

All Sensors **Pressure Points** are application tips to simplify designing with microelectromechanical systems (MEMS) pressure sensors and avoiding common pitfalls.

Pressure Point 14:

Expanding MEMS Pressure Sensor Applications with Parylene

In the description of a microelectromechanical systems (MEMS) pressure sensor, it is common to find a statement such as “intended for use with non-corrosive, non-ionic working fluids such as air, dry gases and the like.” Following this guideline, users can expect a long working life for a MEMS pressure sensor. But what if the intended application does not fall within the guidelines? In some cases, the pressure sensor supplier may offer alternatives to cope with harsh applications or unintended ingress of harsh media. This white paper will explain why protection is required for MEMS pressure sensors, discuss potential solutions, including Parylene, and provide user information regarding the addition of Parylene to high-volume pressure sensor packages and product families.

Why MEMS Pressure Sensors Require Additional Protection

Introduced over 40 years ago, MEMS pressure sensors using piezoresistive technology (PRT) provide a solution to more pressure sensing needs than any other technology. The reasons are simple: PRT allows absolute, gage and differential pressure measurements that address both high and low volume application requirements through batch processing techniques common in the semiconductor industry. In addition, these sensors are highly accurate, highly repeatable and meet the cost objectives better than other alternatives. As a result, they are used widely in automotive, medical, industrial, commercial and consumer applications. A pressure range that suits the measurements in the application, especially a range with high sensitivity, and other factors help differentiate one sensor from other.

To keep their cost low, many MEMS pressure sensors are available in plastic packages but metal and ceramic versions are also offered. Wire bonds connect the electrical contacts on the pressure sensor’s die surface to the leads of the package to interface to external components.

In these silicon pressure sensors, [a passivation layer](#) applied near the end of the wafer manufacturing process protects implanted or diffused elements on the top surface but the diaphragm area is masked to avoid the dissimilar material interface and dampening effect (with lower response time) that would be caused by the protective glass layer. As a result, subsequent protection at the package level is frequently required, especially for harsh applications. An example of the cross-section with a protective gel is shown in Figure 1.

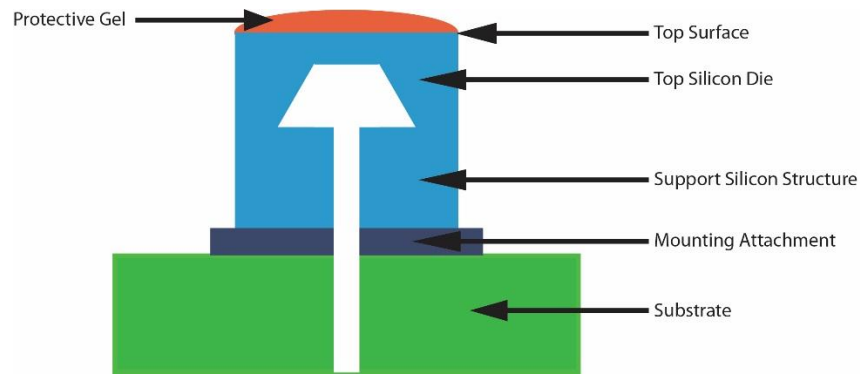


Figure 1. The cross section and typical materials of plastic-packaged MEMS pressure sensors.

Potential Protection Techniques

Different pressure sensor-specific solutions have been developed to isolate and protect MEMS and other pressure sensors from harsh media in a variety of applications. These include oil filled, hermetically-sealed stainless steel, O-rings/diaphragm, hydrostatic methyl-silicone gels and more. While the sensitive surface of the pressure sensor must be isolated from harmful media, the pressure must be accurately transmitted to the pressure sensor's diaphragm for static and dynamic measurements. Air voids in oil or gel fills can cause inaccurate measurements. Also, the need to fill the cavity with these materials adds a weight on the diaphragm that can impact the reading as well, especially for low pressure sensors. As long as the sensor manufacturer's recommendations are followed, silicone gel coatings can typically be used down to pressures as low as 5 psi but for many applications in lower pressure ranges, such as ± 30 -in H₂O (± 1.08 psi) to ± 1 -in H₂O (± 0.036 psi), a different approach is required.

