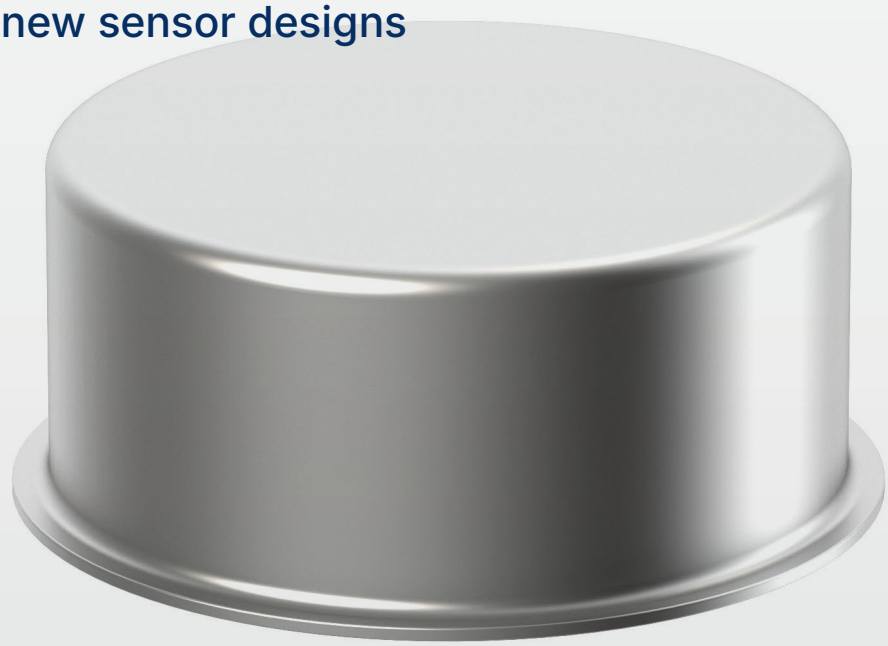
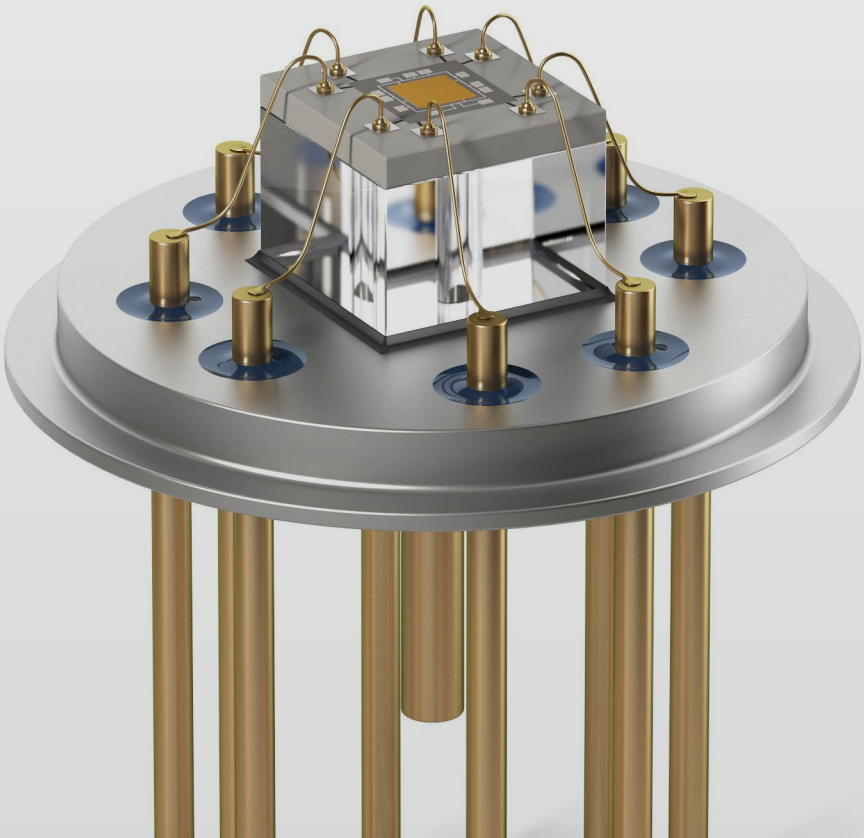
SCHOTT

Hermetic vs. non-hermetic sensor packaging

How material choices affect reliability, accuracy, and enable new sensor designs





1. Executive summary

Sensor packaging plays a critical role in long-term sensor performance. Initially, hermetic and non-hermetic packages may exhibit similar performance. Over time, however, polymer-based sealing or packaging solutions can allow 100× to 10,000× more gas ingress, leading to gradual moisture and gas diffusion. In contrast, hermetic cavity packages, with a sealed gas-filled volume, are designed to provide a stable, near-impermeable barrier. This difference in gas ingress rates can lead to time-dependent effects such as drift, signal instability, and failure under real operating conditions. At the same time, hermetic packaging can enable new design approaches. By providing stable internal boundary conditions, it can reduce the need for compensating measures and allows more integrated, compact architectures. Packaging, therefore, acts not only as a protective measure but also as a key factor in both reliability and system design.



