History of Parylene

Parylene development started in 1947, when Michael Szwarc discovered the polymer as one of the thermal decomposition products of a common solvent p-xylene at temperatures exceeding 1000 °C. Szwarc first postulated the monomer to be para-xylylene which he confirmed by reacting the vapors with iodine and observing the para-xylylene di-iodide as the only product. The reaction yield was only a few percent, and a more efficient route was found later by William F. Gorham at Union Carbide.

The Parylene Deposition Process

Parylene coating is applied through a vapor deposition process onto the substrate or material that is being coated. Depending on the coating type and required thickness, typical parylene deposition rates are about .2/mils per hour, so machine runs can vary from as little as 1 hour to over 24 hours. The process begins with raw dimer in solid state (these are: Parylene C, Parylene N, Parylene D, Parylene AF-4, or other variants) being placed into a loading boat, which is then inserted into the vaporizer. The raw dimer is heated between 100-150º C. At this time, the vapor is pulled, under vacuum into the furnace and heated to very high temperatures which allows for sublimation and the splitting of the molecule into a monomer. The monomer gas continues to be drawn by vacuum one molecule at a time onto the desired substrate at ambient temperatures in the coating chamber. The final stage of the parylene deposition process is the cold trap. The cold trap is cooled to between -90º and -120º C and is responsible for removing all residual parylene materials pulled through the coating chamber.

The process is visually described through figure 1 below:

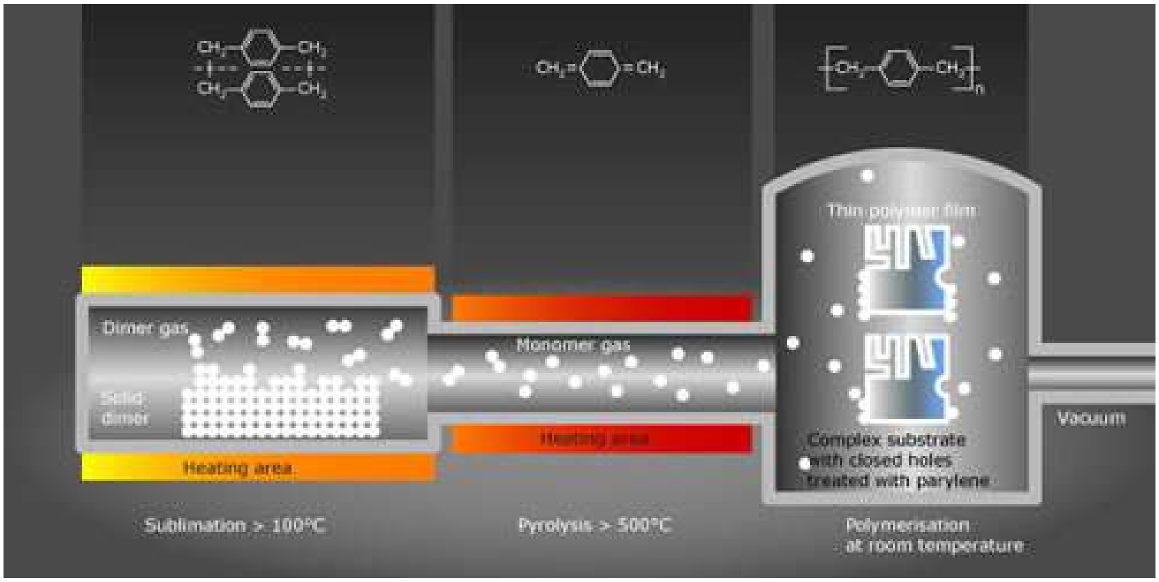


Figure 1.

The parylene deposition process is relatively simple to understand, but tough to master. A thorough understanding of the process is key to controlling thickness and ensuring a successful coating cycle.

All about the Parylene Coating Process

Parylene Coating Process – Phase 1 – Prior to Parts Arrival

Once we receive a purchase order from a customer, all of the pertinent information such as drawings, specifications, and special instructions are given to the quality department from our marketing team to create custom work instructions for that particular part.

Parylene Coating Process – Phase 2 – Coating Processes

After the work instructions and other administrative tasks have been completed, the parylene coating production process truly begins in our shipping department. Once all of the items have been unpacked, they are then routed to incoming inspection. Here, parts are counted to verify quantity against the customer purchase order and packing slip, as well as inspected to verify that no damage occurred to the assemblies prior to arrival at Diamond-MT. After incoming inspection, assemblies are then ready for individual processes. For example, if cleaning or cleanliness testing were required, it would be performed at this time. Once any unique processes have been completed, the products are then routed to masking. Masking is done in accordance with the customer's drawings and requests for coating keep-out areas. Once completed, the parts go into masking inspection to verify compliance with the customer's masking drawing. After parts pass masking inspection, adhesion promotion is administered. At last, the parylene coating is applied through a deposition process. Once coating has been deposited, the coated materials have the masking material removed using great care not to damage the thin layer of parylene applied. The parts are nearing completion, but before they can be packaged up and sent back to the customer, they need to go through a final inspection. The final inspection ensures that all previous steps were successfully completed and that the final product completely complies with the customer's drawing and specifications. Final inspections cover 100% of the product. Once the parts pass the final inspection, they are returned to the shipping department to be packed back into the boxes they came in and be returned to the customer. This is usually a ten business day evolution, but can be completed quicker on a negotiated basis.

