



Scalable Reliability for Consumer Electronics

Exceed Customer Expectations
and Accomplish Business Objectives
with Protective HZO Coatings

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Why HZO?

HZO is the global leader & innovator in protective solutions that keep the world running, delivering highly reliable nano conformal coating solutions that safeguard electronics, electrical products & critical applications in an ever-changing market. HZO works with some of the largest companies across industries from design through production, no matter the volume, complexity, or protection required, to deliver a better, more reliable, and more durable product.



Introduction

Consumer electronic (CE) design teams face unique challenges, including balancing priorities such as minimizing form factors, improving product performance, cutting costs, and reducing time to market. As users pay more and rely more on their devices, reliability is quickly becoming a top critical concern.

For the consumer electronics industry, the user environment can be highly variable, with the size of electronic components decreasing at an impressive rate. Over the last few years, the size of ICs has decreased by a factor of ten. For components on a PCB, the spacing of solder joints can be as little as 200 microns. This reduction in distance and size between components puts systems at more risk for corrosion problems; shorter distances between charged components, smaller features for contamination to hide in, and more complex signals all create a perfect environment for failures.

That said, in the landscape of “smart” products, premature product failures are very costly, resulting in brand devaluation, loss of revenue, or possible litigation. Hardware recalls are typically pricier than software recalls, as software patches can be easily downloaded and installed once problems come to light.

For consumer electronics, designing for reliability is becoming a crucial part of the product development process. Avoiding mass recalls including negative publicity, repair costs, and replacement logistics should be a priority of every CE design team.

Designing reliable products in this industry can be challenging, however, as they are exposed to various operating conditions and are more likely to be exposed to drops or accidental liquid exposure including swimming pools, rain, and sweat. As an engineer working in consumer electronics, it is your job to ensure that “portable” doesn’t mean “breakable.”



Smart Products Are Calling for a Shift in Solutions

As product design teams face these challenges, old methods of protection may no longer suffice. Consumer electronics products often incorporate seals into the design to prevent device damage caused by exposure to the operating environment. Seals do have their place as a legacy solution, though, as devices become smaller, the added bulk of seals is a growing problem.

Additionally, falls and physical shocks are common with consumer electronic products, which can potentially damage or dislodge a mechanical seal that will require subsequent repair or replacement to ensure the original level of protection.

Conventional conformal coatings are another option to protect consumer electronics devices from exposure to harsh operating environments. These thin polymeric layers applied directly to substrates and components provide barrier protection, thereby eliminating the problems concerning drops. Still, many of these coating materials may prove too thick and bulky when used to acquire a level of protection adequate for many of today's consumer electronics applications.



HZO provides an alternative solution to seals and conventional conformal coatings ideal for consumer electronics OEMs, providing Parylene coatings with processes that cut costs and allow easy ramp-up to mass production. Whether used in conjunction with seals as redundant protection or alone, our Parylene coatings can solve many reliability problems associated with harmful exposure to the operating environment.

The images below compare the results of a mechanical seal breach with a PCBA that has been coated with our Parylene a week after exposure. Parylene conformal coatings come in various types, including Parylene C, Parylene N, and Parylene F (VT-4), with nearly 50 years of excellent performance

with critical applications and industries. The coating is superior in uniform coverage, barrier properties, and performance at comparably thinner films, with less stress on mechanical structures and virtually no added weight.

Unlike liquid conformal coating methods that may lead to coating defects, Parylene conformal coatings are unique in their ability to be polymerized and deposited by vapor deposition onto substrates maintained near room temperature. The result is extremely thin, pinhole-free, high purity coatings that fulfill the reliability requirements of consumer electronics design.

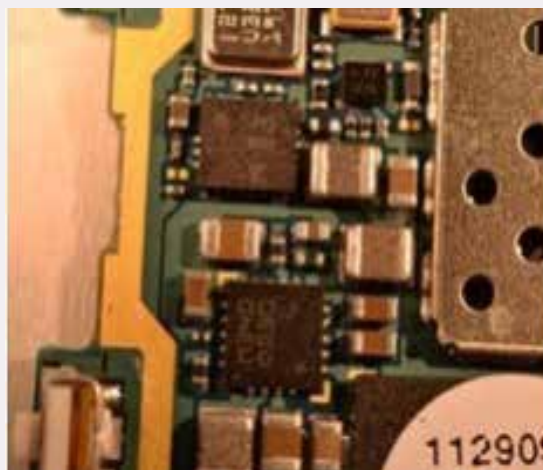
HZO provides an alternative solution to seals and conventional conformal coatings ideal for consumer electronics OEMs.