An alternate solution for protecting pressure sensors from harsh media is a Parylene coating. Widely used to protect sensors and electronic components in medical, automotive and other applications for over 40 years, the thin-film coating can be used to provide a moisture, chemical and dielectric barrier and also offers thermal and ultra-violet (UV) stability and dry-film lubricity. In fact, Parylene is the thinnest effective coating technique available. One of the Parylene's important [characteristics is its ability](#) to coat all surfaces, including penetration deep into multi-layers and crevices. Unlike the added weight of oil, gel or any other cavity-filling liquid, the thin conformal Parylene coating has a minimal impact on the sensor's accuracy and repeatability.

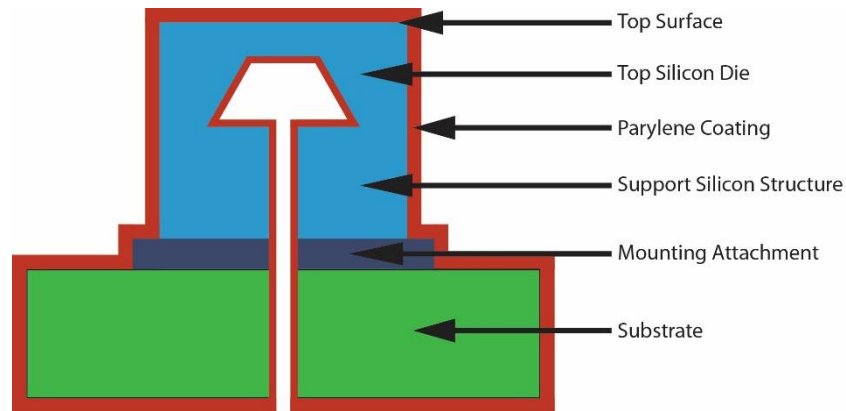


Figure 2. The cross section and typical materials of a plastic-packaged MEMS pressure sensor with a Parylene coating shown in red.

Parylene as an Optimal Cost-Benefit Protection Solution

Parylene is applied using a specialized chemical vapor deposition (CVD) process to provide a highly uniform, conformal coating. Commonly used in high-volume semiconductor wafer manufacturing, CVD is a batch processing technique. To perform the vapor deposition polymerization process, products to be coated are placed in the product chamber of the specialized vacuum deposition equipment.

Next, [dimer](#), the raw material, is placed upstream into the system. Dimer (an oligomer, or molecular unit with repeating units consisting of two monomers) is a solid, granular material. The dimer is heated under vacuum until it is vaporized into a dimeric gas to pyrolyze (or thermally decompose) it into a monomeric gas.

In the next step, the monomeric gas flows into the ambient temperature chamber with products to be coated where it polymerizes on all surfaces in a thin, transparent film. At this point, the process is complete and coated products can be removed from the chamber since no post-deposition curing is required.

Because it is applied as a gas, the Parylene coating encapsulates all exposed substrate surfaces and easily penetrates small crevices and tight areas on multi-layer components, providing complete and uniform encapsulation. The target thickness of the polymer coating is determined based on the application and the coating properties desired. A typical thickness for the chemically-inert material is in the microns range.

Getting Parylene Into/Onto Production Pressure Sensors

Unlike other pressure sensor suppliers offering a Parylene coating, All Sensors performs this process in-house and uses an advanced production system to achieve the highest accuracy and

reliability. This avoids transferring products out of and back to the pressure sensor manufacturing facility, provides complete quality control and improves the delivery time to customers. Specially designed masking techniques allow All Sensors to apply a cost-effective, high-volume Parylene coating in house.

The Parylene that All Sensors uses exhibits faster deposition rates than other types of Parylene. Available in all of All Sensors miniature digital DLVR, DLHR, DLLR series, Millivolt output MLV series and miniature digital and analog ELVR series, the Parylene coating is a frequent request from many customers. Package examples in the DLVR and DLHR series are shown in Figure 3.

