

SCS Parylene Deposition Tool Manual

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12/10/2010
Update: 11/2/2011



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Update: 7/28/2011

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Introduction

Parylene is a unique polymer consisting of a linear chain of Benzene rings with two Methylene groups replacing 2 Hydrogen atoms on opposite sides of the Benzene ring serving as coupling links for the polymer. This film has become known for its imperviousness to water transmission which enables device protection from environmental deterioration via encapsulation and also for its electrical characteristics which are useful for micro-electrical circuitry. The source material for the deposited film is a dimer form of the parylene molecule in which two monomers are coupled in parallel by the Methylene ends. The dimer is sublimated in a Vaporizer chamber, broken into monomer molecules in the Pyrolizer furnace and then deposited on substrates in the deposition chamber.

This manual describes how to run our Parylene Deposition tool (Specialty coating Systems Model PDS 2010 Labcoter™ 2).

Description

The Parylene deposition system consists of a series of connected vacuum chambers that sequentially produce parylene vapor, pyrolize it, deposit it as a polymer, and then capture its effluent. The Vaporizer chamber is a horizontal tube at the bottom of the tool behind the front panel. It has a hinged door that is held in place by a simple latch. This is where an Aluminum foil boat with the Parylene Dimer pellets is loaded into the system. The Pyrolizer furnace is a vertical tube connected to the back of the horizontal Vaporizer, and is the place that the Dimer vapor is broken into Monomers in preparation for deposition on the substrates in the Deposition Chamber. The exhaust is pumped into a LN2 trap by a mechanical oil pump. Figure 1 depicts the Parylene chemistry process and the vacuum system schematic.

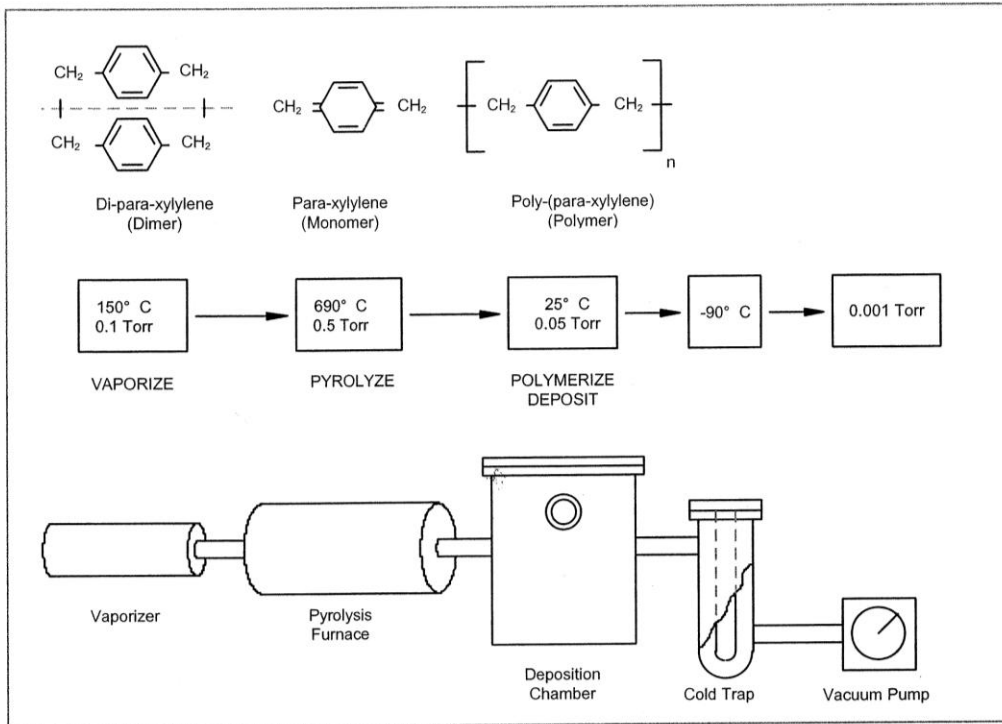


Figure 1. Parylene chemistry, process concept, and vacuum system schematic. For the Parylene-C chemistry, the vaporization temperature is 175 C, and in our system the cold trap is chilled by Liquid Nitrogen at 77 deg K, or -196 C (77-273=-196 C).



Figure 2. Elements of the Parylene Deposition vacuum system: 1) Vaporizer, 2) Pyrolizer Furnace, 3) Vaporizer Door, 4) Deposition chamber, 5) Cold Trap, 6) Vacuum Pump.

Process Overview

The Parylene Deposition process step sequence can be described visually by observing the process parameter timing chart shown in Figure 3. After the Dimer is installed in the Vaporizer chamber and samples are in the sample chamber and a vacuum is established in the system, the process is started by enabling all heaters and pushing the start button. Figure 3 shows the process temperatures and deposition chamber vacuum pressures as time proceeds through the process. When the green start button is pushed, the Pyrolizer and vacuum gauge temperatures are ramped up to operating levels. As the Pyrolizer furnace temperature increases, the Vaporizer chamber also heats up a small amount by thermal conduction, causing the Dimer to outgas adsorbed vapor and the deposition chamber pressure rises a little from the Base Vacuum Pump Pressure to the “Process Base” pressure. Just before the Pyrolizer furnace rises to its set point, the Vaporizer furnace is turned on. As the Vaporizer temperature reaches about 90 C, the Dimer begins to sublime in earnest and the process pressure begins to rise rapidly until it reaches its set point. Even though there is a small overshoot in the process pressure, the temperature of the Vaporizer is adjusted on feedback instructions from the pressure gauge to stabilize the pressure at the Process Set Point. Note the gradual temperature rise in the Vaporizer is required to maintain the process pressure as the dimer is used up. This process pressure is maintained at the Process Set-Point Pressure by the Vaporizer temperature until all the Dimer source material is vaporized. Then the process pressure drops rapidly back through the “Process Base Pressure” in spite of the Vaporizer temperature rise. After about 5 minutes of maintaining Vaporizer temperatures to be sure all the Dimer is vaporized, the system shuts down all the heaters and begins to cool. At this point the green Start button flashes to note the end of the process. However the system cannot be opened until the Vaporizer temperature drops below 90 C to prevent harmful gases from reaching the user.

