Optimising the Parylene Process for Sensor Applications

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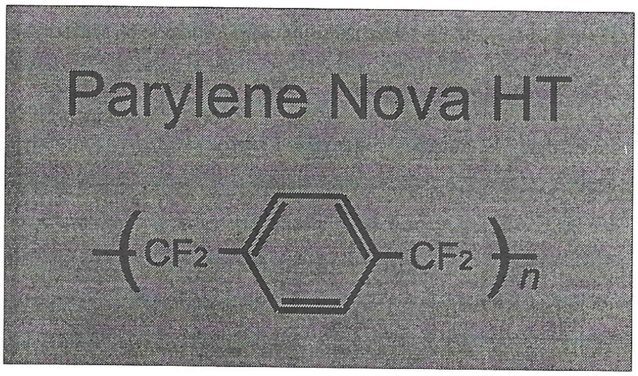
Parylene conformal coating technology, originally developed by Union Carbide and acquired by Cookson in 1994 has been in commercial use for more than 25 years. Parylene application benefits include solvent-free processing, elimination of cure by-products, and an environmentally friendly process.

The purpose of this paper is to discuss issues to be considered in optimising the Parylene process for sensor coating. Specialty Coating Systems has conducted an extensive evaluation of commercially available dimer to determine the primary factors required producing high quality, defect-free Parylene film. The objective of the SCS Parylene dimer evaluation was to identify ways to reduce cycle time, minimise dimer consumption, increase Parylene film voltage breakdown, improve penetration of the polymer inside housings, and maximise film clarity.



Apart from Parylene N, C and D a new, SCS Nova HT, is under development and nearing commercialisation, for applications demanding high temperature. Nova HT polymer is a fluorinated version of Parylene N, and has a crystalline melting point above 500 °C which is at least 250°C higher than the recommended continuous exposure level for conventional Parylenes N, C and D. Superb dielectric properties are realised due to the integration of fluorine into the Parylene molecule and the resulting stability of the polymer, including UV resistance.

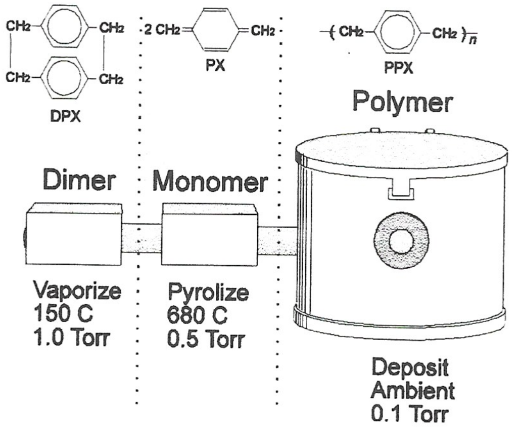
The development of Nova HT is a result of the VIP™ AF-4 Parylene program, which is under development for use as an interlayer dielectric in next generation integrated circuits. Its dielectric constant of only 2.28 minimises interlayer capacitance and enhances circuit operating speed by minimising both power consumption and cross-talk.

The benchmark study for the conventional Parylene dimers confirmed that there are 4 primary factors involved in optimising the process for consistent, defect-free film. Viz.

1) the Parylene dimer precursor
2) vapour deposition equipment
3) deposition process parameters in pressure, temperature and cycle times
4) process control methodology

