



HOW TO RESOLVE SMART WATER METER RELIABILITY ISSUES WITH PARYLENE COATINGS

Produce Longer Lasting Products Able to
Withstand Harsh Metering Environments

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ABSTRACT

Smart water meters provide promising capabilities, but lifetime cost factors can be a hurdle for their implementation. A single service call from a technician can exceed the total price of the smart water meter, making reliability over the entire product lifetime one of the highest design priorities. Parylene conformal coating is an ideal solution to reliability concerns, including corrosion. It also addresses issues such as sustainability and miniaturization, providing truly conformal protection that withstands the lifecycle of smart water meters.

BACKGROUND

The global population has nearly tripled since 1950,¹ and the increase in water demand has doubled that of population growth.² Yet water supply is depleted and continues to decrease due to climate changes, land use, and energy generation changes. Over 163 million people in India go without household access to safe water, as do inhabitants in other countries, such as Indonesia and Pakistan (with 32 million and 16 million people, respectively).³ Without intervention, more than four billion people will be chronically short of water by 2050.⁵ Smart water meters – devices that support remote reporting and provide two-way communication between utility organizations and users, are a critical means of crisis mitigation.

Smarter water infrastructure yields enhanced functionalities that can prevent water wastage, such as improved leakage detection. In 2019, water leakage accounted for more than 20% of the water supply in urban water networks in most countries. However, with autonomous metering of water usage and real-time leakage alerts, smart water meters can prevent further damage.

The accurate accounting and data acquisition provided by smart water metering are also invaluable, as real-time information from automatic water reading helps improve conservation.⁶ Visualized smart meter data reporting ensures that consumers are aware of their consumption patterns, leading to more responsible behavior. In fact, simple awareness of these patterns can produce savings of 20% or more.⁷ Further, with the opportunity to save money by minimizing resource use, consumers will take action, resulting in savings upwards of 50%.⁸

Utility companies also profit from the possibilities of smart water metering. Benefits include reducing human errors from manual readings, the availability of instantaneous fault detection and diagnoses for predictive maintenance, real-time pricing, and the ability to postpone services for times when the service cost is lower.

Due to these promising capabilities, the smart water metering market is experiencing notable growth, with market projections estimating a CAGR of 10.3% during the forecast period of 2019-2024.⁹ Still, the costs associated with the implementation and service of a smart water meter infrastructure may slow down progress. A significant challenge to smart water meter adoption is the potential for a high price related to the device itself^{10 11} and the fact that a single service call from a technician can exceed the entire cost of the smart meter.¹²

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For this reason, smart water meter product design teams must produce sturdier devices to lower the total cost of ownership and reduce service calls. Reliability over the entire product lifetime is one of the most critical smart water meter design priorities.

Why Should We Care About Smart Meters?

Most Common Homeowner Insurance Claims



1 in 10 people around the globe lack access to clean water



Water usage has increased

2x the rate of population increase over the last century



¹ <https://www.statista.com/topics/776/population/>

² <https://www.statista.com/statistics/216527/global-demand-for-water/>

³ <https://www.statista.com/statistics/551809/countries-with-the-highest-number-of-people-living-without-access-to-safe-water/>

⁴ <https://core.ac.uk/download/pdf/82246628.pdf>

⁵ <https://www.eea.europa.eu/data-and-maps/indicators/water-use-efficiency-in-cities-leakage/water-use-efficiency-in-cities-leakage>

⁶ <https://www.sciencedirect.com/science/article/abs/pii/S0921344910000686?via%3Dihub>

⁷ <https://www.analog.com/en/technical-articles/wireless-technologies-for-smart-meters.html#>

⁸ <https://www.analog.com/en/technical-articles/wireless-technologies-for-smart-meters.html#>

⁹ <https://www.marketsandmarkets.com/Market-Reports/smart-water-metering-market-250996975.html>

BACKGROUND (CONT.)