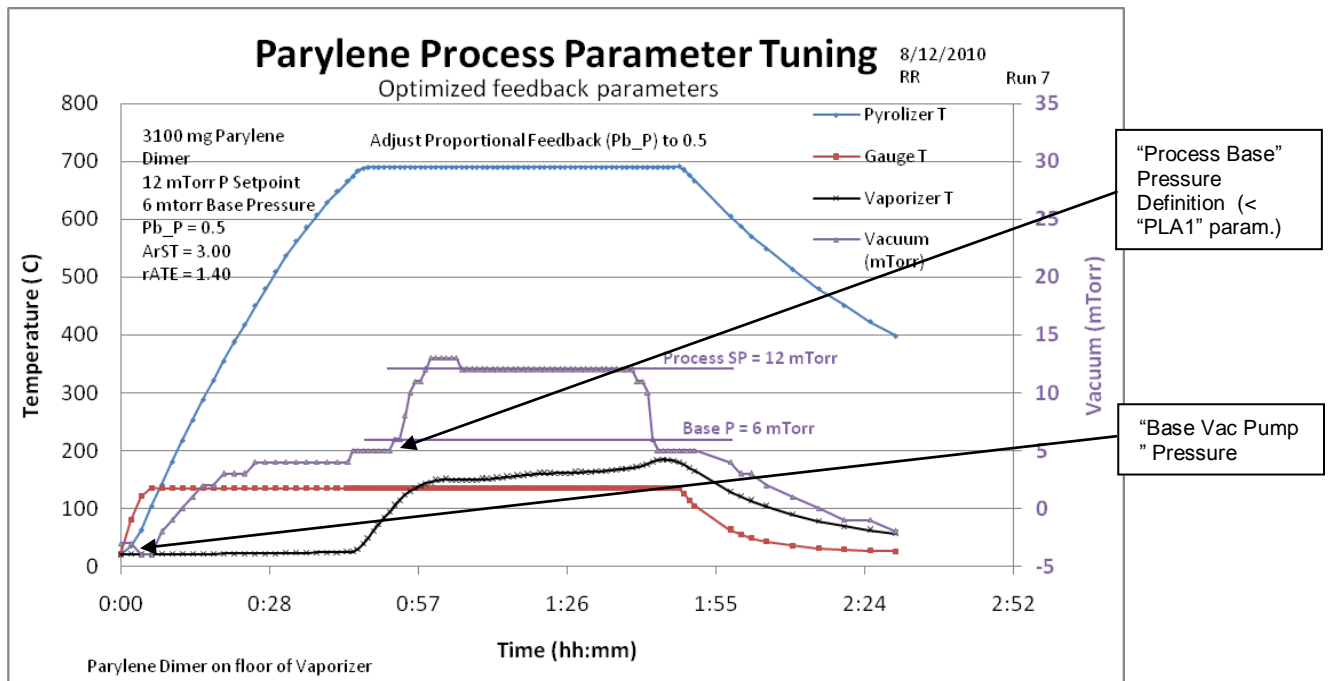


Figure 3. Parylene deposition parameter timing chart. Note the definition of “Process Base Pressure” (Process Base Pressure Setpoint Parameter “PLA1” must be set just above this value).

Operating Instructions

Logbook

This tool requires time reservation on the UTD Cleanroom Scheduler. The scheduler is found at <http://10.110.49.95/cleanroom> but it requires a password to access – obtain this from the staff member who trains you. In addition each tool in the scheduler list requires permission to access (given only after proper training). A normal time reservation would be about 3 hours max, but the run time is somewhat dependent on the amount of Parylene to be deposited.

There is a paper logbook at the tool which must be filled out.

Tool Preparations

Before the tool can be operated, there are some preliminary steps required to prepare the system and material for the run. Normally, the starting configuration for a new run would have the system under vacuum with the cold trap outside and the cold trap flange sealed with a SS plate to hold vacuum with the vacuum switch in “HOLD.”

As is routine in the clean room, please fill out the logbook before starting any operation on any tool.

Step 1 Clean the Cold Trap

- a. Scrape off the thick waste parylene using a knife blade. Usually the thick film will flake off fairly easy.

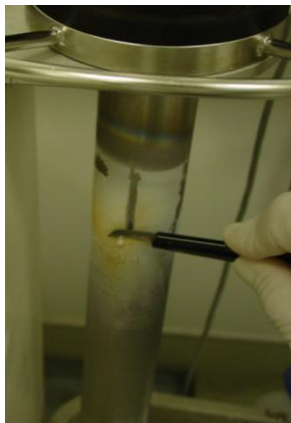


Figure 4. Scraping cold trap to remove Parylene deposits before starting run.

- b. Clean off the remaining deposits using a Soft Scrub pad. Ask Staff for replacement pads when they become unusable.

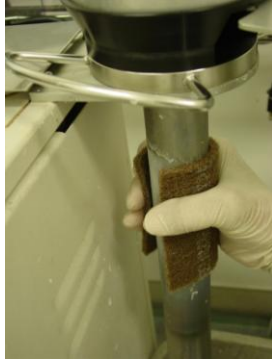


Figure 5. Soft Scrub cold trap to remove thin films of Parylene.

- c. Deposit waste scrapings in the lined trash can – usually placed under the cold trap to catch the droppings.
- d. Spray a thin coat of Micro 90 2% solution onto the cold trap and then gently wipe off excess with a lint-free cloth. This solution reduces the adhesion of Parylene to the cold trap and makes cleanup much easier. It also removes parylene flakes still clinging to the cold trap. Make sure that you clean off all particles especially at the top of the cold trap so they will not fly back into the vacuum pump during pump down or fly up into the process chamber during vent.



Figure 6. Spraying cold trap with Micro 90 2% DI H₂O and wiping excess liquid off to reduce future Parylene adhesion for ease in cleanup.

- e. After this operation your Cleanroom gloves will most likely be coated with lots of small Parylene particles – it is highly recommended that you change gloves at this point to prevent tracking electrostatic particles into other parts of the tool or clean room. There should be some clean gloves on the parylene table somewhere, but if not, bring some with you from the smock room.
 - a. Optionally, you can put on a second pair of gloves over the first pair before starting the cleanup, clean the cold trap and then pull off the outer pair. Now you have a clean pair already on without having trouble pulling new gloves onto sticky sweaty hands.

Step 2 Create a Parylene Dimer Boat

- a. Obtain Al foil and cut a rectangular patch of foil about 3.5 x 6 inches for the boat.
- b. Curl the patch of Al foil around the former tube to shape it for insertion into the Vaporizer Furnace. Smooth out the wrinkles with your hand to improve the thermal link between the Vaporizer wall and the Parylene itself. This simple act will improve the performance of the thermal control.



Figure 7. Curl a patch of Al foil around the former cylinder with the bright side against the former tube.

Step 3 Weigh out the Parylene Dimer

- a. Weigh out the Parylene Dimer according to the film thickness required using the Ohaus Balance. Appendix B has a chart of Dimer mass vs. actual film thickness produced for Parylene-C. Use a thin folded piece of weighing paper on the balance so that you can transfer the dimer to the Al boat.
- b. If you spill any parylene Dimer, please clean it up immediately. Do not leave any Dimer in the balance – ever. It will damage the balance over time.



Figure 8. Weigh out the desired mass of Parylene Dimer onto a weighing paper.

Step 4 Power up the system

- a. Power up the system if needed
 - a. Release the red EMERGENCY STOP button.
 - b. Press the MAIN POWER button.

- c. Switch the Furnace vacuum gauge and the Vaporizer rotary switches to “DISABLED” and the Vacuum should be set at HOLD.



