrasive chemicals, bodily fluids, solvents, liquid water and water vapor.

Printed circuit boards (PCBs) and similar assemblies with specialized component configurations – angular surfaces, crevices, exposed internal surfaces, flat facades, pointed or sharp edges --benefit from parylene's all-inclusive conformal protection. The process is eminently repeatable and controllable, delivering extremely consistent results from batch-to-batch.

However, despite its superiority as a conformal coating, parylene is not flawless. Its overlying chemical structure may restrict dependable interface, limiting adhesion with some substrates. The CVD process that sources the majority of parylene's advantages as a conformal coating simultaneously nullifies chemically-based substrate adhesion; only mechanical adhesion is possible.

In these cases, delamination can emerge as a problem for parylene coated surfaces. Delamination occurs in cases where the conformal coating separates from the covered surface, producing a poor, unacceptable finish by lifting away from the substrate, resulting in a torn, unattached, and non-conformal coating. Although surface exposure may not be complete, delamination uncovers at least some segment of the region to-be-protected, entirely defeating the purpose of conformal coating.

Delamination is one of the worst outcomes confronting the use of parylene. Partial lifting of the parylene coating is sufficient to qualify as delamination. Either standard or corrective processes -- such as demasking or a reaction to production materials -- can instigate delamination. Care must be taken both prior to and during CVD application procedures to assure subsequent delamination episodes do not occur. Post-production and inspection procedures must similarly target the possibility of delamination, an extremely negative outcome that must be avoided or identified and corrected.

Sources of Parylene Delamination

Factors that influence delamination include:

- **Materials incompatibility**: The parylene coating and the substrate surface to-be-adhered-to need to bond together. Incompatibility between the parylene and the surface to-be-covered generates an incongruity of surface energies where the parylene and substrate meet; in these cases, only minimal bonding occurs, if it develops at all, frequently leading to delamination.
- **Coating porosity**: A difference in vapor pressure develops in the region between the parylene coating and the surface, causing a susceptibility to moisture intrusion and permeation through to the PCB. Consequent fluctuations of temperature and pressure generate osmotic pressures that can separate the coating from the substrate.
- **Surface cleanliness**: Above all, a clean surface is necessary for adhesion. Contaminated surfaces do not support adhesion and are conducive to delamination.

Taking these conditions affecting the adhesion between parylene and the substrate as the foundation of subsequent delamination issues generates solutions to the problem.

Preventing Parylene Delamination

Delamination can be prevented by enacting the following techniques prior to-, during, and post-CVD processing:

- **Assuring materials compatibility:** Appropriate coordination between the grade of parylene conformal coating and the substrate material generates reliable adhesion and lamination. It may be necessary to change either the coating type or modify the surface energy. The objective is transform the interaction of surface energies so they better support adhesion.
- **Moisture permeability**: Selecting a parylene type exhibiting appropriate moisture impermeability while maintaining materials compatibility with the substrate is necessary.
- **Surface cleanliness**: Contamination – dirt, mold release agents, process residue, etc. – should be removed from components before application. Cleaning the PCB enhances parylene's adhesion/laminate and surface energy qualities.

Materials selection must be connected to an assembly's composition and uses. Parylene C's elongation-to-break factor is superior to either types D or N, suggesting enhanced delamination properties, but each coating job will have specialized factors to consider.

Surface Treatments Prior to Parylene Coating

Pre-coating Essentials

Poor parylene adhesion negates many of the coating's most-valued functional properties, including dielectric strength, and resistance to the effects of chemicals, corrosive agents, and moisture. Surface treatments that amplify the interface adhesion between the deposited parylene and the coated substrate are therefore highly desirable. These treatments entail depositing parylene on a clean hydrophobic surface before its chemical vapor deposition (CVD) process is enacted.

Parylene is applied to substrates at ambient temperatures within a specialized vacuum, conducted at pressures of around 0.1 torr. To assure complete impingement of the parylene monomer, uniformly encapsulating the substrate, provision of appropriate surface support prior to CVD limits subsequent factors of peeling force, soaking undercut rate, and vertical attack bubble density (VABD). that can lead to lack of coating adhesion and delamination.

A truly conformal coating, parylene provides superior, uniform barrier protection on almost any surface geometry or topography. However, any contaminants present on a substrate surface prior to CVD will inevitably have a negative impact on parylene adhesion. Chemicals, dust, oils, organic compounds, process residue, wax – contaminants of any kind – need to be thoroughly removed, leaving the substrate surface entirely devoid of their presence; if unattended, issues such as mechanical stress can develop. Contamination generated by dirty surfaces can stimulate coating delamination and severe degradation of affected operating systems, as the parylene coating begins to disengage from the surface.