Solution to Mechanical Seals

As the visual below indicates, a mechanical seal can easily be breached. With HZO's Parylene protection, moisture ingress is not an issue.



Mechanical Seal Breach



HZO Parylene

One week after water exposure

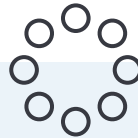
HZO Coating Benefits for Consumer Electronics



High levels of submersion protection up to IPX8 rated protection when combined with compatible product design.



Resistant to a wide range of environments and chemistries in everyday environment – moisture, humidity, sweat, solvents, acids.



Uniform, pinhole free coating. Significantly reducing the risk of corrosion.



Excellent conformity. Can completely penetrate voids as narrow as 0.01mm.



Optically transparent and can be used to coat optical elements.



Biostable, biocompatible, environmentally friendly. No VOCs, no solvents.



No initiators or catalysts in polymerization process, coating is pure and free from trace ionic impurities.



REACH, RoHS, PFOA/PFOS-free, and CA Prop 65 compliant.



Room temperature formation makes the coatings effectively stress-free.



Low dielectric constant with good high frequency properties, good dielectric strength, and high bulk and surface resistance.



No cure time means no additional production time or equipment required for curing.



No pooling of coating in low areas, ensuring consistency.

Lightweight Protection

Staying competitive in the consumer electronics industry is a race to make products thinner, smaller, and more energy-efficient. Components are becoming increasingly smaller and more complex with increasing integration to keep up with market demands.

Our Guardian™ Series of Parylene conformal coatings have passed the IPC-CC-830C test at 50% of the film thickness of conventional conformal

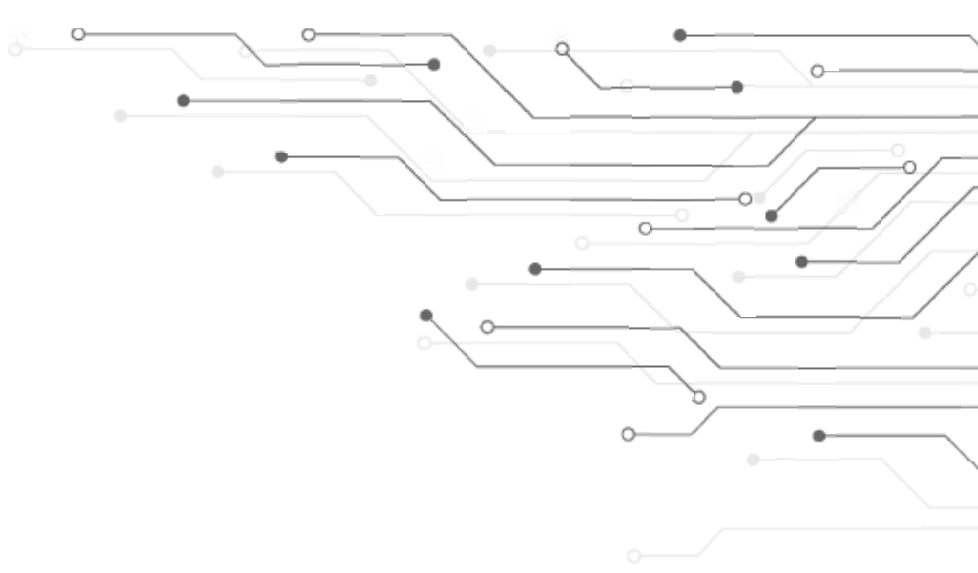
coatings, proving that we can provide as much - or more - flexibility, fungus resistance, flammability, dielectric withstanding voltage, thermal shock, moisture, and insulation resistance at a fraction of the mass, allowing you to design miniaturized, reliable products easily.