Smart Meter Capabilities Rest on Reliability

Electronic water meters are designed to use new measurement principles that facilitate the enhanced metering functions discussed. While these features are helpful, the circuitry enabling them is sensitive to harsh, corrosive environments. The table below indicates that as more electronics are added to water meters, more protection is required.

TYPES	ADVANTAGES	DRAWBACKS
Fully Mechanical	Simple design, low-cost, reliable operation	Narrow measurement range, reduced accuracy at low flow rates, cumulative measurement only, lack of real-time information
Electromechanical	Real-time information	Requires extra protection for the electronic component, reduced stability
Fully Electronic	High accuracy, real-time information	Requires extra waterproof protection and power supply

Table 1 - Comparison of Smart Water Meters

Anecdotally, smart meters post-failure rates in the 5% per annum range, ten times the failure rate of traditional meters.¹³ Many of these failures can be attributed to electronic component failures due to inadequate protection from the hostile application environment.

Corrosive Conditions

Corrosion is a severe problem for the utility industry, incurring costs of \$47.9 billion every year.¹⁴

Corrosion is a severe problem for the utility industry, incurring costs of \$47.9 billion every year. This naturally occurring phenomenon can cause water leakage in the distribution network¹⁵ or induce unexpected smart water meter failure. Yet smart water meters are expected to work for ten years or more in highly corrosive environments.¹⁶ High humidity levels, outside condensation, and the possibility of full submersion can put these devices in jeopardy. If not submerged, smart water meters will still be exposed to hot and cold saltwater and rainwater. These conditions can decimate electronic components, affecting the overall reliability of the system and impacting maintenance costs that must be kept very low.

Miniaturization Issues

Although reliable corrosion resistance is paramount to smart water meter reliability, incorporating an appropriate amount of protection is increasingly difficult as the devices become miniaturized. Conformal coating materials such as acrylics, epoxies, urethanes, and silicones must be applied in thick layers to attain a proper amount of protection. Seals, enclosures, and potting can also add to the bulk and weight of the device. Compounding the bulk problem, if there is a failure for any reason, a heavy, bulky electronic product must be disposed of properly, leading to e-waste and sustainability concerns. Additionally, smart water meters use low power radio frequency (RF) signals to collect and transmit information about the use of services, and thick layers of conformal coating protection can interfere with the transmittance of RF signals, leading to disruption in service.

¹⁰ <https://www.advancemarketanalytics.com/reports/80620-global-smart-water-meter-market>

¹¹ <https://www.nrel.gov/docs/fy11osti/52788.pdf>

¹² <http://assets.fiercemarkets.net/public/smartgridnews/Low-Power-MCU-Metering.pdf>

¹³ <https://energycentral.com/c/iiu/dirty-little-secret-smart-devices-are-consumer-electronics>

¹⁴ <https://www.power-eng.com/emissions/air-pollution-control-equipment-services/corrosion-comes-in-different-forms/#gref>

¹⁵ <https://www.sciencedirect.com/science/article/pii/S0263224120310071>

¹⁶ <https://www.analog.com/en/technical-articles/wireless-technologies-for-smart-meters.html>

ADDRESSING SMART WATER METER RELIABILITY CHALLENGES WITH PARYLENE

Parylene conformal coatings are an ideal solution for smart water meter reliability challenges. Parylenes come in various types, including Parylene C, Parylene N, and Parylene F (VT-4), and have nearly 50 years of excellent performance in critical applications and industries. The coating is often 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 at room temperature. The result is extremely thin, pinhole-free, high purity coatings that fulfill many, if not all, the reliability requirements of smart meter design.

Corrosion Resistant Properties

Parylene is among the best coatings for moisture impermeability¹⁷, with a WVTR among the lowest of the polymers. Moisture “breathes” in and out and will not become trapped beneath the coating. Additionally, Parylene coatings are of high purity, so any moisture that does become absorbed or permeates will not contribute to chemical corrosion.