Figure 9. Front panel switches and buttons and process controller readouts. Red numbers (top) are actual readings; Green numbers (bottom) are set point values.

Step 5 Vent

- a. Turn the Vacuum rotary switch to VENT.
- b. Wait until the pressure gauge stops increasing its readout numbers (~912 vacuum units at atmosphere).

Step 6 Load Samples

- a. Lift the Deposition Chamber lid by the handles and set it upside down on a table. The lid is heavy.
- b. Lift the rotary sample table out of the chamber and set it on the table.
- c. Load your samples onto the shelves. Note that there will be some uniformity differences between samples on different shelves.¹
 - a. To reduce non-uniformity, do not place your samples close to the rim of the rotary table shelf or close to the shelf support posts.
 - b. Deposition rates are calibrated for the center shelf.

¹ Robbins, Roger, “SCS Parylene Deposition Uniformity,” <http://www.utdallas.edu/~rar011300/Parylene/ParyleneDepUniformity.pdf> , (9/3/2010).

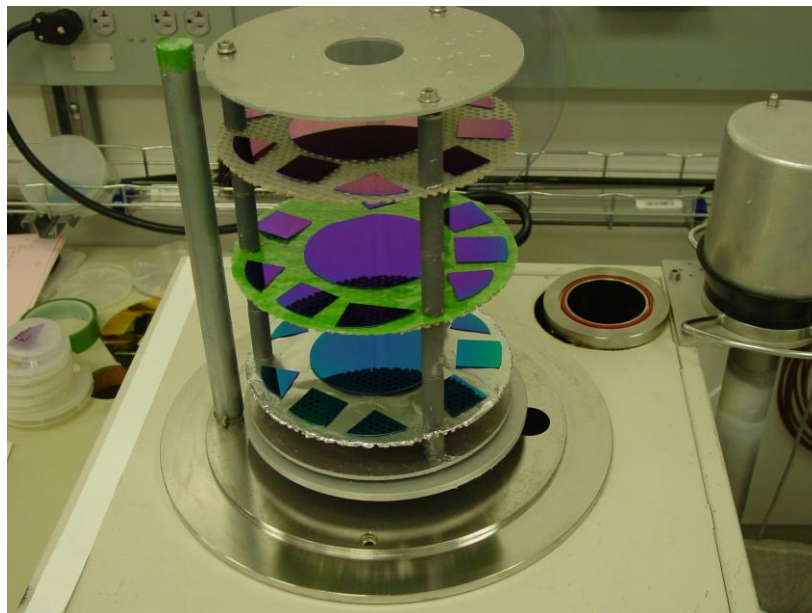


Figure 10. Rotary sample table sitting on the rotating platform in the bottom of the deposition chamber. Outer edges of samples close to the edge of the rotary sample shelves receive slightly more film thickness than positions more interior to the shelves. Also note the color differences of the samples on different shelves. This color difference represents film thickness variation. [Deposition Chamber removed to show sample tower]

- d. Return the rotary sample tower to the deposition chamber and set it on the rotating platform, making sure that the rotary table is seated flat and centered.
- e. Replace the chamber lid. Make sure that the o-ring and the sealing surfaces are clear of any parylene film that may have fallen across the seal.

Step 7 Insert the Parylene Dimer

- a. Open the front cabinet door of the tool.
- b. Open the Vaporizer Door
- c. Remove the old Aluminum dimer Boat from the furnace.
- d. Insert the new parylene Dimer boat with the Dimer mass prepared earlier.



Figure 11. Vaporizer door open for Parylene Dimer insertion.

- e. Spread the Dimer with the spatula into a granular layer 1 – 2 layers thick in the bottom of the Al Boat. Do this in order to achieve close thermal linkage to the furnace floor for better control of the process pressure. Leave about a ½ inch clear space between the door and the start of the Dimer pile.
- f. Close the Vaporizer door and latch it.
- g. Close the front panel.

Step 8 Replace the Cold Trap

- a. Remove the SS plate seal from the cold trap hole.
- b. Carefully lift the cold trap from its outside mounting and place it in its vacuum system hole. Please do not stress the electrical cable or the LN2 line during cold trap handling. Make sure that the o-ring is clear of any water remnant or parylene debris. Also make sure that the cold trap itself has no Parylene debris under its top flange that would lie across the seal and cause a vacuum leak or fly into the vacuum pump at pump down or back into the process chamber during vent.

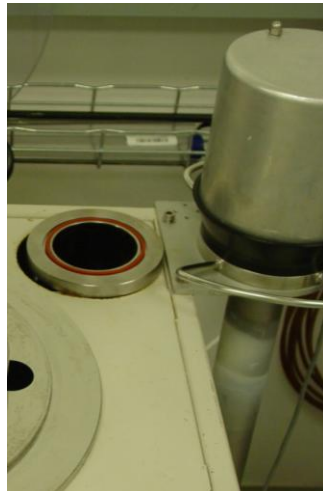


Figure 12. Cold trap set on external mount at standby before insertion into vacuum system hole with orange o-ring.

Step 9 Start Vacuum Pump

- a. Switch the vacuum switch to PUMP.
- b. Immediately hold down both the Chamber Lid and the Cold Trap against their o-rings to reduce air leaks so that the vacuum pump can start making a vacuum in the system.

Figure 13. Operator holding both chamber lid and cold trap tight against o-rings to start vacuum pump down.

- c. When the numbers on the vacuum gauge begin dropping, you can release your pressure on the lid and cold trap.
- d. After the vacuum pressure reaches a minimum ($\sim < 20$ m Torr). Open the LN2 valve on the LN2 tank to start the cold trap operation. The vacuum indicator should drop to < 5 m Torr. (At ultimate vacuum pump performance the vacuum pressure can drop to -4 mTorr.)
- e. Wait until the vacuum system achieves base vacuum pump pressure - (will not pump down further) - and write the number in the logbook. This value is important to know – it denotes the condition of the vacuum system and indicates when it needs service.
 - a. The actual Base Vacuum Pump pressure must be less than the Process Base Vacuum Set Point in the Vacuum controller for the system to even start your process.
 - b. If the actual Process Base Pressure observed on the Vacuum Gauge is higher than the base pressure set point, call appropriate staff for service.

Set Operating Parameters

- A. Process Pressure Set point
 - a. Set this parameter to a value in the range of 5 to 20 m Torr above the Process Base Pressure to determine the deposition rate for your samples.
 - i. This is the key parameter that determines the quality of your film. Smaller numbers produce better films in general.
 - ii. Default Process Pressure Setpoint value is 12 m Torr.
 - b. On the Vacuum controller press the Function key (Far right key).
 - i. Use the up or down arrow key to change the Process Pressure Set Point value.
 - ii. Value cannot be less than the Base Process Pressure value [PLA1 Default value = 8 m Torr].
 - iii. Value should not be greater than the max pressure achievable with the amount of Parylene in the Vaporizer. (See graph in Appendix C.)
 - c. Press the Function key again to exit the setup mode.