IPC CC-830C Results

Class	Type	Specimen - Avg. Coating Thickness (µm)			
		Specimen 1	Specimen 2	Specimen 3	Specimen 4
XY	Parylene N	25	25	23	23
XY	Parylene C	31	30	30	32
XY	Parylene F	46	36	43	29
AR/UR	Acrylic	73	73	69	72
SR	Silicone	102	99	114	154
AR/UR	Acrylated Polyurethane	91	91	107	107

HZO's Parylene passed all IPC CC-830C at 50% of the Film Thickness of the Traditional Conformal Coatings.

Sustainability Support



Sustainability is top of mind for the consumer electronics industry as governments become more focused on minimizing e-waste. The average American household uses around 28 devices, and with the growing demand for consumer electronics products, the e-waste problem continues to escalate. In 2018, The EPA found that Americans generated 2.7 million tons of consumer electronics e-waste.

With high turnovers and low costs, consumers may throw unwanted electronic products away with the regular garbage, which means items with potentially high recycling or reuse value go to landfills. E-waste policy has recently emphasized reusing whole

appliances, encouraging reuse and repair.

The solution for OEMs may be to produce long-lasting devices to keep them out of the waste stream for a more extended period. When the Parylene type and thickness are selected carefully and the surface preparation is correctly done, Parylene conformal coatings are very stable and will withstand – and extend – the life of the devices they protect.

Furthermore, we understand the importance of green manufacturing, offering sustainable materials, processes, and guidance.



HZO's support includes:

 Material oversight	Responsible end-of-life management	Preparation for repair, reuse, and recycling 
 Proactive chemical management	 Corporate social responsibility	
 Green material usage		

HZO's Parylene coatings are:



REACH Compliant



RoHS Compliant



Prop 65 Compliant

HZO Parylene coatings have:



Biostability

Stability within a biological operating environment.



Biocompatibility

Compatible within a biological operating environment.



No VOCs

No volatile organic compounds.



No Solvents

No solvents found within the material.



No Catalysts

Pure and free of trace ionic impurities.



No Disposal Issues

Ability to be disposed of safely and within regulation.



No Pollution Threats

No harmful pollutants found with the material.



No Cure Time

No additional time or equipment required for curing.

Meet and Exceed IP Marketing Claims

To remain competitive in the consumer electronics industry, it is often necessary to make marketing claims about ingress protection standards, such as passing IPX8 protection tests. Our proven Parylene coatings can sustain electronics through liquid

submersion, thereby allowing you to exceed any IP level of protection without the need for hours spent on customizing designs for seals or risking failure with conventional conformal coatings.

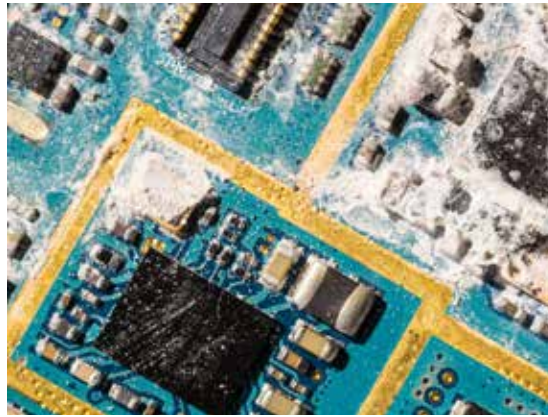
Liquid Ingress Protection Standards (e.g., IPX7)

Level	Protects Against	HZO Coating Protection
0	None	Exceeds
1	Dripping Water	Exceeds
2	Dripping Water When Tilted at 15°	Exceeds
3	Spraying Water	Exceeds
4	Splashing of Water	Exceeds
5	Water Jets	Exceeds
6	Powerful Water Jets	Exceeds
7	Immersion, Up to 1 Meter Depth for 30 Minutes	Exceeds
8	Immersion for Greater Time and Depth Than IPX7 (Typically 2 Meters for 1 Hour)	Exceeds

Reliable Corrosion Resistance

Consumer electronics devices run on batteries and electricity. If they are not adequately protected, one drop in water can be a sufficient catalyst for the corrosion process, leading to unexpected premature failure.

