UV rays that can damage other types of conformal coatings and degrade transmission signals. Parylene is UV stable and holds a dielectric constant of 7,000 volts per mil at 25 micron thickness. Courtesy of NREL/National Renewable Energy Laboratory

The right coat for effective protection

ALL RENEWABLE energy systems rely on precision electronics to ensure they can deliver energy in a consistent manner. These electronics are subject to harsh use and hostile environments and need protection. One solution is Parylene protective coatings.

Whether solar, wind, or any other renewable energy technology, electronics are the critical component to convert, invert, connect, transmit, track, regulate and monitor the system. The electronics are, however, often the weak spot in all systems.

Take solar PV technology. Currently solar panel/module systems carry a warranty of 25-30 years. Most inverter electronics need replacement in 10-15 years. In wind turbines failure of the electronics within the nacelles are the leading cause of downtime and repair expense for OEM's and wind farm operators.

It's not that the industry is using less that the very best possible in electronic assemblies, components and boards. They are using top of the line and the latest in integral electronics for sensor, transmission and data analysis technology.

The issue is that unlike consumer electronics or even the electronics within motor vehicles that see a harsh working environment, these electronics are installed in very hostile working environments and are expected to perform trouble-free for 30 years. Not many vehicles are expected to last that long nor consumer electronics which are quickly replaced by the latest and greatest.

While there definitely are going to be upgrades as technology advances over the years, the goal should be to upgrade because it is wanted, not because of a failure that requires an emergency repair and replacement.

The question is then, how to protect these densely populated and highly sophisticated electronics so 'long-life' becomes a reality. For many reasons, typical conformal coatings are not the answer.

Parylene - the answer?

Alan Hardy, electronics market manager for **Specialty Coatings Systems**, based in Indianapolis in the US, notes most electronics in these applications can not be protected using standard conformal coating materials because they are too thick, too hard to apply, do not cover completely, add too much weight and do not provide a stable dielectric constant.

For these reasons, Parylene has been used in military and aerospace applications for decades. It's now time renewable energy manufacturers look at this ultra-thin coating, he believes.

"Rather than using dip, spray or other mechanical deposition process, Parylene coatings grow one molecule at a time through the vapor deposition process," Hardy explains. "The deposition chamber and items to be coated remain at room temperature throughout the process. No solvents, catalysts or plasticisers are used in the coating process. No curing process or added steps are required. Because there is no liquid phase in this deposition process, there are no subsequent meniscus, pooling or bridging effects as seen in the application of many liquid coatings. As a result, dielectric properties are never compromised."

He adds: "Parylenes' vacuum deposition process ensures that there is no potential for the trapping of air bubbles in or under the coating, unlike coatings that are sprayed, dipped or brush applied. When this occurs and the coating is exposed to harsh environments, air bubbles have the potential to open and expose the component to the environment ... and a possible short circuit. Coupled with its extremely light weight and high dielectric constant, Parylene is the ideal protection for all electronics used within the support devices that enable, transmit, track and monitor all types of renewable energy installations."

The family of Parylene conformal coatings (N,C,D and Parylene HT®) has been trusted as rugged and reliable protection solutions for a wide range of aerospace applications for over 40 years. Parylenes provide "excellent ultra thin" barriers for moisture, chemical and biological agents, are RoHS compliant and have