Cleanliness Inspection and Testing

Thorough surface inspection is the first step to delivering a substrate surface suitable to parylene adherence. Identifying contaminants significantly lowers the risk of incomplete surface cleansing, while informing selection of task-appropriate materials and methods.

Costly cleaning and rework issues can emerge if thorough surface-inspection is overlooked at any stage during the production/coating process. Poor inspection fails to detect and identify contaminants, leading to delamination, exposed surfaces and component dysfunction. In such cases, it is not uncommon for leakage of non-organic, electrically-conductive sediments beneath the parylene to interfere with and ultimately wreck the performance of electrical components.

Useful surface inspection techniques for organic contaminants include Gas Chromatography (GC) and Fourier Transform Infrared Spectroscopy (FTIR). Sometimes used in conjunction with mass spectroscopy, GC splits unidentified organic chemical mixtures into their distinct components, specifying their discrete properties. FTIR identifies specific organic contaminants by comparing evidence from spectrum analysis to those of known substances; contaminants such as silicon oils and mold-release agents are identified with FTIR. Valuable for determining the presence of inorganic contaminants like chloride, fluoride, potassium, or sodium, Ionic Exchange Chromatography (IOC) uses electrical-charges to separate the compounds' ions and polar molecules.

In all cases, the aim is verifying not only the contaminant substance, but also the optimal solvent and cleaning system suitable to its eradication.

Parylene Surface Cleaning Agents

A variety of nonhazardous cleaning agents can be effectively applied to substrates, according to their precise identification. Regular detergent cleaning is suggested for soluble contaminants. Less soluble contaminants require use of biodegradable, multi-faceted, solvent-strength solutions like deionized water, isopropyl, and methyl ethyl.

Cleansing methods are also dependent on the composition of both the identified contaminants and surface materials, to achieve satisfactory levels of substrate neutralization. Solvent immersion, surface-spraying, substrate-tumbling, or vapor-degreasing are primary disinfectant procedures. However, the substrate surface may also require manual, hand-cleaning, or application of batch, inline, or ultrasonic methods.

Masking

Integral to surface preparation, the masking process is implemented to assure designated components of a PCB or similar electrical assembly are protected from the effects of the parylene itself, which can interfere with expected functionality. Some of parylene's key properties can be both desirable and detrimental to an assembly, if applied to the wrong areas. For instance, parylene's excellent dielectric properties simultaneously disable a PCB's contacts, rendering it inoperable, even as they safeguard the substrate surface from electrical interference.

Masking the contacts resolves this issue, coating only those PCB-parts that won't be negatively impacted by conformal protection. In this way masking preserves an assembly's operational integrity and performance. This critical pre-phase of the parylene coating process can be exceptionally labor-intensive. Considerable operator attention to the task is necessary to ensure effective masking of each connector, sealing it from penetration by gaseous parylene molecules during deposition. All tape, or other covering materials, must thoroughly shelter the keep-out regions, without gaps, crevices or other openings, to ensure connector function is retained after coating.

A-174 Silane

A-174 silane adhesion promoter chemically bonds with the substrate surface to stimulate resolute parylene adhesion. Manual-spray, soaking, or vapor-phase processing methods are used to apply A-174 to the substrate after the masking-operation, forming a chemical bond with the surface. Substrates responding well to treatment with A-174 silane prior to implementation of parylene coating processes include those made of elastomer, glass, metal, paper and plastic.

A-174's molecules form a unique chemical bond with the substrate surface, sufficient to improve parylene's mechanical adhesion. However, not all substrate materials benefit from A-174. In its place:

- Plasma-surface treatment methods have limited parylene delamination for medical implantables.
- Silicon substrates roughened with xenon difluoride gas demonstrate enhanced parylene adhesion.

Researchers continue to seek additional cleansing/adherence agents to improve parylene's conformal utility for these purposes.

The diversity of adhesion promotion methods requires a similarly diverse list of raw materials and techniques. Surface treatments prior to CVD begin with cleanliness-testing and cleaning to remove surface contaminants, followed by masking of connectors and electrical components. Materials such as glass, metal, paper and plastic benefit from application of A-174 silane adhesion promoter for necessary, pre-CVD surface modification. Establishing best-adhesion practices and strict adherence-standards is critical to maintaining quality conformal coatings and minimizing delamination.