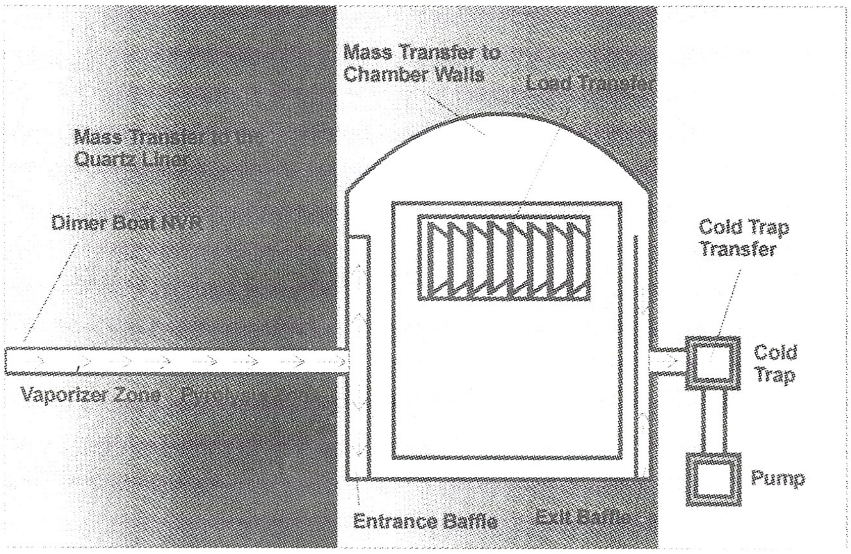
The Parylene Coating Process

Parylene dimer, di-para-xylylene, the precursor to polymer film, is a white crystalline solid. Dimer undergoes sublimation, cracking, and chemical vapour deposition to form Parylene film. Parylene dimers N, C and D are sublimed in a vaporiser at 100C-150°C, molecularly cleaved in a pyrolyser at 600°C to 700°C to form the diradical, para-xylylene, an active monomer gas that polymerises on substrate in the deposition chamber at 20°C-40°C



Dimer Precursor

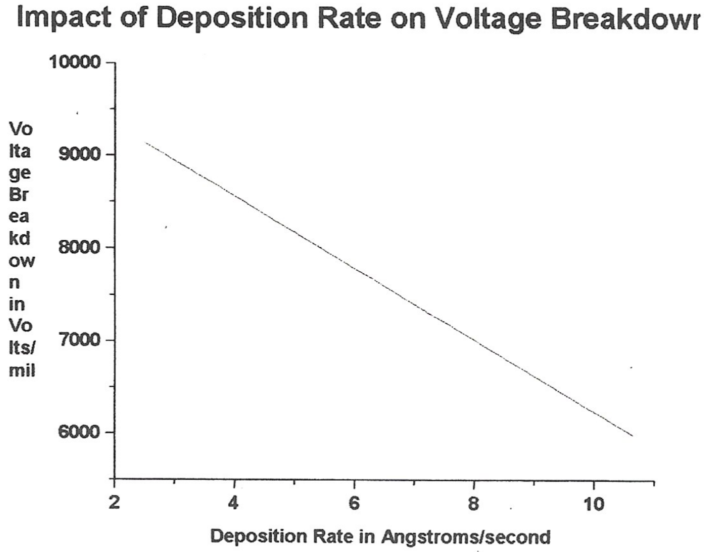
Commercially available dimer is manufactured by essentially two different processes, and the chemical compositionof the dimer depends on which process is used. Chemical composition has been shown to be of minor importance provided the dimer is manufactured to industry-accepted standards. Statistical process control is important – dimer must be consistent from lot-to-lot to support a controllable deposition process. SCS tests show that some commercially available dimers can vary from lot to lot depending on the supplier. This is critical as an optimised process may be affected by changing dimer sources.



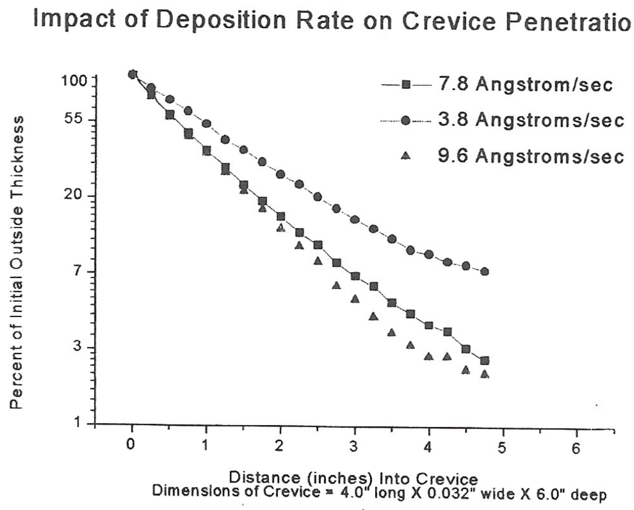
Parylene mass transfer was measured at key process points for each dimer type. Depending on the variation of the manufacturer's process and dimer quality, Parylene deposition process control can range from extremely critical to very general. The optimum Parylene dimer offers wide process latitude so the user can produce within an adequate operating window.