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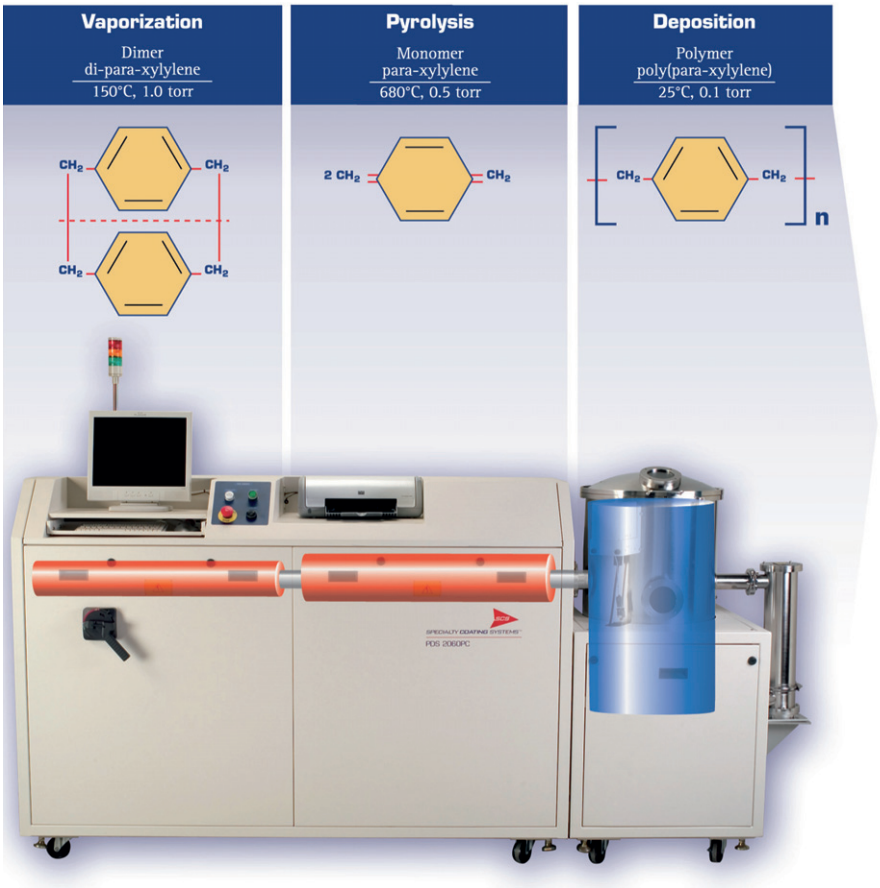
been proven to mitigate metallic whisker growth in lead-free solder applications.

Hardy says Parylene coatings are typically applied in thicknesses ranging from 500 angstroms to 75 microns. "A 25 micron coating, for example, will have a dielectric strength of 7000 volts. No other conformal coating materials can be applied as thinly and uniformly as Parylene and still provide the same level of protection." An added benefit of Parylene, he continues, is it can actually strengthen delicate wire bonds by an estimated factor of 10, "providing excellent durability where vibration is present" such as in wind turbines and energy harvesting systems.

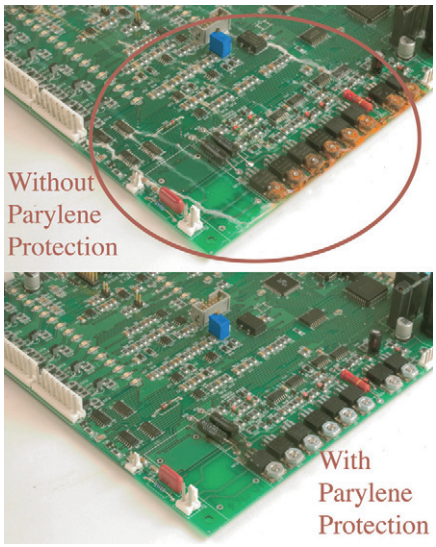
The polymerisation process and ultra-thin nature of Parylene enable it to conform to all surfaces, edges and crevices of a substrate, including the interior of multi-layer electronic packages and PCBs. This assures complete encapsulation of the substrate without blocking or bridging even the smallest openings. In addition, Parylene coatings are lightweight and do not add significant mass or dimension to delicate components.

Safeguarding renewables

Wind turbines come in many sizes and configurations and are unique to each manufacturer. However, regardless of proprietary designs, basically all wind turbines contain up to 8000 parts, including gearboxes, power systems, generators, sensors and electronic control and power systems. These and other components are typically housed in the nacelle, which is mounted on the tower. They must be able to withstand and operate with constant vibration, temperature extremes, location environments (land or sea water), and limited accessibility (for maintenance).



Rather than using dipping, spraying or other mechanical deposition process, Parylene coatings grow one molecule at a time through the vapor deposition process. Courtesy of Specialty Coating Systems (SCS).



Comparison of an electronic assembly exposed to hostile environment with and without Parylene protection. Photo: SCS

"Aside from the basic need to protect all these electronics from a very harsh working environment, the latest move is to reduce weight in wind turbines. Several top manufacturers are saying they want to reduce weight in wind turbines," Hardy says, noting the trend to cut weight and thus costs for larger turbines. "This is where Parylene can add superior protection, without adding significant weight."