POLYMER	GAS PERMEABILITY AT 25 °C, (CC-MM)/(M2-DAY-ATM)							WVTR, (G-MM)/ (M2-DAY)
	N2	O2	CO2	H2	H2S	SO2	Cl2	
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	-	-	-	-

Table 2 – Permeability and WVTR of Parylene and other polymers

Parylene performs extremely well as a barrier to corrosion due to the coating’s ability to minimize the influence of the factors that affect coating lifetime and performance, including the following:

- **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 to 8 microns, Parylene forms a pinhole/pore-free coating.

Miniaturization Concerns

Parylene provides superior corrosion resistance at a fraction of the mass of more conventional protection methods, facilitating miniaturization, RF signal transmittance, and minimizing environmental issues in instances of failures.

THICKNESS (MM)	0.1 TO 5	5 TO 12.5	12.5 to 18	12.5 to 25	12.5 to 50.8
Relevant Standards	UT Type** in Upcoming IPC-CC-830C	UT Type** in Upcoming IPC-CC-830C	MIL-I-46058C	IPC-CC-830B	NASA-STD- 8739.1B
Protection Level***	IPX3 / IPX4	IPX4 / IPX7	IPX7 / IPX8	IPX7 / IPX8	IPX7 / IPX8
Appropriate Products	Consumer Electronics & MEMS Devices	Consumer & Industrial Electronics	Aerospace & Defense	Aerospace, Automotive, Industrial, Medical Device, Telecom, & Other High-Reliability Markets	Aerospace, Defense, & Very Harsh Industrial

Table 3 – Parylene thickness levels and best applications

Long Lifetime

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 lifetime of the smart water meters they protect.

	60 °C	80 °C	135 °C	150 °C	12.5 to 50.8
Parylene C	~100 years	~20 years	~70 hours	~24 hours	NASA-STD- 8739.1B
Parylene N	~10 years	~1 year	~9 hours	~1 hour	IPX7 / IPX8

Table 3 – Lifetime of H2O coating at different temperatures in air (with oxygen)

¹⁷ Licari, James J. Coating Materials for Electronic Applications - Polymers, Processes, Reliability, Testing. William Andrew Publishing, 2003 and various companies' literature.

* Relative to Parylene C and including the same pump downtime for evacuating the deposition chamber with the same number and type of products to be coated.

** UT Type describes a general class of ultrathin coatings that range from 0.1 to 12.5 microns thick.

*** The protection level as related to IEC 60529 - Degrees of protection provided by enclosures (IP Code), but is also dependent on product design.

CHEMICAL VAPOR DEPOSITION (CVD)

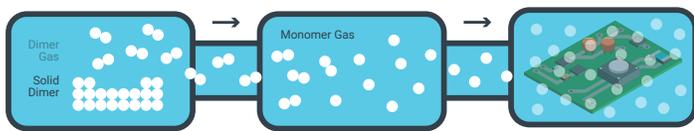
Parylene coatings are ultra-thin, lightweight, and due to the chemical vapor deposition (CVD) application process, the coatings are highly conformal, wrapping around every edge available. The CVD process is performed under vacuum, with specialized equipment that includes a coating chamber. All surfaces are coated evenly regardless of chamber position, and the coating deposits the same thickness all around the objects being coated. This vapor phase coating process also leads to pinhole-free coatings free from defects.

The most common method of depositing Parylene is through the "Gorham Process," developed by William Franklin Gorham at Union Carbide in the late 1960s and is described in general below.

CVD Process

Parylene dimer is placed in the vaporizer chamber, and the system is placed under vacuum. The vaporizer is heated to around 150 to 170 °C until the dimer sublimates from a solid to a gas.

The dimer gas travels through the pyrolyzer, heated at a much higher temperature, from 550 to 700 °C, where the dimer is "cracked" into two activated monomers. From there, the monomer travels into the room temperature deposition chamber and coats everything in the chamber with monomers that connect to other monomers, forming a polymer film.