Figure 14. Setpoint Screen

- B. Process Base Pressure Set point
 - a. Set this parameter to a value just above the actual Process Base Pressure (See Process Overview section for definition and example). This is a critical value to ensure that the process proceeds to the sublimation step.
 - b. Use the procedure described in Appendix A to find and set the PLA1 parameter to the proper value depending on the condition of the vacuum system. Values range between 6 and 15 mTorr, but don't guess on this parameter – if you don't know the Process Base pressure, don't change the PLA1 parameter. This value has to be measured periodically and will vary with time and the condition of the vacuum system. If you measure it, please write it down in the logbook for the next user.

Start Process

Step 10 Start Process

- a. Switch both the Pyrolizer and Vaporizer switches to “ENABLE.”
- b. Leave the Vacuum switch in “VACUUM.”
- c. Check to make sure the LN2 source valve is open.
- d. Press the Green Start Button to start the process.

Step 11 Wait

- a. The process will start and go through its flow, but it will take a while... You can go away and come back in about <2 hours expecting your process to be complete. (Green Start button flashing Green).

Rules-of-Run Logic

- a. If the Process Pressure is below the process base pressure set point (Default base pressure set point (PLA1) = 8 m Torr), when the Pyrolizer reaches its spec value (690 for parylene C), then the deposition process is officially “started.”
 - a. If this condition is not met, the process will not progress - the process will continue indefinitely without ever heating the Vaporizer.
 - b. If the process pressure never rises to Process Set Point (SP), but does fall below process base pressure (PLA_1) at the end of vaporization, then the run will terminate after 5 – 10 minute delay
- b. When the Parylene is totally sublimated, the Process pressure must fall below the process base pressure set point for the process to end normally. Normal ending is a 5 minute delay after the Process pressure falls below the base pressure set point to allow the vaporizer to heat up and be sure the Parylene dimer is all vaporized.
 - a. If the process pressure does not fall below the base pressure set point, the system will continue for 30 minutes and then time out and shut down all heaters.
 - b. If Process Pressure falls below baseline pressure, but the Vaporizer temperature is below 174 C, End of Run Trigger will not trip and Run will continue until the Vaporizer Temperature rises above 174 C or 30 minute time-out applies.

End Process

Step 12 End of Process

- a. When the Green START button flashes green, the process is over.
- b. Turn off the LN2 delivery valve on the Dewar.
- c. Switch the Pyrolizer and Vaporizer knobs to “DISABLE.”
- d. Let the system cool until the Vaporizer temperature is less than 90 C to prevent harmful gases from escaping and affecting nearby people, including you.

Step 13 Vent System

- a. Switch the Vacuum switch from PUMP to VENT
- b. Wait until the vacuum gauge numbers quit rising
- c. Immediately lift the cold trap out of its hole and fit it into the external holder ring over the side of the tool. Be careful not to stress the wires or LN2 line. The immediacy of this action prevents moisture from condensing on the cold trap and entering the vacuum system. If water gets into the vacuum system the pump will have a hard time achieving base pressure for the next run. It can also foster an HCl acid attack of the cold trap weld joints.
- d. Place the SS plate over the cold trap hole to prevent anything from falling into it.

Step 14 Retrieve Samples

- a. Lift the chamber lid and set it on the table upside down. The lid is heavy.
- b. Lift the rotary sample table out of the deposition chamber and set it on the table also.
- c. Remove your samples
- d. Return the sample table to the deposition chamber.
- e. Make sure that the lid and lid o-ring are free of parylene debris and return the lid to its chamber seat.

Idle Tool

Step 15 Pump down System

- a. Turn the Vacuum switch to "VACUUM."
- b. Hold down the SS plate over the Cold Trap hole and the Deposition lid until the vacuum gauge shows that the system is pumping down.
- c. When the pressure drops below something like 100 m Torr, turn the Vacuum knob to "HOLD." This prevents vacuum pump oil from migrating back into the system over time.

Step 16 Finish Logbook Entry

- a. Finish Logbook entry.
- b. Take your samples and run.

Consolidated Operating Instructions



Step by Step Operation

This section is a brief reminder of the operating procedure order for those who have been trained and just need a reminder guide.

1. Fill out the logbook.
2. Clean the cold trap
 - a. Put on a second pair of gloves over the first pair [simplifies glove change]
 - b. Scrape off the thick Parylene deposit with a knife blade
 - c. Clean the remaining deposits with a Soft Scrub pad
 - d. Rinse the cold trap with Micro90 2% in DI Water.
 - e. Wipe lightly with a lint free cloth - leaving the trap slightly moist.
 - f. Change gloves after this operation to prevent tool or clean room contamination from electrostatic Parylene particles. (i.e. Pull of the second pair of gloves)
3. Create a Parylene Dimer Boat out of Aluminum foil.
 - a. Cut foil into a rectangle about 3.5 x 6 inches
 - b. Curl the foil around the cylindrical former to form a "boat"
4. Weigh out the Parylene Dimer according to the film thickness required using the Ohaus Balance. Use a thin folded piece of weighing paper on the balance.
 - a. Use a weighing paper to transport the Dimer to the Aluminum boat.
5. Power up the system if needed
 - a. Release the red emergency button
 - b. Press the power button
 - c. (Both left rotary switches should be disabled)
6. Vent the system
 - a. Turn the Vacuum rotary switch to Vent.
 - b. Wait until the pressure gauge stops increasing its readout numbers (~912 Torr).
7. Remove the lid from the top of the deposition chamber.
 - a. Place the lid upside down on a stable surface.

8. Remove the rotary sample tower
 - a. Just lift it out of the chamber and set it on a table
9. Load samples onto Rotary sample tower.
 - a. To get the best uniformity do not place samples close to the edge of the shelves or next to a support post. Leave about a centimeter between samples.
 - b. Center shelf is best location for thickness control.
10. Replace Rotary sample tower into the deposition chamber on top of the rotary table.
 - a. Make sure it is seated flat and centered.
11. Replace the chamber lid.
 - a. Take care that no parylene is trapped between the o-ring and its sealing surface.
12. Open the Vaporizer Furnace Door (behind front panel).
13. Carefully Insert the Al Dimer boat with Dimer into the Vaporizer
 - a. Spread the Dimer with the spatula into a granular layer 1 – 2 layers thick in the bottom of the Al Boat, but leave about a ½ inch clear space between the door and the start of the Dimer material.
14. Close and latch the Vaporizer door
15. Remove the SS plate seal from the cold trap
16. Carefully place the cold trap back into its operating position.
17. Turn the Vacuum switch to pump and hold down the deposition Chamber Lid and the Cold Trap to help the vacuum pump produce a vacuum in the system
18. Wait until the vacuum pressure drops to minimum (~<20 m Torr).
19. Open the LN2 liquid valve to fill the cold trap with LN2.
20. Check or set Process Parameters if necessary.
 - a. See [Set Operating Parameters](#) section and [Appendix A - Process Control Parameters](#) for details.
21. Enable the Furnace (Pyrolizer) / Chamber Gauge, and Vaporizer switches.
 - a. Vacuum Switch should remain on "Vacuum".
22. Press the Green Start Switch when the vacuum gets below base pressure (Default Base Pressure (PLA1) = 8 m Torr).
23. --- Long delay while process runs ---
24. Ending the Process Run
 - a. When the Green Start lamp flashes the run is over.
 - b. Turn off the LN2 Valve.
 - c. Disable the Pyrolizer Furnace and Vaporizer via the 2 switches on the front panel.
 - d. Let the system cool until the Vaporizer temperature is less than 90 C.
25. Vent the system by switching the switch from Pump to Vent.
 - a. Allow system pressure to rise to atmosphere.
 - b. Immediately remove the cold trap and set it in the holding ring.
 - c. Place SS plate over cold trap to prevent anything from falling in.
26. Remove the Chamber Lid and set on a firm surface upside down.
27. Lift out the rotary sample tower and set on a table
28. Remove your samples
29. Place the rotary sample tower back into the deposition chamber.
30. Replace the Chamber lid
 - a. Make sure the o-ring and sealing surfaces are clear of parylene.
31. Pump down the system
 - a. Turn the Vacuum switch to Vacuum