Does Parylene Adhere Chemically?

Parylene only adheres to substrates mechanically, and this can require assistance from additive substances; parylene's chemically-based adherence is nonexistent. Adhesion is a consequence of molecular attraction stimulating the surface unification of two dissimilar substances; their joining creates a significant physical bond between them. Of the two primary types of adhesion, chemical adhesion results when a compound joins with another, because they share sufficient mutual chemical interaction to form a bond with each other. Because parylene is chemically inert, chemical adhesion is impossible; it adheres using the other method -- mechanical adhesion. Applied mechanical processes can stimulate this binding force between surface molecules.

One might think chemical substances are suitable to stimulate superior adhesion of parylene coatings, since its substrate-application employs the unique chemical vapor deposition (CVD) process. However, this is not so. In fact, the opposite is true. On their own, the chemical structures of virtually all parylene types (C, D, N, etc.) undercut good interface adhesion. The chemical vapor deposition (CVD) process that generates so many of parylene's benefits also nullifies chemically-based substrate adhesion; only mechanical adhesion is possible.

For instance, low surface energy materials, such as Kapton (polymide), limit parylene for even mechanical applications, and entirely reject chemical adhesion, causing rapid delamination and peeling of the conformal coating. Even standard MEMS' processes, such as lift-off or sacrificial photoresist releasing, can suffer serious delamination, wherein the parylene separates from other coating or component materials. Because chemical adhesion is impossible, mechanical methods must be used.

On its own, parylene does not technically adhere to substrate surfaces. It attaches to itself instead, becoming absorbed into the often microscopic pits and cracks typical of some substrate surfaces; once it is so attached, parylene doesn't easily decompose, or otherwise relinquish its adhesion to the substance. However, if parylene is deposited on a perfectly smooth surface, the lack of inherent exterior cracking and pitting offers no imperfections to fill, significantly diminishing coating reliability.

The impossibility of chemical adherence specifies mandatory use of mechanical processes to improve parylene surface adherence. Such is the case when using parylene to conformally coat noble metals.

Parylene Adhesion to Noble Metals

Characteristics of Noble Metals

Selecting the appropriate pre-treatment procedures is a key factor to this success of parylene adhesion to any substance. Procedures vary quite considerably, according to the materials designated for conformal coating and substrate. Chemically inert surfaces like gold, silver and other noble metals, and nonpolar thermoplastics such as parylene, are extremely difficult to bond; they require additional surface treatments besides cleaning.

Managing noble metal adhesion is further complicated because parylene sticks to itself, rather than the substrate surface, raising difficulties for suitable attachment on the smooth surfaces typical of assembly components formulated of noble metals. Thus, in usage where the substrate bond is subjected to sliding friction or comparable forces applied perpendicular to the surface, the parylene coating may break away. Similar adhesion difficulties emerge for parylene concerning most functional applications where it is applied as a conformal coating for noble metal substrates.

This is less the case where a metal substrate has a high RA, the arithmetic average of a particular substrate's roughness parameters; higher RA signifies a sufficient quantity of surface cavities (flaws and fissures) to capture parylene, holding it to the surface, prompting acceptable levels of adhesion and diminished tendency toward delamination. However, once refined, the RA of most noble metal surfaces is low. The minimal micro-porosity of these surfaces is absent the required quantity fissures or flaws for generating longer-term parylene adhesion, mandating application of adhesion promotion techniques.

Improving Surface Energy

Without appropriate treatment, fundamental limitations inherent to parylene can render it unsuitable for applications exposed to friction, pressure, heat or thermal cycling. Parylene is inert, very soft and exhibits poor "creep" attributes during untreated application to noble metals. A general absence of active sites for forming intra-molecular bonds results in poor adhesion, a propensity to dislodge from the substrate; delamination and similar non-adhesion problems can occur if the surface is unmodified prior to CVD.

The importance of cleanliness-processing and masking pre-CVD to improve parylene adhesion have already been discussed, as has the use of Methacryloxypropyltrimethoxysilane. This A-174 silane compound is the surface treatment of choice for most applications where developing a reliable, longer lasting adhesive bond between parylene and a noble metal substrate is desired. Adhering chemically to the metal, the introduction of A-174 silane provides precisely the kind of uneven, flawed surface that stimulates parylene attachment, helping it to bond far more conformally to the generated surface cavities and fissures during CVD.

