EmPowering Reliability: Protective Coatings for Lithium-ion Batteries

Add proven durability without adding bulk or weight

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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

Batteries are a critical energy source, as ubiquitous as the electronic products they power across diverse industries. As electronics continue to proliferate, so does the demand for the batteries that enable their operation. Lithium-ion (Li-ion) batteries specifically are experiencing notable growth, as they provide benefits such as low self-discharge, low "memory" (the tendency to acquire a minimum or maximum state of charge), and the highest energy density for any battery commercially available on the market. Uses are found for these batteries in the military, automotive, aerospace, communications, consumer electronics, industrial, and marine applications, to name but a few.

Although they are often critical components of electronic products, the truth is, all batteries fail, whether nickel-cadmium, alkaline, or lithium-ion. This pending failure is simply a matter of time, physics, and chemistry. While many batteries fail benignly, causing inconvenience or aggravation at most, premature failure is of extreme concern to manufacturers and product design teams. The results of premature Li-ion battery failure can range from exorbitant costs (as in unplanned downtime) to life-threatening situations (in the case of mission-critical applications) to catastrophic events causing cascading systems failure.

Understanding these consequences, HZO has engineered solutions that can extend battery lifetime, increase reliability, and minimize e-waste. Our thin-film coatings, protective barrier layers applied to vulnerable components of lithium-ion batteries, can prevent premature failure induced by exposure to harsh environments.

How HZO's Coatings Can Prevent Premature Battery Failure

As they are used to power cell phones and miniaturized devices, lithium-ion batteries are often required to fit into smaller form factors. Still, robust protection from harsh environments is needed. Yet, the thickness of traditional conformal coatings raises limitations as they add weight and bulk.

On the other hand, HZO has passed IPC CC-830C testing at 50% of the film thickness of traditional conformal coatings, proving that our coatings 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.

HZO Guardian Plus™ & Guardian Zero™ Material Properties

Physical and Mechanical Properties	HZO Guardian Plus	HZO Guardian Zero	ASTM Method
Density (g/cm^3)	1.31	1.10	D1505
Tensile modulus (GPa)	3.2	2.4	D882
Tensile strength (MPa)	55	45	D882
Yield strength (MPa)	55	42	D882
Elongation to break (%)	220	40	D882
Yield elongation (%)	2.9	2.5	D882
Coefficient of friction-static	0.29	0.25	D1894
Coefficient of friction-dynamic	0.29	0.25	D1894
Water absorption [% (24 hr)]	< 0.01	0.01	D570
Index of refraction	1.64	1.66	D542

Electrical Properties	HZO Guardian Plus	HZO Guardian Zero	ASTM Method
Dielectric strength (V) @ 25.4 μm (1 mil)	5,500	7,000	D149
Dielectric strength (V/μm) @ 25.4 μm (1 mil)	220	276	D149
Dielectric constant (60 Hz)	3.13	2.65	D150
Dielectric constant (1 kHz)	3.01	2.65	D150
Dielectric constant (1 MHz)	2.92	2.65	D150
Dissipation factor (60 Hz)	0.022	0.0002	D150
Dissipation factor (1 kHz)	0.017	0.0002	D150
Dissipation factor (1 MHz)	0.013	0.0006	D150
Volume resistivity (23 °C, 50% RH, Ω·cm)	6.0×10^{16}	1×10^{17}	D257
Surface resistivity (23 °C, 50% RH, Ω)	1.0×10^{15}	1×10^{13}	D257

Thermal Properties	HZO Guardian Plus	HZO Guardian Zero	ASTM Method
Melting Point (°C)	290	420	D3417
Linear coefficient of expansion, (10^{-5}/°C)	3.3	6.9	D696
Thermal conductivity [25 °C, W/(m·K)]	0.084	0.13	C177
Specific heat [20 °C, Cal/(g°·C)]	0.17	0.20	

Barrier Properties	HZO Guardian Plus	HZO Guardian Zero	ASTM Method
Water vapor transmission (38 °C 90% RH, g·mil/100 in²·day)	0.25	1.74	F1249
Gas permeability [cm^3·mil/100 in^2·24 h·atm (23°C)]			
N_2	0.7	7.7	D3985
O_2	5.1	30	D3985
CO_2	5.4	214	D3985
SO_2	11.0	1,890	D3985
Cl	0.35	74	D3985
H_2S	13	795	D3985

Superior Corrosion Resistance

Corrosion is a natural process that, when left unaddressed, can be devastating to lithium-ion batteries. Thankfully, this damaging process can be hindered with the proper choice of protection. By coating battery components soldered to the system entirely or strategically coating everything but the connectors with Parylene, it is possible to avoid premature failure caused by exposure to corrosive substances in the environment.