- b. At the same time hold down the Chamber lid and the cold trap sealing plate.
 - c. When the vacuum gauge begins to drop to lower pressure release your pressure on the lid and cold trap plate.
 - d. When the pressure drops to base $\sim < 100$ m Torr, switch the vacuum switch to Hold to prevent vacuum pump oil from migrating back into system.
32. Finish the logbook entry
33. Take your samples and run away.

Appendix A - Process Control Parameters

Process control parameters are set in the four process controllers on the front panel of the Parylene deposition tool. The first exposition describes the procedure of accessing the control parameters in the controller software. The process control parameters are listed in two tables later in this Appendix.



Figure 1A. Parylene Deposition tool front panel.

Enter Setup Mode

- Step 1 Depress and hold the Function Key (Far right key)
- Step 2 Depress the Up Arrow Key (Middle right key).
(Photo below shows resulting readout).



[SLCt = Select; OPtR =]

Step 3 Press the Up Arrow key once (Middle right key)



[SLCt = Select; SEtP = Setpoint]

Step 4 Press the Function key once. The lower display will show ULoc. Press up Arrow to increment the unlock code number to 10. Then push the Function Key to accept.



[ULoc = Unlock; Code = 10]

Step 5 Use the Function key to scroll through the parameters. Use the up and down arrow keys to increment the function values. Note the “MAN” light will come on for this operation.



[SP = Process Pressure Setpoint; Value = 25]

Exit Setup Mode

Step 1 Depress and hold Function Key and press up Arrow key to return to select mode [SLCt = SEtP]

Step 2 Press Down Arrow key to select [OPtr]

Step 3 Press Function key to select the operation mode. You are now exited from the setup program.

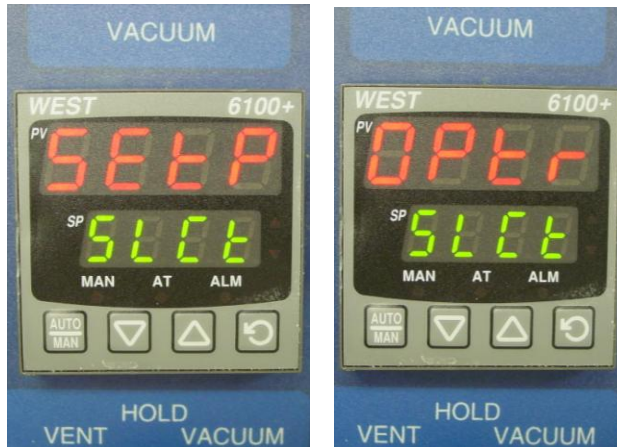


Table IA
Vacuum Controller Parameter list

Parameter	Description	Value
FiLt	Input Filter Time Constant	2 sec
OFFS	Process Variable Offset	0
PPLJ	Primary (Heater) Power	Read Only
Pb_P	Proportional Band	0.5%
ArST	Auto Reset (Integral Time)	3.00 sec (default=3)
rAtE	Rate (Derivative Time)	1.4 sec
biAS	Manual Reset (Bias)	25
SPuL	Setpoint Upper Limit	100 mTorr
SPLL	Setpoint Lower Limit	-4 mTorr
OPuL	Output Power Limit	100%
Ct 1	Output 1 Cycle Time	8 sec (Norm=32)
bAL 1	Band Alarm 1	-
PhA 1	High Alarm 1	-
PLA 1	Low Alarm (Base Pressure)	8 mTorr
AHY 1	Alarm 1 Hysteresis	1
PhA 2	High Alarm 2	-
AhY 2	Alarm 2 Hysteresis	1
Apt	Auto Pre-Tune	Disabled
PoEn	Auto/Man control Selection	Disabled
SPr	Setpoint Ramping	Disabled
rP	SP Ramp Rate value	OFF
SP	Process Pressure Setpoint	12 mTorr
SLoc	Setup Lock Code	10

Note: Key parameters are listed in Red

Table 2A
Vaporizer Controller Parameter list

Parameter	Description	Value
FiLt	Input Filter Time Constant	2 sec
OFFS	Process Variable Offset	0
PPLJ	Primary (Heater) Power	Read Only
Pb_P	Proportional Band	5%
ArST	Auto Reset (Integral Time)	2.00 sec
rAtE	Rate (Derivative Time)	0.3 sec
biAS	Manual Reset (Bias)	25
SPuL	Setpoint Upper Limit	180 C
SPLL	Setpoint Lower Limit	0 C
OPuL	Output Power Limit	100%
Ct 1	Output 1 Cycle Time	8 sec (Norm=32)
bAL 1	Band Alarm 1	-
PhA 1	High Alarm 1	200
PLA 1	Low Alarm (Base Pressure)	-
AHY 1	Alarm 1 Hysteresis	1
PhA 2	High Alarm 2	174 C
AhY 2	Alarm 2 Hysteresis	1
Apt	Auto Pre-Tune	Disabled
PoEn	Auto/Man control Selection	Disabled
SPr	Setpoint Ramping	Disabled
rP	SP Ramp Rate value	OFF
SP	Process Pressure Setpoint	175 C
SLoc	Setup Lock Code	10

Note: Key parameters are listed in Red. No need to adjust parameters on this controller.