Application of A-174 is implemented through soaking, spraying or vapor phase techniques. Spraying is recommended when only selected portions of the substrate require treatment; soaking or vapor phase are suggested modalities for treating an entire assembly or component. Appropriate operational caution needs to be observed during processing of A-174 silane adhesion promoter; it is a moderate skin, respiratory, and eye irritant. Although not overly flammable, it is combustible, and should be handled with care. While A-174 silane is favorably endorsed throughout the industry as a surface treatment for noble metals requiring the benefits of parylene conformal coating, other treatment methods offer advantages of their own.

Surface Treatment Alternatives to A-174 Silane

Plasma polymerization processing can improve the adhesion and barrier properties of conformal films deposited on such noble metals as platinum; systematic approaches tailored to specific coating requirements are suggested. This approach has been successful as a pre-treatment for MEMs and nano- applications. Recommended for use in aggressive, harsh biomedical environments, plasma activation technology positively energizes the surfaces of many noble metal substrates, and is implemented immediately prior to CVD processing. In this regard, recent research demonstrated chemical oxygen plasma insertion pretreatments characterized by microscopic and surface-sensitive techniques could increase barrier hydrophilicity and surface energy for metal implant coatings, improving their overall biocompatibility and performance. This evidence suggests further development of parylene coating functionality, based on applications of plasma surface treatments for parylene coatings intended for noble metal substrates.

Mechanical abrasion processes treat noble metal surfaces with a very fine industrial grit. The objective is roughening the smooth surfaces by scraping them with the grit through tumbling or similar industrial processes, lightly abrading the designated substrates. Parylene coated wire mandrels used in manufacturing biocompatible metal tubing for medical devices can be pre-CVD treated with abrasion processes before parylene application.

Nevertheless, chemical bonding pre-treatment with A-174 -- applied either through soaking, spraying or vapor deposition -- remains the most commonly used pre-treatment to promote parylene adhesion with noble metals. The consequent chemical surface-bond is significantly improved by this mechanically-induced method. Where pretreatment procedures are appropriately implemented, they forestall coating delamination and enhance the effectiveness of conformal parylene corrosive barriers for noble metal substrates and devices.

The Impact of Temperature on Parylene Adhesion

Basic Thermal Properties of Parylene Conformal Coatings

CVD-generated parylene combines high thermal stability with a low dielectric constant, minimal moisture absorption, and other advantageous properties which sustain its adhesion to substrate surfaces. Among the most beneficial of the parylenes' thermal properties is their ability to function at an exceptional range of temperatures. Depending on the parylene type, they are operative at temperatures as low as -271º C, and as high as 450º C, representing an ability to perform within a span of 721º C.

Much depends upon the specific parylene type, its explicit product purpose, and the environmental conditions affecting performance. However, when parylene type and purpose are appropriately matched to the expected thermal conditions of the assembly's operational environment, parylene conformal coatings offer superior adhesion and minimal delamination.

For instance, Parylene C can endure constant exposure to 100° C for eleven+ years, accounting for 100,000 hours of use, without appreciable delamination. In contrast, more recently developed parylene HT is useful in high temperature applications (short-term up to 450°C), although this represents an extreme range. More generally, the parylenes can provide similar service (11.4 years of persistent adhesion) in vacuums or atmospheres free of oxygen, working through ongoing exposure to 220° C, making them an excellent choice as conformal coatings for aeronautics' and space flight uses. Higher temperatures can shorten parylene use-life in oxygen rich environs.

For most terrestrial uses, heat-treating for three hours at temperatures of 140°C, beneficially activates longer-term adhesion and insulation. Parylene's low thermal expansion helps it retain uniform conformal qualities through innumerable functional settings.

Further thermal properties of parylene types C, N and D are provided in Table 1.

Table 1: Thermal Properties of Selected Parylenes

Properties	Parylene C	Parylene D	Parylene N
Melting point, ° C	290	380	420
T5 point (where modulus = Taken from secant modulus temperature curve)	125	125	160
T4 point (where modulus = Taken from secant modulus temperature curve)	240	240	300
Thermal conductivity, 25° C	2.0	--	3.0
Specific heat, 25° C	0.17	--	0.20

Optional Methods of Heat Pre-treatment

Heat treatments to improve parylene for adhesion may occasionally include:

- **Bilayer encapsulation**: Accelerated testing implemented by boiling the coated materials can confirm two distinctive outcomes pertinent to adhesion of the Parylenes N and C. (1) Glow-discharge polymerized methane applied under a thicker layer of Parylene-N in a solution of isotonic sodium chloride noticeably enhanced substrate-adhesion. (2) In comparison to a film composed solely of parylene, components immersed in phosphate-buffered saline (PBS) at 57°C demonstrate superior surface-adhesion for dually-composed of atomic-layer bilayers of deposited Al2O3 and 6 µm Parylene-C provided superior to that of parylene alone.
- **Parylene-on-parylene interfaces**: Interaction with hydrofluoric acid during processing, parylene heated at 140°C with no oxygen-purging for three hours exhibits substantial wet adhesion strength. Testing also shows whether oxidation from the heat-treatment also added brittleness or a susceptibility to the film's tearing, both factors of inappropriate adhesion.

Parylene coatings exhibit dependable consistency for many applications where exposure to ongoing thermal pressure is the rule. However, in some circumstances parylene films covering component substrates become fragile and inflexible due to persistent thermal stress, reducing their usefulness as conformal coatings. Unfortunately, cases of diminished coating adhesion have particularly presented themselves for biomedical implant applications, where malfunction may be life threatening. Improving these performance conditions is a significant challenge to the development of more adaptable parylene conformal coatings.

Parylene may be annealed to increase cut-through resistance, enhance coating hardness, and improve abrasion resistance. This is the result of a density and crystallinity increase, occurring after contact with heat.

At the same time, properties of crystallinity and surface morphology generally undergo some degree of transformation during deposition and thermal annealing, affecting parylene film adhesion, as well. These conditions suggest that, with proper treatment, conformal coating properties can be adapted to specified production details. Thus, the incidence of failure due to film delamination can be limited, if processes are carefully and thoroughly implemented, according to conditions of projected product use. Typically, substrates are pretreated with A-174 silane.

However, the fact that thermal stress generated in the film during CVD processing may weaken the conformal coatings' adhesive force may further oblige customized coating procedures, to ensure delamination or similar adhesion failure does not become an issue. For instance, in certain cases, excessive temperatures (+ 150°C), and prolonged exposure to thermal sources – longer than 20 minutes – can lead to coating degradation, particularly if the films' thicknesses are <3-µm and exposed to the higher temperature ranges. Degraded adhesion following annealing at 150°C for 20+ minutes can impair parylene's encapsulation properties.

While heat treatments of even 80°C may initiate thermal stress -- somewhat compromising the parylene conformal coating, leakage rates' prevention -- factors of diminished adhesion generally do not significantly degrade the film at 150°C for the longer service durations (11.4 years), suggested previously.

Therefore, despite some inconsistencies of performance under conditions of thermal stress, parylene's properties generally provide good thermal adhesion and endurance, in comparison to competing coating materials, for innumerable products and purposes. In some cases of terrestrial application, higher operating temperatures may shorten parylene's functional life; oxygen-free, space vacuums are not affected by these conditions and can operate for similar timeframes at higher temperatures (220°+ C). Testing the complete structure conformally coated by parylene under conditions closely resembling intended operating settings is recommended to verify its ability to withstand or exceed these temperature-time-atmospheric conditions.

However, parylene reliably performs under most situations -- in air or a vacuum – at a wider temperature range than competing conformal coatings. It does so for a decade or more, at an extreme range of temperatures, without significant loss of physical properties, providing superior adhesion and limited delamination.

Testing Parylene Adhesion

The Need for Adhesion Testing

Applied mechanical processes stimulate the binding force between surface molecules required for parylene adhesion to substrates, which is essential to both good parylene performance and assembly/component functionality. The emergence of conditions characterized by non-adherence and delamination squander parylene's typically exceptional substrate protection against chemical attack, corrosion and moisture, as well as its superior dielectric insulation (er = 3.1).

Parylene adheres poorly to low surface energy substrates, under any circumstances, leading to delamination, separating from the surface its meant to protect. A variety of preparatory substances -- including hexane, propylene carbonate (PC.), A-174 silane, tetrafluoromethane (CF4) plasmarface, and toluene -- can significantly improve interface adhesion between the substrate and parylene, when applied to the substrate surface prior to CVD.

Suitable Methods of Parylene Adhesion Force Testing

Improving parylene adhesion requires a close review of all of the current processes affecting its bond with the selected substrate. As with all aspects of the adhesion process, care needs to be taken in this regard. At present, there is no single widely-accepted test for conformal coating adhesion. Determination of adhesion priorities needs to be made on a case-by-case basis. It is very important to match the test methodology to the type of parylene being used, and the expected conditions under which the component will function, when operative.