Water vapor transmission rate (WVTR) and gas permeability are properties that indicate barrier effectiveness for corrosion resistance. As the following chart illustrates, Parylene C and N's WVTR and gas permeability properties are exceptionally low, evidence of HZO coating's corrosion-resistance capabilities.

Figure 1 - Uncoated coin cell battery

Figure 2 – HZO Parylene coated coin cell battery

Polymer	Gas Permeability at 25 °C, (cc·mm)/(m²·day·atm)							WVTR, (g·mm)/(m²·day)
	N_2	O_2	CO_2	H_2	H_2S	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 D	1.8	12.6	5.1	–	0.6	1.9	0.2	0.09
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	–	–	–	–

Source: Ref.: Licari, James J. Coating Materials for Electronic Applications - Polymers, Processes, Reliability, Testing. William Andrew Publishing, 2003 and various companies' literature.

Minimizing Weight and Space

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Weight Reduction Due to Thinner Protective Layers

Class	Type	Specimen – Average Coating Thickness [μm]
XY	Parylene N	24
XY	Parylene C	31
XY	Parylene F	38
AR/UR	Acrylic	72
SR	Silicone	117
AR/UR	Acrylated Polyurethane	99

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

Enabling Heat Dissipation

Overheating can pose serious reliability challenges for lithium-ion batteries. The energy storage devices require protection from environmental constituents such as corrosives, but when used in thick layers, conventional conformal coatings can interfere with the heat transfer path, impeding heat dissipation. As thermal conduction is inversely proportional to thickness, integrating the thinnest coating possible is a solution that does not hinder heat dissipation while allowing for the highest levels of corrosion protection possible.

As the chart below indicates, Parylene coatings are a fraction of the mass of traditional conformal coatings. Meanwhile, epoxy or acrylic conformal coating applied at 50μm thickness can reduce an uncoated sample's ability to dissipate heat by 10x.

Coating	Thermal Conductivity (W/mK)	Emissivity	Film Thickness (μm)
Desired	High	High	Low
Parylene N	0.13	-	2-50
Parylene C	0.08	-	2-40
Acrylic	0.13-0.25	-	30-130
Acrylic	0.17-0.21	-	30-130
Silicone	0.15-0.31	-	50-210
Urethane	0.21	-	30-130

Thermal conductivity, emissivity, and film thickness are the most critical parameters to consider for heat dissipation when selecting a conformal coating.

Sustainability

Battery storage and non-use for long periods affect how they charge and the overall life cycle of the battery - if stored for a long time, lithium-ion batteries are more susceptible to damage. HZO's coatings not only prevent premature failure but sustains the product life cycle with superior protection, averting e-waste issues common with batteries.

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 the life of the lithium-ion batteries they protect.

	60 °C	80 °C	135 °C	150 °C
Parylene C	~100 years	~20 years	~70 hours	~24 hours
Parylene N	~10 years	~1 year	~9 hours	~1 hour

Lifetime of HZO coating at different temperatures in air (with oxygen)

Furthermore, our coatings are inherently sustainable, REACH, and RoHS compliant, with no cure time. There are:

- No VOCs
- No Solvents
- No Catalysts
- No Disposal Issues
- No Pollutant Threats

Applications

Battery Chargers

Battery chargers are just as crucial as batteries themselves. Coating areas around the battery charger with Parylene prevents corrosion, promoting reliability and product longevity—the chart below outlines Parylene's protection characteristics versus other solutions.

Protection Characteristic	Unprotected PCB	Mechanical Seal	Silicone/Acrylic Coatings	Parylene Coating
Protection Barrier	None	Good, but can be compromised with drops & temperature.	Good, but can be thick & porous depending on application.	Excellent. Can peel if not properly applied.
Hydrophobic	No	No	Yes	Partial
Thickness	N.A.	Millimeters	µm – Millimeters	2µm – 50µm
Water Protection	Poor	Good – Ingress Poor –Penetration	Good	Excellent
Salt / Chemical Protection	Poor	Poor	Varies	Excellent
Durability	Low	Varies	Varies	High
Submersion Test Time to Failure	Seconds (IP Rating N.A.)	Varies	Varies	Days to Weeks (IPX7-IPX8)

Applications

Busbars

In industrial and automotive applications, busbars connect battery cells and distribute power from high-energy battery packs to other components. For consistent operation, busbars require a dielectric coating with excellent adhesion, corrosion, and chemical resistance combined with mechanical, thermal, and electrical properties. Parylene's exceptional dielectric properties prove useful as protection for these applications. As the data below indicates, the resistance of an HZO coated connector is multiple times as substantial.