2. Hermetic vs. non-hermetic: measurable differences

Packaging performance is not only defined by initial sealing quality but also by how materials behave over time under real operating conditions. For packages requiring a controlled internal atmosphere, barrier/seal performance becomes a key differentiator. While polymer-based and hermetic seals can meet similar requirements in early validation, their long-term performance diverges as the materials experience environmental exposure. This difference is primarily driven by the permeability and instability of polymer materials, which inherently allows moisture and gas diffusion, gradually changing the internal conditions.

Hermetic cavity packaging, manufactured using only inorganic materials such as glass and metals, is designed to maintain a stable internal environment over years or even decades. As a result, differences in reliability do not appear immediately, but emerge over time as the hermetic cavity packaging protects from moisture ingress, aging effects, and thermo-mechanical influences that affect sensor performance.

For cavity packages with an enclosed internal volume, the core difference lies in barrier performance and the resulting stability of internal environmental conditions over time. Ultimately, the choice between hermetic and non-hermetic cavity packaging comes down to maintaining environmental stability long-term versus managing the effects of gradual gas and moisture ingress.





Type	Hermetic packaging	Non-hermetic packaging
Materials	Inorganic (e.g. Glass-to-Metal Seals)	Organic polymers, epoxies, PEEK materials
Gas permeability	Negligible	Time-dependent diffusion
Moisture barrier	Near-zero moisture and gas permeation	High inherent permeation rates
Aging effects	Virtually no aging or material degradation	Natural aging and embrittlement may alter barrier and mechanical properties over time
Mechanical stability	Stable material properties over time	Material properties may change over time due to creepage, swelling, stress relaxation, or embrittlement
Internal atmosphere stability	Typically maintained for years to decades	Can change within days to months depending on permeability and package design
Helium leak test relevance	Meaningful	Misleading, as helium fine-leak testing measures leakage, not long-term permeation. Helium tightness does not prevent moisture diffusion.
Harsh environment suitability (i.e. high moisture, demanding temperature, pressure, or chemical exposure conditions)	Suitable for long-term exposure to demanding temperature, pressure, moisture, and chemical conditions	Limited because performance depends on material selection and exposure conditions

3. Moisture as the dominant failure driver

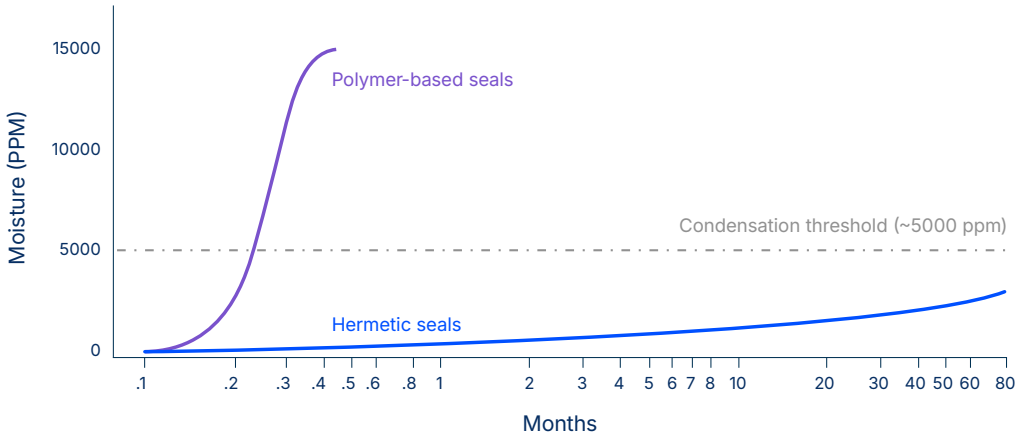
To maintain stable sensor performance over time, internal moisture levels must remain below critical thresholds throughout the device lifetime. Even trace amounts of water vapor can affect electronic and photonic systems by altering electrical and optical behavior.

In practice, internal moisture levels below approximately 5,000 parts per million (ppm) are required to prevent condensation. Above this threshold, the internal dew point increases, and even moderate temperature changes can lead to condensation, corrosion of metal interconnects, electrical leakage, unintended short circuits due to ion migration, and reduced optical stability caused by light scattering. This behavior is closely linked to packaging design.

Although “airtight” solutions may initially resist gas flow, only hermetic packaging maintains long-term stability against moisture diffusion by maintaining barrier properties. In non-hermetic systems, internal moisture can increase gradually over time, particularly in smaller packages with higher surface-to-volume ratios. Once critical moisture levels are reached, degradation mechanisms accelerate, and performance typically deteriorates before visible failure occurs.