ASTM D3359 – Tape Testing for Adhesion

The Tape Test consists of two variations:

- **X-Cut Tape Test**: A technician applies a utility knife and straightedge to mark the parylene coating with two intersecting, small-scale cuts, situated at angles of 30-45 degrees to the surface. The cuts need to penetrate to the substrate surface, forming an "X" shape. Tape is placed at the X's vertex (where the lines intersect), and then is briskly pulled from the cut surface. The center of the "X" is then inspected to see if the tape caused any of the parylene to pull away from the component's surface, indicating poor adhesion.
- **Cross Hatch Tape Test**: Typically applied in a clinical setting, cross-hatched parallel lines rather than an X are cut into the coating, using either a customized cross-hatch cutter, or a utility knife/straightedge. The result is a series of slightly raised squares across the coating surface, where the cross-hatched lines intersect. Here again, tape affixed to the surface is rapidly removed. If any of the squares pull away from the surface, coating adhesion is faulty, requiring repair.

ASTM D3359 is valuable because it offers a high standard for adhesion testing; passage verifies exceptional levels of conformal performance for parylene bonding to the selected substrate. Tape testing is very similar to the "Knife Test" described below,

Knife, Pull-off, and Scrape Tests

Additional testing methods of value for verifying parylene adhesion include:

- **Knife Tests**: Very similar to the X-cut and Cross-hatch methods, a utility knife and straightedge mark the parylene coating with two intersecting cuts that penetrate to the substrate surface, forming an "X." Rather than applying tape to attempt lifting the parylene film from the substrate, the knife's tip is inserted into the X's vertex in an effort to separate the parylene from the substrate. Described in ASTM D6677, the knife test accurately determines the quality of parylene adhesion, as a variable of two factors – (1) the level of exertion required to remove the parylene from the substrate, if removal does in fact occur, and (2) the size of the removed coating. Any removal indicates coating problems; greater quantities of removed film suggest a poor bond between parylene and the surface.
- **Pull-off Tests**: In comparison to the shear stress forces applied by other adhesion testing methods, pull-off testing maximizes tensile stress. A loading-fixture known alternatively

as either a “dolly” or “stub” is bonded to the parylene film. Then, a portable pull-off adhesion device applies increasing pressure to the surface until the dolly either (1) is detached from the surface or (2) withstands a predetermined level of force, measured as tensile strength as (1) pounds per square inch (psi) or (2) mega Pascals (MPa). Failure of the parylene film results in a fractured surface at the weakest plane along the coating. Pull-off adhesion tester devices of different sizes are adaptable for use with specified substrate substance materials. Pull-off testing application and performance standards are available in ASTM D4541 and ISO 4624.

- **Scrape Tests**: As described in ASTM D2197, scrape tests are recommended for assessing smooth, flat panel surfaces ONLY. The coated panels are placed underneath a balanced-beam scrape-adhesion tester, a stylus or loop that exerts increasing quantities of abrasive pressure until the coating is worn through, either in selected areas or across the entire substrate surface. Adhesion is determined by: (1) the amount of pressure required to penetrate the coating, and (2) how long it takes to do so. Ideally, removal is minimal and time-consuming, suggesting appropriate adhesion.

Whatever method is used, it is a mistake to opt for too-rigorous an adhesion standard for parylene films. Parylene has repeatedly demonstrated its capacity to provide superior conformal coating under exceptionally ruggedized conditions. While its adhesion capacities should always be subjected to appropriate testing, there is no value in creating test standards so demanding that a new collection of coating materials must be invented to meet them.

Conclusion

Inadequate adherence of parylene conformal coatings significantly lowers the operational life of components and parts, causing them to malfunction during use. This can be a problem because the chemical structures of the parylenes may actually reduce good interface adhesion, sometimes significantly. Systematic cleansing of substrate surfaces stimulates better interface adhesion.

Heat-treated parylene (140°C, 3 hours) can also respond beneficially, engendering dependable adhesion and film insulation, minimizing delamination and other coating erosion. Heat testing can determine whether a high, consistent adhesion strength is the outcome, as it generally is with heated parylene. Appropriate heat-treatment can generate parylene adhesion-improvement as much 800% greater for conditions of prolonged operational duration.

In comparison to using parylene alone, bilayer encapsulation of PCBs and related assemblies improves the overall adhesion and performance-stability of active, wired devices, particularly in cases where superior adhesion is essential to persistent functionality.

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