The HZO Solution for Busbars

HZO's proprietary equipment can be used to eliminate the high cost of epoxy coating by mitigating the effects of corrosion with VOC, solvent, and cure-time-free Parylene.

The data below represents recent testing of both uncoated and HZO coated MDPS connector samples that were tested for resistivity. The resistance of the uncoated samples was exponentially lower than the HZO coated samples.

Note: Multimeters will show 1 or OL (Open Loop) if the component or circuit being tested does not have continuity. Hence, it has infinite resistance.

Resistance measurement of power connector pins		**Resistance measurement of network connector pins**	
0.35 Ω	0L Ω	0.28 Ω	0L Ω
Uncoated	HZO Coated (Open Loop Reading)	Uncoated	HZO Coated (Open Loop Reading)

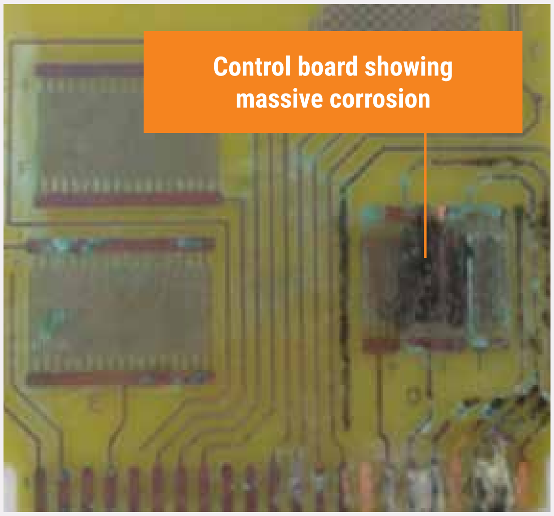
Applications

Cold Plates

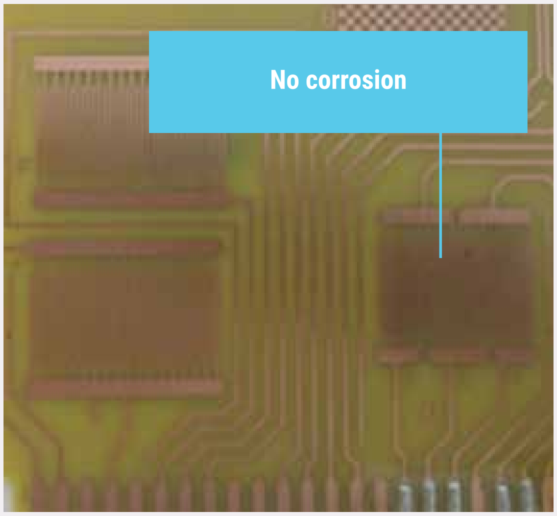
Cold plates are essential in industrial and automotive industries as batteries can overheat when delivering a large amount of power and while charging. Cold plates require protective coatings that firmly adhere to the substrate, can be used in operating temperatures that may range widely, and provide excellent moisture resistance to prevent overheating produced by cold plate failure.

Parylene can protect cold plates and busbars from highly corrosive environments, as the image below indicates. HZO subjected an unprotected board and a board with our coating to salt fog to illustrate the difference that a thin layer of protection can make.

Parylene can protect cooling plates and busbars from high levels of corrosion



Uncoated Board



HZO Coated Board

Testing Parameters

Temperature:
35 °C

Concentration:
5% NaCl by weight

Duration:
168 hours

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. However, as a leader in nano conformal coatings, HZO 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 houses more substrates and components than any other Parylene supplier in the industry, decreasing turnaround time and improving throughput. We utilize intellectual property backed equipment that automates the required masking and demasking process to ensure that critical components such as connectors do not get coated. When performed manually, this process can be labor and cost-intensive, 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. In addition to optimized equipment, HZO exceeds quality assurance expectations. Since our inception, there has not been a single product return attributed to coating issues, although we have coated millions of components. Our Spectrum of Protection™ portfolio of coating solutions allows for alternate options, such as plasma-polymerized nanocoatings, which can also be an excellent option for lithium-ion battery protection. Finally, we offer considerable convenience, with highly configurable processes that integrate into production, providing a turnkey solution with hands-on help from dedicated engineers that help companies walk through solutions from beginning to end.

To learn more about HZO's lithium-ion protection solutions, contact us today at HZO.com

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