Parylene Coating Process – Phase 3 – Post Coating Follow-up

Our sales and marketing team is in very close contact with our customers after the coating process to make sure the coating is exactly as the customer requires. If any changes are necessary to our process, our quality department will work hand in hand with the customer to make sure that the end product is exactly what is needed.

Choosing Parylene Thickness

A question that is often brought up by customers who are new to conformal coating is what thickness to apply parylene.

One of the different factors to take into account when trying to determine the proper parylene thickness is the amount of clearance needed. If it is a printed circuit board that is an enclosure, there usually will not be too many clearance issues. However, in some cases, even an extra mil of coating can cause extra mechanical abrasion to the parylene which can result in damaged parylene.

Another factor to consider is the dielectric strength required. For applications that require higher dielectric strength, a thicker coat of parylene has higher dielectric properties than a thinner coat. Trying to balance the dielectric strength issue with the clearance issue is a tight rope to walk and will usually require some testing to determine the proper balance.

In the easiest of cases, an end item customer has specified the coating thickness to be applied and put this into writing on a drawing. After we review the drawing and compare the drawing with the assembly, we will be able to determine if any potential issues with the parylene thickness are present.

How to Improve Parylene Adhesion

Parylene, through its deposition process, does not adhere chemically, only mechanically, to any given substrate. In order to improve parylene adhesion to its best possible levels for a wide variety of substrates, different methods of surface modification via adhesion promoters must be used. Adhesion promotion methods are typically used prior to the actual coating process, however some can be integrated during the process itself.

The largest factor affecting parylene (or any conformal coating) adhesion is surface cleanliness. Contaminants on the substrate that have accumulated during all phases of manufacturing, as well as handling and transportation, can cause very poor adhesion and lend to poor overall coating quality. It is highly recommended that substrates be cleaned prior to coating (Contrary to

popular belief, this INCLUDES No-Clean Fluxes). Cleaning can be done via manual methods, inline, batch, or ultrasonic means.

The most common surface modification method to improve parylene adhesion is the use of A-174 silane. A-174 silane is usually applied after the masking operation, either by a manual spray, soaking, or a vapor phase silane process, depending on each individual application. The A-174 silane molecule forms the chemical bond to the surface enabling parylene's mechanical property to form improved adhesion characteristics.

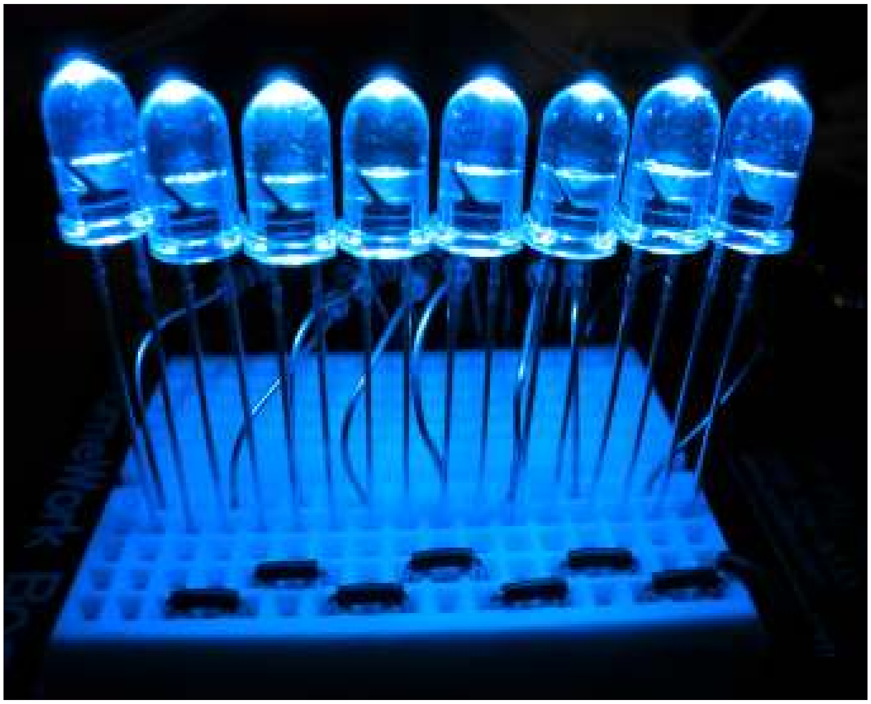
When looking to improve parylene adhesion, a close review of all of the current processes, to include handling, is a necessity. Once best adhesion practices have been established, it is of utmost importance to enforce strict adherence to the processes. If adhesion becomes an issue, any deviation from a process can be a good troubleshooting start-point.

Using industry best practices, such as substrate cleaning and A-174 silane application, combined with standard, repeatable processes will ensure strong adhesion for parylene coating.