Altitude, he stresses, has no adverse effect on Parylene. "There is no issue of outgassing as in other forms of conformal coatings. Also, salt water and harsh winds have little effect on Parylenes, due to the superior barrier properties. Therefore, on any ocean or seaside installation whether wind turbine, wave action or seaside solar farm, the inverters, transmitters or monitoring electronics are all protected."

Hardy notes that transmitters monitoring solar farms in arid, hot landscapes, PV or CSP are continually exposed to high heat, dust and UV rays. These can damage other types of conformal coatings and degrade transmission signals. "Parylene HT offers excellent UV stability to protect in such environments."

Bioenergy/Bio Digestible energy faces another issue, Hardy continues. "Aside from the extreme heat generated by the process, it also creates substantial methane type gases that

Key Properties of Parylene Coatings						
		Parylene HT	**Parylene C**	**Parylene N**	**Acrylic (AR)**	**Epoxy (ER)**
Dielectric Strength V/mil		5,400	5,600	7,000	3,500	2,200
Dielectric Constant	60 HZ 1 KHz 1 MHz	2.21 2.20 2.17	3.15 3.10 2.95	2.65 2.65 2.65	- - 2.7 - 3.2	3.3 - 4.6 - 3.1 - 4.2
Dissipation Factor	60 HZ 1 KHz 1 MHz	<0.0002 0.0020 0.0010	0.020 0.019 0.013	0.0002 0.0002 0.0006	0.04 - 0.06 - 0.02 - 0.03	0.008 - 0.011 - 0.004 - 0.006
Water Vapor Transmission Rate (g · mm)/(m^2 · day)		0.22	0.08	0.59	13.9	0.94
Water Absorption (% after 24 hours)		<0.01	<0.1	<0.1	0.3	0.5 - 0.10
Service Temperature	Continous Short-Term	350° C 450° C	80° C 100° C	60° C 80° C	82° C -	177° C -
UV Stability		≥ 2.000 hrs	≤ 100 hrs	≤ 100 hrs	-	-
Tensile Strength (psi)		7,500	10,000	7,000	7,000 - 11,000	4,000 - 13, 000
Penetration Ability		50 × dia.	5 × dia.	40 × dia.	Spray or Brush	Spray or Brush
Rockwell Hardness		R122	R80	R85	M68 -M105	M80 - M110

A comparison of the properties of three Parylene variants vs. Acrylic and Epoxy conformal coating materials. Courtesy of SCS.

Salt water and harsh winds cannot penetrate a Parylene barrier so any ocean or seaside installation whether wind turbine, wave action or seaside solar farm, the inverters, transmitters and monitoring electronics are all protected. Courtesy of SCS.

must be monitored and controlled to prevent release into the atmosphere. This requires a specific type of monitoring and control system. The electronics within these systems must not be affected by these gases or they will continually fail and need replacement. The barrier properties of Parylene make it impervious to methane and all types of hostile gases."

Taking this one step further, even monitoring on commercial and residential installations can benefit from Parylene protection, he contends. New smart meters monitor more than just solar or solar thermal performance usage data. These boxes are tapping into all areas of power usage within homes or commercial buildings. They are "set them, forget them" type installations that continually transmit data to the utility company and often the consumer too, depending on the type. They are invaluable – until they stop working correctly.

With the burden of more sophisticated electronics being created for smart meters, the computer-like intelligence must perform in environments filled with constant thermal changes, dirt and weather. "Smart meters don't have the luxury of the short life of a smart phone or PC. Nobody would leave their phone or PC out in a snowstorm or in the blistering heat. However, these smart boxes have the same type of electronic assemblies," Hardy says. They therefore require extra protection. "They have to endure the elements and keep working for years. Unlike a PC or phone, they are not meant to be replaced every year or sooner. Coating the internal electronics with one of the varieties of Parylene will ensure the electronics stay clean, moisture free and that transmission of signals will remain strong and clear."

Along with the more standard FR4 circuit board assemblies, Parylene is well suited for all flex circuit and rigid flex substrates. Even those using the latest in exotic materials are easily coated. Hardy says AdPro Plus® and AdPro Poly® from Specialty Coating Systems solve the adhesion challenges for difficult metallic, plastic and polyimide substrates without adding weight or changing the protective qualities of the Parylene coating itself. These enable Parylene conformal coatings to protect virtually every type of modern electronic assembly, he insists.

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