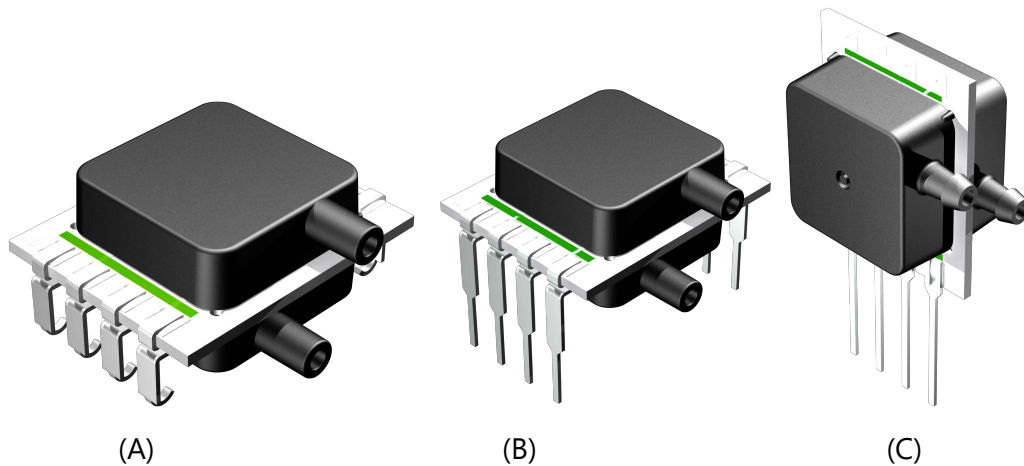


Figure 3. The (A) E1NJ, (B) E1BD and E1ND, and (C) E1BS and E1NS packages are all available with a Parylene coating.

In addition to these packages, Compact U2, D4 and D2 packages as well as packages in the MLV series are also available with Parylene. In the MLV series, this includes the E1NJ, E1BD, E1ND, E1BS and E1NS as well as EGNS, EGNJ, EGNL, EGB and EGBD variants. The classic A6AAF package, shown in Figure 4, is also available with the Parylene option.

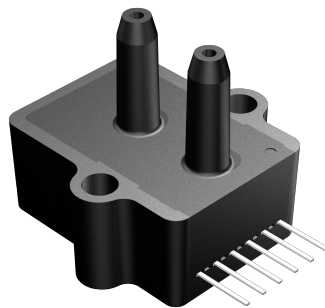


Figure 4. The A6AAF package is available with a Parylene coating.

With its in-house Parylene process, All Sensors successfully coats pressure sensors as low as ± 1 -in H_2O (± 0.036 psi) full scale (FS) with sensitivities in the range of 4.5mV/V/in H_2O .

Examples of Sensors with Parylene Protection in Harsh Environments

In addition to medical applications, where it has been used for over 40 years, Parylene is ideal for industrial applications such as flow controllers, gas/propane appliances and more.

Medical Applications

Since Parylene is chemically inert, it is biocompatible and safe to use as a coating for medical equipment. Also, it has minimal potential for infection or distorting data readings. Parylene retains its compositional stability and performance in the presence of bodily fluids and tissues. During medical procedures, instruments coated with parylene can be safely used in less accessible, more-constricted regions of the body than those with alternative coatings.

Industrial Applications

Monitoring or controlling methane, the primary constituent of natural gas, are natural applications for Parylene protected pressure sensors. For flow control, a sensor with a range as low as ± 1 -in H_2O (± 0.036 psi) may be required. As the cleanest burning fossil fuel, methane has great potential as an alternative to other fossil fuels. Controlling and monitoring methane, especially to detect leakage is essential for its safe usage.

Propane appliances are another targeted industrial application for Parylene-protected pressure sensors. In fact, any low-pressure measurement in an industrial control environment could benefit from the stability and performance abilities of a low-pressure sensor with Parylene protection.

Summary

Successfully surviving a wide range of applications requires addressing all of the application's key parameters. For pressure sensors, this include the proper protection for harsh and sometimes corrosive media. For over 40 years, Parylene has been used to provide this protection to pressure sensors and other electronic products. Parylene coating can be found as an option on a wide variety of All Sensors' products. Interested users should contact the factory regarding an application requiring parylene coating.