Appendix B - Film Thickness vs. Dimer Mass

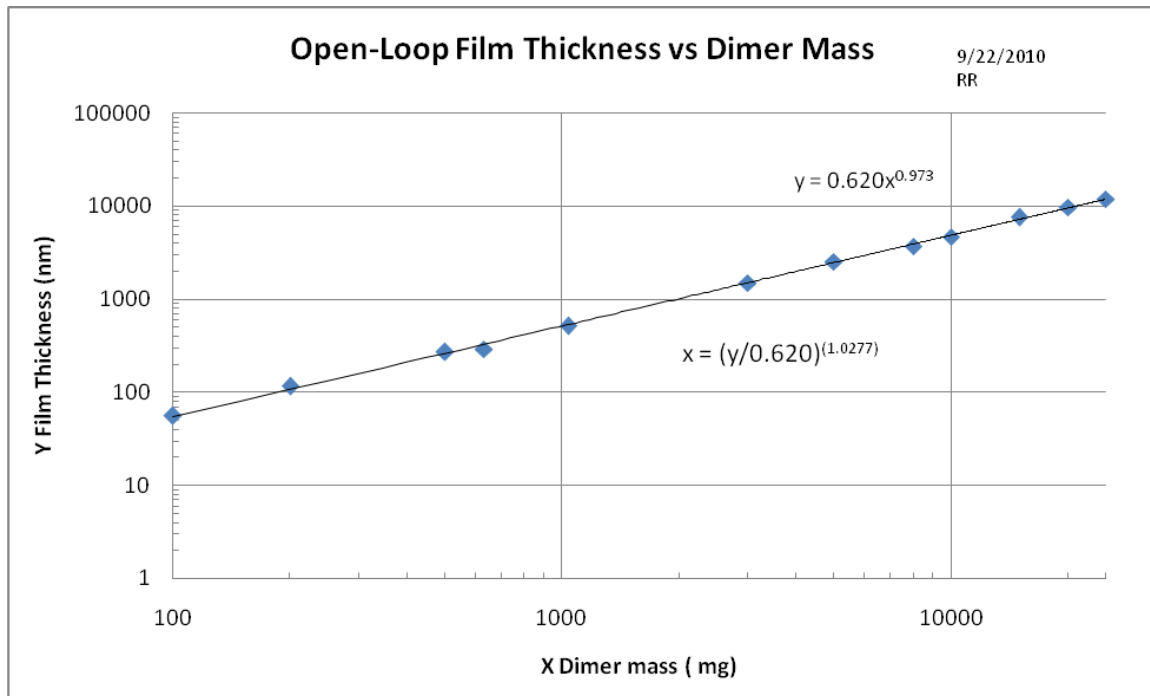


Figure B1. Chart of film thickness vs. Dimer mass in the Vaporizer. A more accurate estimate of the Dimer mass required for a given film thickness can be had by using the equations in the chart and a scientific calculator.

Appendix C - Peak Process Pressure vs. Dimer Mass

Parylene deposition at high rates of deposition create poor parylene films.² The purpose of showing this graphic relation is to define the maximum process pressure envelope so that the user can set a practical process pressure setpoint to limit the deposition rate to levels consistent with a good film deposition. The process setpoint must never be set higher than the curve in Figure C1. To do so would defeat the feedback loop control of the deposition rate. This would lead to defective films produced by process runs using the larger dimer masses.

This graph defines the maximum process pressure that can be achieved with no limit-control feedback loop as a function of the amount of parylene dimer in the vaporizer. This maximum is established by the maximum evaporation rate of the dimer set by the maximum vaporizer temperature and balanced with the pumping rate of the vacuum system. The process pressure falloff at low dimer mass occurs because the dimer is depleted before the vaporizer can achieve its set maximum temperature.

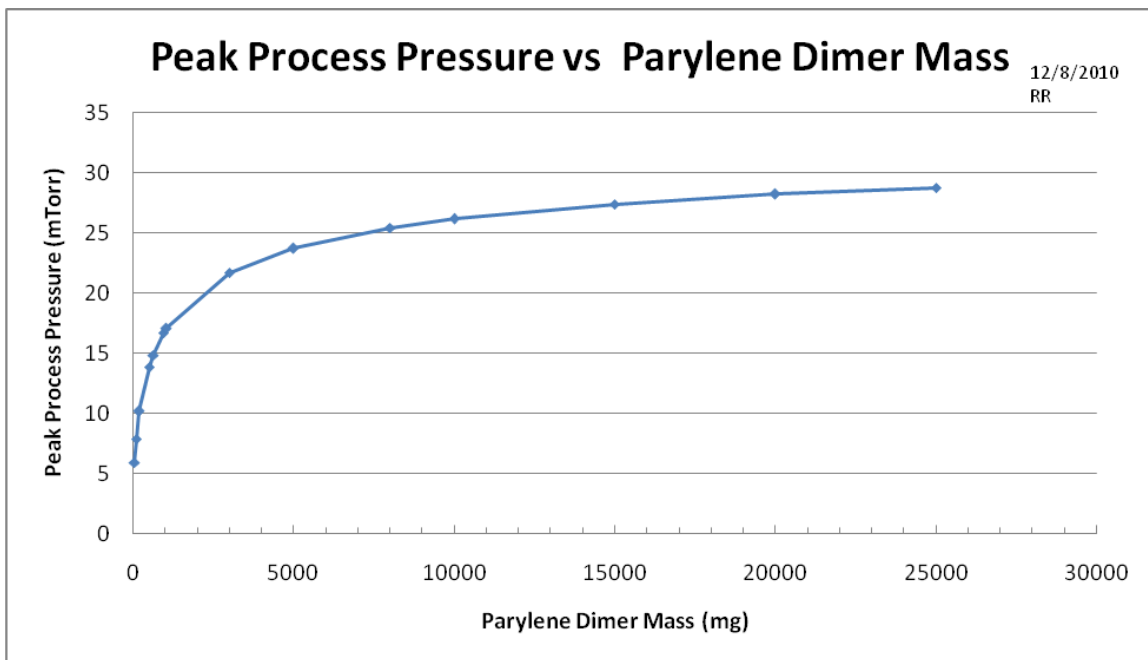


Figure C1. Graph of peak process pressure vs parylene dimer mass. The accuracy of this curve depends on the vacuum system being leakless, and the vacuum pump being in good condition with a proper base pressure capability. This curve follows a logistic Dose Response Function fit with 4 fitting constants.

NOTE: This graph was established with Vaporizer Temperature set point of 175 C. Peak Pressure curve will be different for different values of this Vaporizer temperature.