Despite the thinness of HZO coatings, our Parylene performs exceptionally well as a barrier to corrosion due to its ability to minimize the influence of the factors that affect coating lifetime and performance, including the following:



Uncoated PCBA with corrosion

Parylene Corrosion Resistant Properties

Oxygen permeability	Low oxygen permeability for a polymer coating
Water vapor permeability	Very low WVTR for a polymer coating
Liquid water uptake	Parylene absorbs very little water
Ionic permeability	Salts have a difficult time passing through the coating
Coating porosity	At a thickness of just 5 μm , Parylene forms a pinhole/pore-free coating

Parylene C is the most effective conformal coating available for corrosion protection at its thickness.

Water vapor transmission rate (WVTR) and gas permeability are properties that indicate barrier effectiveness for corrosion resistance. As the table below shows, Parylene C's WVTR and gas permeability properties are extremely low. Consumer electronics devices are often exposed to various corrosive conditions, and corrosive damage can be particularly frustrating to your customers. If they experience device failure immediately after a drop into liquid, it would be expected. But because corrosion is a slower process, premature device failure may seem inexplicable and "out of the blue," leading to mistrust and damage to your brand. Fortunately,



Uncoated PCBA with corrosion

our consumer electronics partners have enjoyed increased brand loyalty in part due to our coatings as we ramp up production for them to meet escalating demands.

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Barrier Properties of Conformal Coatings

Polymer	Gas Permeability at 25 °C, (cc·mm)/(m ² ·day·atm)							WVTR, (cc·mm)/ (m ² ·day·atm)
	N ₂	O ₂	CO ₂	H ₂	H ₂ S	SO ₂	Cl ₂	
Parylene C	0.4	2.8	3.0	43.3	5.1	4.3	0.1	0.08
Parylene N	3.0	15.4	84.3	212.6	313	745	29.2	0.59
Parylene F (VT-4)	-	-	16.7	-	-	-	0.28	-
Epoxy (ER)	1.6	4	3.1	43.3	-	-	-	0.94
Polyurethane (UR)	31.5	78.7	1,181	-	-	-	0.93	-
Silicone (SR)	-	19,685	118,110	17,717	-	-	-	-

Applications

Hearables

In recent years, headphones have evolved and witnessed vast improvements in technology, transforming into multi-functional smart gadgets. These technological innovations and features, including noise cancellation, improved wireless connectivity, and fast charging technology, expand their use and increase demand. But one of the most critical features driving consumer adoption is water resistance.

Hearables are not only exposed to fresh water, however. They are frequently subjected to different types of moisture – sweat, cleaning fluids, salt water, and chlorinated water that can also lead to cor-

rosion and subsequent device failure much quicker than fresh water would. Cold weather condensation can also create a layer of moisture on hearables.

Along with corrosion and electrical shortages due to these hazards, perspiration or sweat is another concerning form of moisture, permeating the hearable circuitry and causing more severe damage. Many hearable devices cannot be repaired and must be replaced. It can cost over \$60 per bud to replace damaged products in addition to customer inconvenience and other costs associated with replacement.



Seals present design constraints for small hearable products, and it is difficult to use them for sweat proofing. Corrosive and slippery, sweat can easily penetrate these intended barriers to entry. Humidity is also damaging and exists as a vapor, allowing easy passage through seals used for water resistance.

Our customers have found that coating internal PCBs and batteries with our Parylene is a thin, lightweight, effective corrosion protection solution, allowing for the minimization of space constraints.

The image below outlines a hearable protection solution that HZO provided for a major consumer electronics manufacturer.



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Sweat Is One Of The Most Difficult Properties To Protect Against



PCBA PROTECTION

Salt from sweat can quickly compromise integrity. Accidental submersion is a frequent occurrence.

SPEAKERS

Acoustic vibration quickly dissipates moisture and water. Coatings are not necessary and can alter tone.

BATTERY

Coin cell battery should be protected from corrosive liquids.

MICROPHONE

Coatings are not recommended or required - they are inherently waterproof.

Applications

Wearables

Wearable products, including fitness monitors, smart jewelry, and smartwatches, have also made significant technological strides. Advancements in sensors and battery life enhance customer experience, and increasing development of next-gen smart interfaces escalates demand.