What can be Parylene Coated?

A question we often get is "Can *X* be parylene coated?" We are often amazed at the sheer number of items that can be and are coated with parylene. A quick look at the different items that we have parylene coated over the years reveals that more often than not, parylene coating is a value add to these and many more products:

- Printed circuit boards
- MEMs
- LEDs
- Catheters
- Stents
- Magnets
- Paper
- Needles
- Sensors
- Ferrite Cores



- Metallic Blocks
- Optical lenses
- Implantable devices
- Valves
- O-rings
- Tubing
- Silicon Wafers
- Keypads
- Stoppers
- Seals
- Mandrels
- Molds
- Motor Assemblies
- Power Supplies
- Backplanes
- Photoelectric Cells
- Forceps
- Test tubes
- Probes
- Fiber Optic Components
- Pace-makers
- Bobbins

- And many more…

This is far from a comprehensive list of items that can be parylene coated, but it should give a good idea how many different applications that parylene can be used for.

How Parylene Cost is Determined

Parylene is often priced out to be one of the more expensive conformal coating options. After a quick look at some of the cost factors, it will be easy to see why. Three of the main factors that influence parylene cost are raw materials, labor, and lot volume.

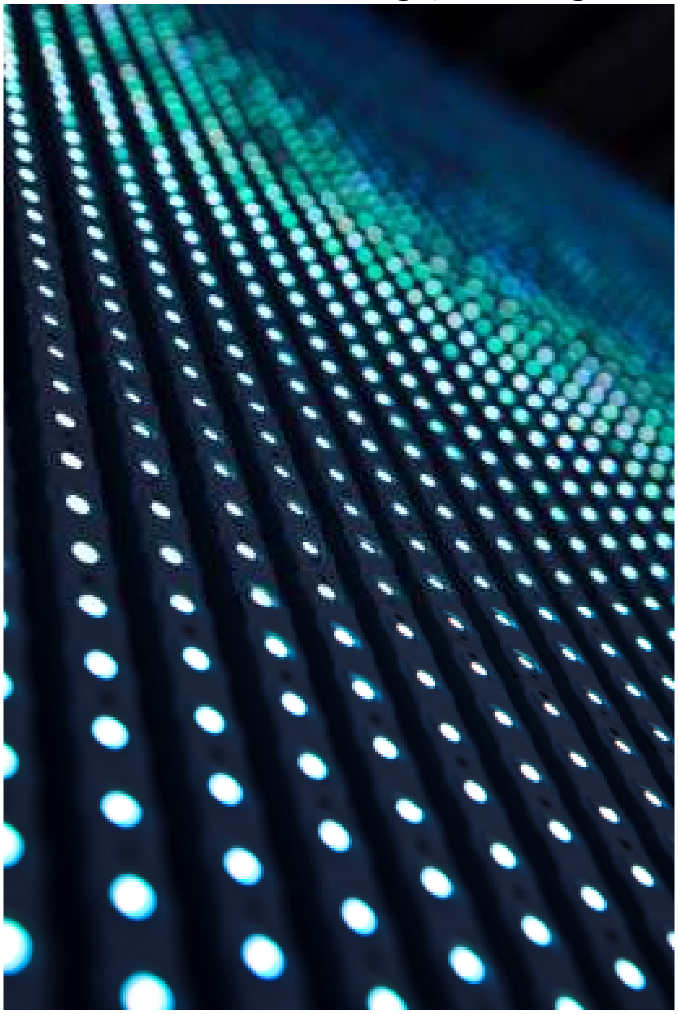
Raw Materials – Parylene Dimer and Adhesion Promotion

Parylene dimer is the raw form of parylene. It is the solid inserted into the machine that is broken down through the deposition process. Cost for parylene dimer can be anywhere from $200 to $5,000 per pound depending on the different type of dimer. A typical coating run is around a pound of dimer.

Different adhesion promotion methods require different raw materials. From various board cleaning solutions to A-174 silane, these raw material costs need to be added to the price per assembly. There is not much that can be done with these costs, as adhesion is the name of the game in parylene.

Parylene Labor Costs

Like all conformal coatings, masking is usually the most labor intensive part



of the process. However, parylene is different from other conformal coatings in that it is applied in a gaseous state through a vapor deposition process. The parylene molecules will penetrate anywhere that air can. As a result, great care needs to be taken during the masking process to ensure that every connector is adequately sealed and all tape is firmly pressed against the coating keep-out areas.

Another factor that will result in increased labor costs is the increased time spent per board to increase parylene adhesion. Spending extra time cleaning products and applying different adhesion promotion mediums will result in increased labor times.

Parylene Lot Volumes

Items to be parylene coated are placed into a vacuum chamber. There is finite space available in the chamber and everything inside gets coated. In order to get the lowest cost, we have to maximize the products in the chamber. If we are able to divide the material costs among a greater number of boards, the cost per board drastically drops.

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 free standing 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 has also formed two joint ventures to offer conformal coating in Shenzen China as well as Manchester in the UK.