Processing parameters

Deposition rate is a processing parameter that has significant impact on film quality and performance. The effect of the Parylene deposition rate on the voltage breakdown value of deposited Parylene C film, for example, at a coating rate below 3 Angstroms per second, the film voltage breakdown in volts per /25 Micron thickness (mil) is greater than 9KV. That value drops by one-third to about 6KV at a Parylene deposition rate of greater than 10 Angstrom/sec.



The relationship between deposition rate and crevice penetration for Parylene C is illustrated by a further result. At a point 5 cm inside a crevice (10 cm long, 0.8 mm wide, 15 cm deep) the percentage of initial film thickness varies from approximately 25% at a deposition rate of 3.5h Angstroms/ second to around 13% at a 9.6 Angstroms/second deposition rate. Parylene users can achieve the required crevice penetration results by making allowance for his performance difference



This is what SCS refers to as a user-friendly process.

Film Quality

High quality Parylene film exhibits optical clarity, high dielectric strength, and proper physical and mechanical characteristics as demonstrated by flexibility/elongation, low permeability, and smooth, featureless micro-topography. The film thickness must be sufficient to meet the user's product requirements, with uniform distribution, crevice penetration, and gap fill across all substrates.

Properly deposited Parylene film is characterised by good transfer efficiency (dimer-to-film conversion on the substrate), good surface adhesion, and minimal uncleaved dimer or pyrolysis by-products. Pushing the deposition process too quickly in order to reduce cycle time may result in a dimer vaporisation rate that exceeds the system's pyrolysis and deposition capacity, and results in poor quality film. The optimum dimer vaporisation rate is based on the dimer selected, the vacuum level in the deposition chamber, load geometry, and the surface area to be coated.

An optimised Parylene process achieves the required film thickness and film quality with minimum dimer consumption and minimum processing time. Reducing cycle time by accelerating the vaporisation process will generally result in film that does not meet the application requirement. In contrast, running the process too slow is an ineffective utilisation of capital and resource investments.

Trends in sensor applications

The main development in sensor protection is to provide an environmental barrier at very low thickness thereby not affecting the mechanical properties of the sensor. Typical examples are pressure and temperature and proximity sensors. A clear trend is to use typically 5 Micron thickness for a relatively robust electrical insulating layer with adequate moisture protection. To make allowance for the geometry of the sensors a controlled deposition rate will aid in penetrating the smallest critical crevices.

Application of sensors at very high pressures for temperatures in excess of 180 can be realised in fuel exposed environments.

In the field of Petrochemical sensor applications, where a life of only 24 hours is required ceramic packages are being replaced by Parylene at temperatures as high as 220C-250C. For longer-term exposure to in high temperature –highly aggressive environments. the application of Nova HT is currently accepted and increasingly used.

Summary

The SCS Parylene deposition benchmark study demonstrates the importance of a Parylene coating specialist as a resource for users that are seeking to optimise Parylene coating operations, for both technical excellence and cost-effective processing. Users of this sophisticated, high-performance coating process benefit strongly from the support of a supplier with a secure source of dimer, state-of-the-art processing equipment, practical experience, and strong technical resources.

Supplier to supplier, and that there are clear differences between commercially available dimers in terms of processing requirements and latitude. It is important that a dimer supplier be capable of producing high quality dimer with consistent, predictable qualities so that the user can adjust and maintain process parameters with confidence.

As stated earlier, the benchmark study confirmed that there are primary factors involved in optimising the Parylene process for consistent, defect-free film. These are

1) the Parylene dimer precursor
2) vapour deposition equipment
3) deposition process parameters in pressure, temperature and cycle times
4) process control methodology

Failure in any of these can result in poor quality film. With experienced technical support, even inexperienced users can integrate Parylene film into the manufacturing process quickly and efficiently, and implement the multiple benefits of this coating technology.