An overview of the chemical structure changes for this process for Parylene N is illustrated below.

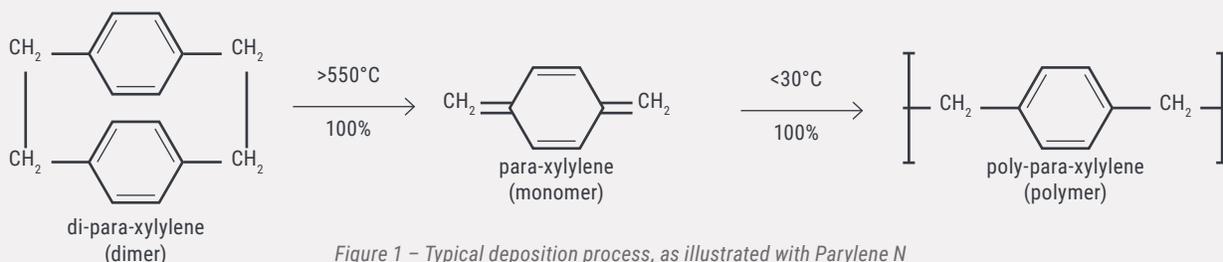


Figure 1 – Typical deposition process, as illustrated with Parylene N

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, Parylene is a truly conformal coating that ensures protection from corrosive environments even at tight corners. Conversely, conventional conformal coatings leave uneven coatings, with much thinner 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 figure below, a conventional conformal coating 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.

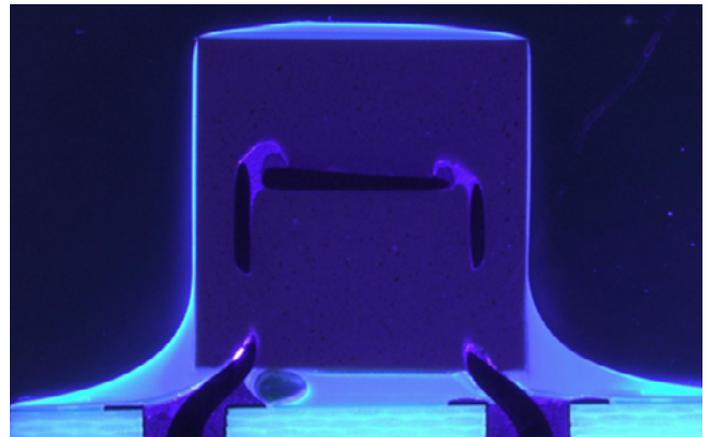


Figure 2 – Conventional Conformal Coating Coverage*

For these reasons and more, Parylene is considered the gold standard of conformal coatings.

*Source: https://ipc.kavi.com/higherlogic/ws/public/download/7394/Hillman_IPC_CRR_IPC_PERM_Webcast_July.pptx



SMART WATER METER PROTECTION WITH HZO

Typically, obtaining the gold standard of smart water meter 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, a leader in nano conformal coatings, addresses these Parylene shortcomings through engineering and manufacturing solutions.

Proprietary equipment with optimized cubed 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. 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 its inception, there has not been a single product return attributed to coating issues, although the company has coated millions of components. Finally, HZO offers considerable convenience, with highly configurable processes that integrate into many points of production, a turnkey solution or other flexible business models, and hands-on help from dedicated engineers that help companies walk through solutions from beginning to end.

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CONCLUSION

While smart water meters are a critical means of mitigating the global water depletion crisis and generally improving water distribution overall, an obstacle to implementation is cost, creating a need for reliability to reduce TCO and the number of service calls. The severe service environment and miniaturization trends can complicate designing for reliability, but Parylene can resolve these issues, improving smart water meters overall.

To learn more about HZO's unique take on Parylene and how we can assist on your next project, reach out to our engineers at [HZO.com/contact-us/](https://www.hzo.com/contact-us/) today.

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