² SCS Instruction manual

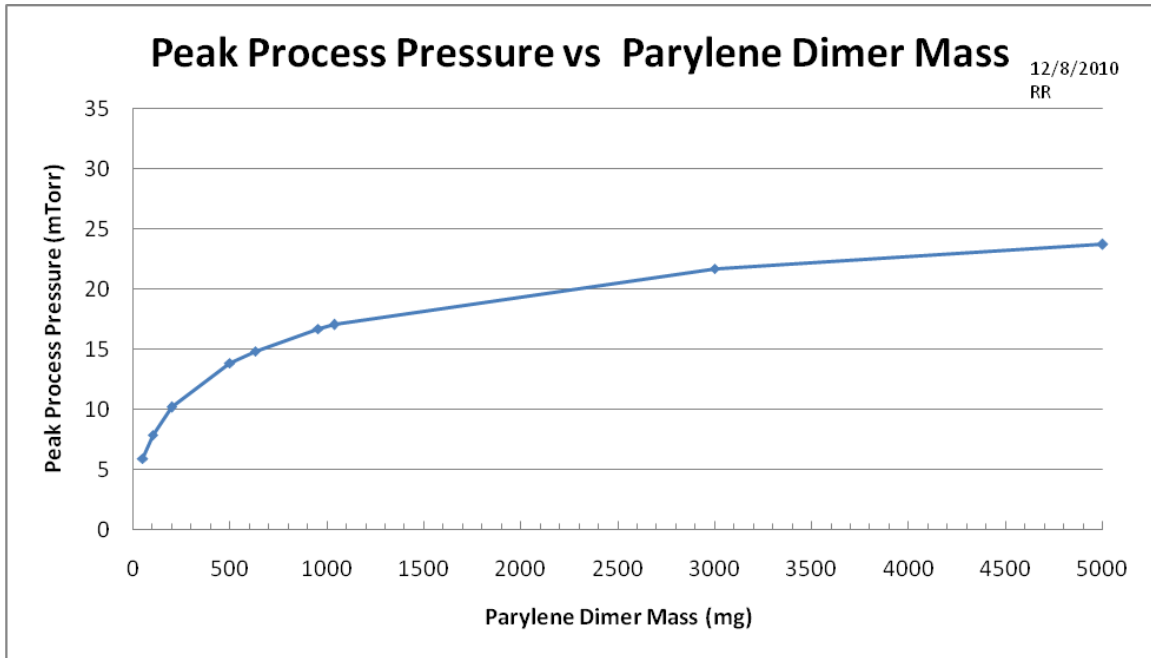


Figure C2. Expanded scale for Open-Loop Max Process Pressure vs Dimer mass showing lower Dimer mass range for easier reading.

Appendix D – Parylene Adhesion Promotion^{3,4}

Native Parylene has the propensity to peel off of some substrates. If you have a strong need to improve the adhesion, there is a way to do that. This Appendix describes a method of improving the adhesion using a chemical monolayer applied by liquid immersion.

The adhesion promoter is commonly called Silane A-174, but the chemical name is officially 3-Methacryloxypropyltrimethoxysilane (C₁₀H₂₀O₅Si). This is a liquid that needs to be mixed with IPA and DI water in a specific ratio and then sit for at least 2 hours to fully react before immersing the samples in it.

Adhesion Promoter Preparation

The steps to prepare the adhesion promoter follow:

1. Mix equal parts of Cleanroom IPA and DI water in a beaker in a solvent hood
2. Add 05% (1 part in 200) by volume of the Silane A-174 to the beaker.
3. Stir the mixture for about 30 seconds and let it stand for at least 2 hours to fully react.

NOTE: The shelf life of the solution is 24 hours, so mix only the amount that will be used during that time. Discard this solution after you have finished preparing all you samples. It can be poured into the solvent sink. (Please drain the sink and rinse with IPA after discarding).

SAFETY ISSUES: Avoid breathing vapors or contact with skin or eyes. Affects lungs (edema), Skin (irritation), Central Nervous system (depression, asphyxiation), and eyes (irritation). Do not remove mixture from the solvent hood to apply coating to samples.

Application to Samples

1. Submerge your samples in the solution for 15 – 30 minutes.
2. Remove the parts and allow them to air dry for 15 – 30 minutes.
3. Submerge your dried parts in IPA for 15 – 30 seconds. Agitate the samples during soak.
4. Blow dry the samples with a N₂ gun.
5. After coating all samples, discard solution in the solvent sink.

Samples should be coated with parylene within 30 hours (max) of applying Silane A-174.

³ Taken from the Specialty Coating Systems PDS 2010 LABCOTER™ 2 Operator's Manual.

⁴ New AdPro Poly Adhesion promoter for low surface energy polymeric substrates:
www.scscoatings.com

New Adhesion Promotion System

Specialty Coating Systems, Inc has recently announced a new adhesion promotion system that enables parylene to adhere very tightly to low surface energy surfaces, such as polyimide (Kapton) and other such materials. Further information can be obtained directly from SCS at their web site: www.scscoatings.com or the corporate phone number, 317 244-1200.

Appendix E – Parylene Properties Reference⁵

Parylene coatings are completely conformal, of uniform thickness and pinhole free. This is achieved by a unique vapor deposition polymerization process. The advantage of this process is that the coating forms from a gaseous monomer without an intermediate liquid stage. As a result, component configurations with sharp edges, points, flat surfaces, crevices or exposed internal surfaces are coated uniformly without voids.

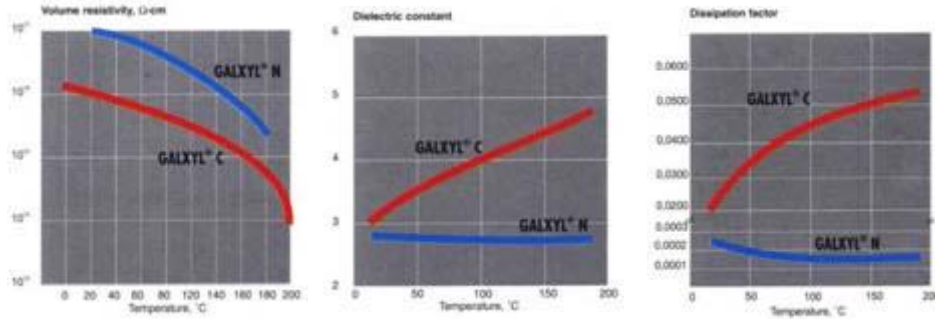
Properties

- High reliability - Suitable for military or commercial applications
- Light weight - Compared to other coatings
- Stress-free coatings - Sensitive circuitry unchanged by coating
- Low coefficient of friction - Use as a dry film lubricant
- Transparency - Thin films can be of optical quality
- Out-gassing - Virtually none
- Outstanding barrier - Very low permeability to moisture and gases
- Fungus and bacteria resistance - Excellent
- Mechanical - High tensile and yield strength
- Truly conformal - Uniform thickness on all surfaces
- Wide temperature range - From -200°C to +200°C
- Radiation resistance - Suitable for space applications
- Bio-compatible - Inertness invaluable for medical applications
- Particle retention - Upgrades electronic and mechanical devices
- Solvent resistance - Insoluble in common solvents
- Acid and base resistance - Resists attack from exposure
- Electrical breakdown - Extremely high dielectric strength

Typical Properties of GALXYL [®] Films	GALXYL [®] Parylene N	GALXYL [®] Parylene C	GALXYL [®] Parylene D
Data recorded following appropriate ASTM methods.			
Typical Physical & Mechanical Properties			
Tensile strength, psi	65,000	10,000	11,000
Tensile strength, MPa	45	69	76
Yield strength, psi	6,300	8,000	9,000
Yield strength, MPa	2,400	3,200	2,800
Elongation at break, %	40	200	10
Density, g/cm ³	1.110	1.289	1.418
Coefficient of friction: static	0.25	0.29	0.33