However, as they are worn on the body, they are exposed to numerous hazards, including water, perspiration, chemicals, corrosive sprays, motion, and vibration. Corrosion is a common cause of wearable

malfunctions, which typically use seals that wear out, allowing for moisture ingress.

Mechanical seal complications also come in the form of RF signal disruption, as this method integrates bulky materials that may interfere with connectivity. Many product design teams see constraints with seals as more processing continues to be packed into smaller spaces, and expectations for reliability, longevity, style, and finish continue to raise the bar.



Our coatings protect wearables from hazards common to their everyday environment. Unlike conventional conformal coating materials, Parylene is applied in thin layers, facilitating RF signal transmittance. HZO coatings make it easy to design and produce competitive wearable products that can exceed expectations now and well into the future.

The chart below describes example Parylene thicknesses and the corresponding standards and IP protection levels they can meet, subject to the overall design of the product.



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Parylene thickness and Ingress Protection (IP rating) Correlation

Thickness (µm)	0.1 to 5	5 to 12.5	12.5 to 25
Relevant Standards	IEC 60529	IEC 60529	IEC 60529
Protection Level	IPX3 / IPX4	IPX4 / IPX7	IPX7 / IPX8

Applications

Smart Homes

Smart home devices control, monitor, and regulate standard household functions, including temperature, security, multimedia, thermostats, entertainment systems, and window and door operations. In addition, connected home products such as thermostats, sensors, and intelligent lighting are used for energy management.

Increasing consumer preference for video doorbells, voice-assisted technologies, surveillance systems, growing internet penetration, and growing dependence on smartphones are major market drivers. The global smart home market is expected to reach \$182,422 in 2025.



Home Monitoring/Security

- Outdoor doorbells
- Security cams
- Smart door locks



Sensor Applications

- Smoke alarms
- Motion sensors
- Carbon monoxide alarms



Entertainment

- Speakers/soundbars
- Smart lighting
- Smart displays



Smart Appliances

- Washing machines
- Refrigerators
- Air conditioners

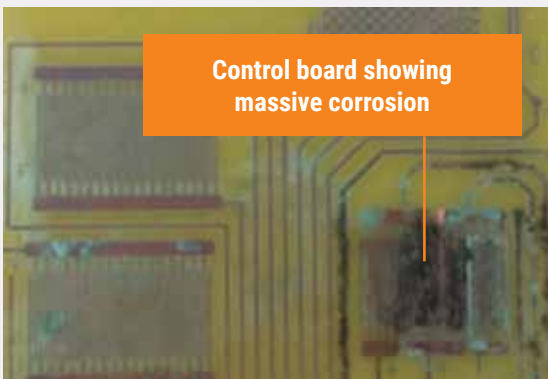
Due to their far-reaching capabilities, connected home products can be subjected to an outdoor (as in the case of a security device or video doorbell exposed to pollution or humidity) or a harsh indoor environment (such as a smart speaker used in a kitchen or a portable device jeopardized by splashes). Some appliances, such as a smart washing machine, need powerful waterproofing protection. Other operating environment threats include salt

fog and high temperatures that could cause legacy protection methods to fail.

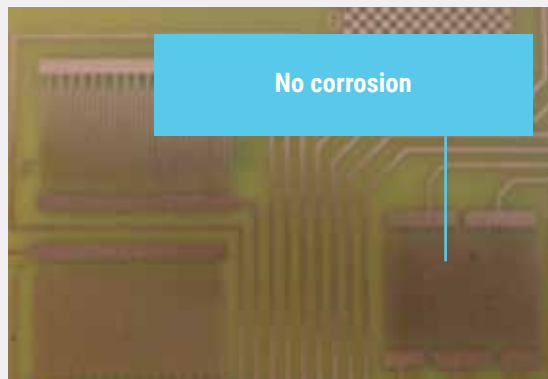
Fortunately, HZO's coating capabilities are as extensive as the environments and functions of smart home products. The images below show our Parylene coating performance when subjected to salt fog and humidity.

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Parylene Salt Fog Performance



Uncoated Board



HZO Coated Board

Testing Parameters

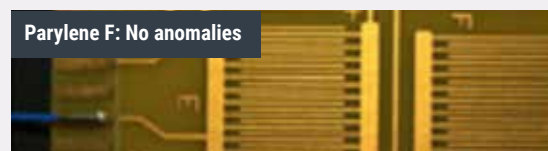
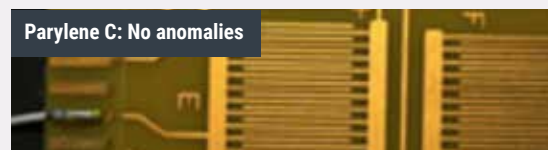
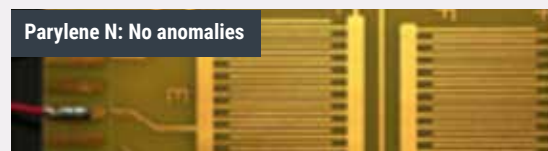
Temperature:
35 °C
Concentration:
5% NaCl by weight
Duration:
168 hours

Parylene IEC 60068-2-30 Humidity Performance 96 hour temp humidity exposure

The parameters within the chamber were set to 25°C with 96%RH to being the cycle. Each cycle consisted of:

- From 25°C with 96%RH to 55°C with 96%RH, ramp time set for 3 hours
- Hold at 55°C with 96%RH for 9 hours
- From 55°C with 96%RH to 25°C with 96%RH, ramp time set for 3 hours
- Hold at 25°C with 96%RH for 9 hours
- This 24-hour cycle was repeated for the duration of 96 hours

The samples were biased using 50VDC for the time of the test.



All testing conducted at certified lab

Scale Reliability With HZO

The Parylene Polymerization Process

Parylene coatings are ultra-thin, lightweight, and due to the chemical vapor deposition (CVD) application process, are highly conformal, wrapping evenly around every edge available. The CVD process is performed under vacuum, with specialized equipment that includes a coating chamber.

Since it is deposited as a vapor that lands on and begins building up a thin film that wraps around components and substrates with little to no change in thickness (fig. 1), Parylene is a truly conformal coating that ensures protection from corrosive environments even at tight corners.

Conversely, (fig. 2) conventional conformal coatings leave uneven coatings, with much thinner, vulnerable layers at the corners of the component or substrate, unless the coating is made so thick that it starts

adding size, weight, and potentially stressing components due to differences in thermal expansion.

In the comparison SEM images below, the conventional conformal coating on the right has poor coverage, in which it is thinner on the top corners, thicker on the top than the sides, and much thicker at the bottom. A bubble trapped underneath the component shows the coating didn't push all of the air from underneath as the coating was deposited. With so much coating at the bottom under the component, the coating may push up on the component or against the soldered leads as the electronic device is heated. After several hot-cold cycles, the coating may break the component's connection to the board, creating an electrical open.

Parylene is considered the gold standard of conformal coatings and is a strong consideration for consumer electronics protection.

Parylene Conformality Compared to Conventional Conformal Coatings

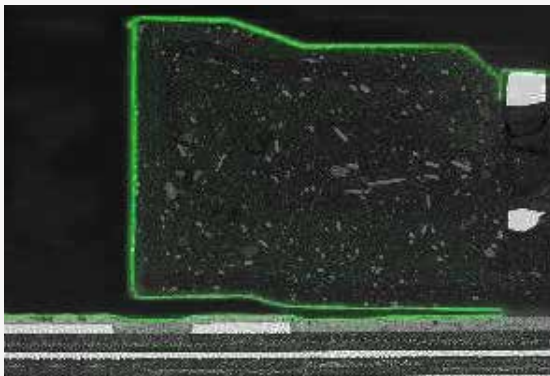


Fig 1: SEM image and chlorine map (combined) of Parylene conformal coating coverage (green line)