⁵ Data compiled and published by V&P Scientific, Inc., 9823 Pacific Heights Boulevard, Suite T San Diego, CA 92121, http://www.vp-scientific.com/parylene_properties.htm .

dynamic	0.25	0.29	0.31
Water absorption, % (24 hr)	0.01 (0.019")	0.06 (0.029")	
Index of refraction, n_D^{23}	1.661	1.639	1.669
Typical Electrical Properties			
Dielectric strength, short time (Volts/mil at 1 mil)	7,000	6,800	5,500
Volume resistivity, 23°C, 50% RH (Ohm-cm), see chart below	1x10 ¹⁷	6x10 ¹⁶	2x10 ¹⁶
Surface resistivity, 23°C, 50% RH (Ohm-cm)	1015	1015	5x10 ¹⁶
Dielectric constant: 60 Hz	2.65	3.15	2.84
1,000 Hz see chart below	2.65	3.10	2.82
1,000,000 Hz	2.65	2.95	2.80
Dissipation factor: 60Hz	0.0002	0.020	0.004
1,000 Hz see chart below	0.0002	0.019	0.003
1,000,000 Hz	0.0006	0.013	0.002
Typical Barrier Properties			
Gas Permeability *			
Nitrogen	7.7	0.95	4.5
Oxygen	30	7.1	32
Carbon dioxide	214	7.7	13
Hydrogen sulfide	795	13	1.45
Sulphur dioxide	1,890	11	4.75
Chlorine	74	0.35	0.55
Moisture Vapor Transmission**	1.50	0.14	0.25
* cm ³ -mil/100 in ² -24hr-atm (23°C)			
** g-mil/100 in ² -24hr, 37°C, 90% RH 1 mil = 1/1000 in = 25.4 microns			
Typical Thermal Properties			
Melting Temperature, (°C)	410	290	380
Linear coefficient of expansion, (10 ⁻⁵ / °C)	6.9	3.5	
Thermal conductivity, 10 ⁻⁴ (cal/sec)/(cm ² °C/cm)	3	2	



Parylene is a vacuum deposited plastic film used to coat many types of substrates. These coatings provide excellent corrosion resistance, barrier properties and exhibit superior dielectric protection. Some items already benefiting from Parylene conformal coating include:

Accelerometers	Bobbins	Capacitors	Catheters	Circuit boards
Coils	Ferrite Cores	Disk Drive Components	Fiber Optic Components	Heat Exchangers
Hybrids	Keypads	Flow Meter Components	Magnets	Pacemakers
Wire	Probes	Photoelectric Cells	P.I.N.D. rejects	Relays
Semiconductors	Sensors	Transformers	Thermistors	Elastomerics

Understanding Parylene

Parylene, unlike other polymeric materials, is not manufactured or sold as a polymer, but rather is produced by vapor-phase deposition and polymerization of para-xylylene (or its substituted derivatives). A highly crystalline, straight-chain compound, parylene as a vacuum deposited plastic has the unique quality of coating in a completely uniform manner. Unlike dip or spray coatings, condensation coating does not run off or sag, is pinhole free, will not bridge, so that holes can be jacketed evenly, will conformally coat over edges, points, and internal areas. With parylene, the object to be coated remains at or near room temperature eliminating all risk of thermal damage. Masking can be used if desired on areas not to be coated.

Parylene is extremely resistant to chemical attack, exceptionally low in trace metal contamination, has superior dielectric strength (5000 volts/mil at 1 mil), a very low dissipation factor, excellent mechanical strength, very high surface and volume resistivities, and other superior electrical properties that remain virtually constant with changes in temperature.

Parylene can simultaneously coat many small parts of varying configurations. In current commercial applications, parylene is deposited in thicknesses ranging from a few thousand angstroms to about 75 microns depending on the function the parylene film has to perform. Parts so small that they cannot be

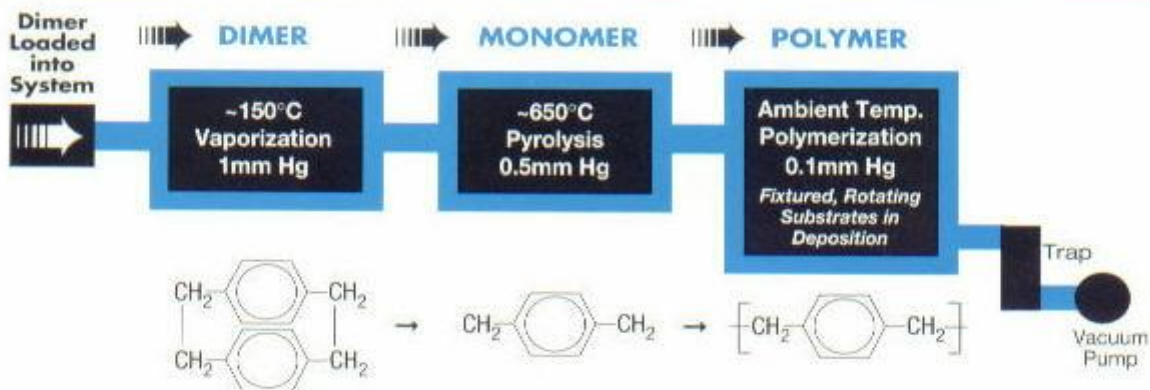
seen by the naked eye can be conformally coated to thicknesses that can be controlled generally to plus or minus 10%. This provides physical barrier properties equal to or better than, the 2-6 mil thickness of epoxies, silicones, urethanes or other conventional coatings which generally require multiple applications to eliminate pinholes. Parylene requires no catalysts or solvents thus eliminating environmental concerns.

Because of very low coefficients of static and dynamic friction, that are virtually the same, parylene can serve as a "dry film" lubricant which aids greatly in devices such as miniature servo motors, where starting torque can be a problem.

Parylene N is poly-para-xylylene which exhibits all of the above characteristics in addition to the ability to be used at temperatures exceeding 220 degrees C in the absence of oxygen.

Parylene C is poly-monochloro-para-xylylene, and is the most widely used member of this unique polymer series due to its excellent barrier properties. Parylene C offers significantly lower permeability to moisture and gases, such as nitrogen, oxygen, carbon dioxide, hydrogen sulfide, sulfur dioxide and chlorine, while retaining excellent electrical properties.

Parylene Coating Process



Parylene is not produced or sold as a polymer. It is not practical to melt, extrude, mold or calender as with thermoplastics. Nor can it be applied from solvent systems. Actually, many of the advantages found in parylene coatings, unlike epoxies, urethanes or silicones are a direct result of the coating deposition process.

The parylene process is a relatively simple vacuum application system, that starts with a dimer, which is placed in a vacuum system and converted to a reactive vapor of the monomer. When passed over room temperature objects, this vapor will rapidly coat them with a polymer (note illustrations). The end result is an almost impervious uniform finish.