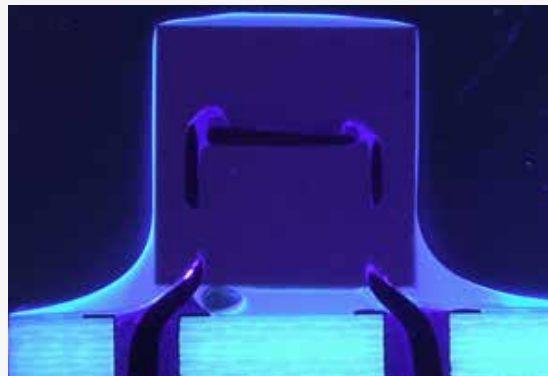


Fig 2: SEM image of conventional conformal coating coverage (Source: IPC-SMTA)

Scale Reliability With HZO

High Volume Manufacturing for Consumer Electronics

Typically, obtaining premium protection comes with a price. Parylene is generally more costly than most other conformal coatings, requiring a batch-style coating process, and sometimes, a longer coating time. HZO addresses these Parylene shortcomings through engineering and manufacturing solutions.

We can rise to mass-scale production within a specified budget or deadline. We focus on creating tight run-to-run repeatability with unique CVD attributes to ensure consistent protection, such as temperature customization, pressure, materials, coverage, and environmental considerations. With the combination of our in-house designed equipment, tested processes, and chemistry, our throughput can be two times faster than the industry standard.

Proprietary equipment with optimized cubed chambers can house more substrates and components than any other Parylene supplier in the industry, decreasing turnaround time and improving throughput. The chambers are larger in size, but the cubed shape also allows for high loading density so that not as much surface area is lost. The numbers of parts coated for consumer electronics vary, but HZO's manufacturing process allows for efficient high throughput. For reference, around 5,000 cell-phone PCBAs may be coated at once. 10,000 – 20,000 hearable components or batteries may be coated in a single batch. The image below outlines our Parylene process for high-volume applications.

The numbers of parts coated for consumer electronics vary, but HZO's manufacturing process allows for efficient high throughput.

HZO Application Process



1. Pre-Processing

- Inspection of PCBAs/components for quality standards and control for product tracking
- Masking of areas and components where coating is not required
- Masking may be manual or automated depending on the needs of the customer



2. Production

- PCBAs/components situated on custom racks and placed in coating chamber
- Raw material sublimated from solid to vapor form, then heated to transform into an activated monomer
- Vapor forms uniform, thin-film polymer barrier around PCBA/components in coating chamber



3. Post-Processing

- Any previously applied masking material is removed from the PCBA/components
- Removal of masking may be manual or automated depending on the needs of the customer
- Manual or automated inspection of PCBAs/Components before final assembly

Our IP (intellectual property) backed equipment automates the required masking and demasking process to ensure that critical components such as connectors do not get coated. This process can be labor and cost-intensive when performed manually, increasing the risk of quality issues down the road. Automated and semi-automated masking and demasking effectively drive down costs associated with the Parylene process. Automated masking and demasking are complex, industry-leading, and somewhat unique to our company.

We are also dedicated to quality assurance. Since HZO's inception, there has not been a single product field return attributed to coating issues, although

we have coated millions of components. Finally, we offer considerable convenience for consumer electronics OEMs, with highly configurable processes that integrate into many production points, a turn-key solution or other flexible business models, and hands-on help from dedicated engineers who help companies walk through solutions from beginning to end.

If you are looking for gold-standard protection that can be acquired at a consumer electronics price point and level of scalability, reach out to us today to learn more about our consumer electronics solutions.

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MORE ABOUT HZO

Traditionally, Parylene can be considered more costly than most other conformal coatings, requiring a batch-style coating process and sometimes a longer coating time. HZO, a leader in nano conformal coatings, addresses these Parylene shortcomings through engineering and manufacturing solutions to meet or exceed manufacturing requirements and compete with legacy solutions.

Proprietary equipment with optimized cubed coating chambers house more substrates and components than any other Parylene supplier in the industry, decreasing turnaround time and improving throughput. The company utilizes IP (intellectual property) backed equipment that automates the required masking and demasking process to ensure that critical components such as connectors do not get coated.

Finally, HZO offers considerable convenience, with highly configurable processes that integrate into production, provide a turnkey solution including hands-on help from dedicated engineers that help companies walk through solutions from beginning to end.

To learn more about HZO's consumer electronic protection solutions, contact us today.

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