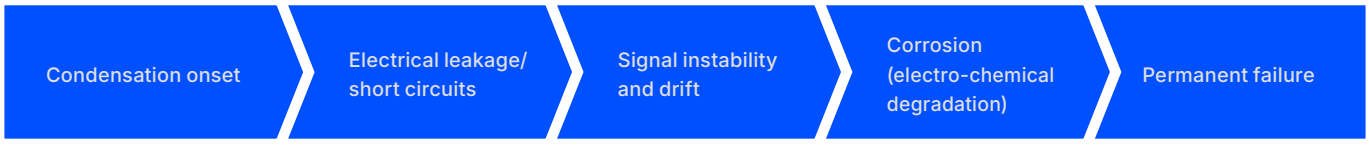
Packaging design plays a critical role in preventing moisture ingress over time

Hermetic seals maintain near-zero internal moisture levels for decades while “near-hermetic,” polymer packaging shows rapid moisture increase within weeks or months.[1]



Failure mechanism in polymer-based packaging

Once internal moisture exceeds critical thresholds, condensation initiates a chain of electrochemical and physical degradation mechanisms that progress from signal drift to functional failure



Special case: Oil-filled sensors

In oil-filled sensors, moisture ingress does not typically lead to condensation because the fill fluid acts as a moisture buffer and little or no free gas is present. However, moisture can still diffuse through non-hermetic barriers and interact with oils, polymers, adhesives, and material interfaces over time.
In these systems, long-term concerns shift from condensation to material aging, interface degradation, corrosion, and drift-related effects. Hermetic packaging helps limit these mechanisms by maintaining stable internal conditions throughout the device’s lifetime.

[1] 10% helium backfill; 30 °C at rH 50% room ambient; package volume = 1 cm^3; measured leak rate (no bomb) = 1×10^{-8} mbar·L/sec (He).

4. Beyond moisture: technical features of hermetic packaging

Hermetic packaging provides defined physical functions based on inorganic materials such as glass, ceramics, and metal. These features remain on the highest level over time due to very low leak rates and virtually absent material aging.

Environmental protection
Hermetic enclosures are designed to remain reliably leak-tight even in extremely harsh operating environments including ultra-high or low temperatures, high pressure, corrosive chemicals, or even subsea conditions.

Electrical passthrough
Hermetic feedthroughs enable reliable transmission of power and signals.

Mechanical robustness
Rigid inorganic materials help maintain structural stability under temperature changes, pressure variation, and mechanical stress.

Electrical insulation
Glass insulators provide dielectric isolation and prevent electrical breakdown.

Thermal management
Metal and glass components provide defined thermal conductivity and controlled heat transfer paths.

Optical passthrough & filtering
Optical windows, fiber optics, and coatings allow controlled light transmission with stable optical properties over time.

Atmospheric control and fine-tuning
Hermetic packages can be sealed with a defined internal atmosphere (e.g., inert gas, dry air, vacuum, or pressure). Gas composition and pressure remain stable due to low leak rates.



5. Beyond protection: enhancing design and performance

Hermetic packaging can change how sensor systems are designed by reducing variability and simplifying system architecture.

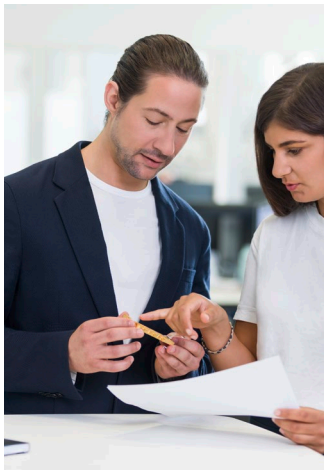
Reduction of system complexity
- Eliminates the need for multilayer sealing.
- Reduces reliance on coatings and compensating features.
- Simplifies overall system architecture.

Improved integration
- Combines sealing, insulation, and feedthrough in one component.
- Reduces interfaces and potential failure points.
- Minimizes system variability from multi-material interactions.

Miniaturization potential
- Enables more compact designs.
- Reduces component count.
- Supports space- and weight-constrained applications.

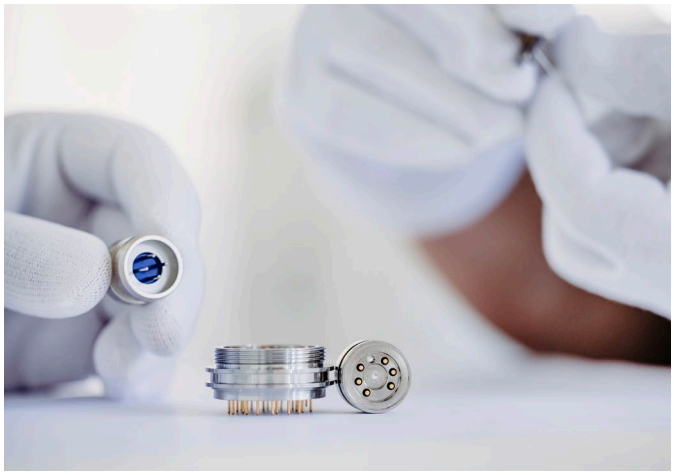
Reduced sensitivity to environmental variation
- Isolates the sensing element from external humidity, contamination, and pressure changes.
- Reduces external influences on signal stability.
- Supports more consistent behavior across operating conditions.

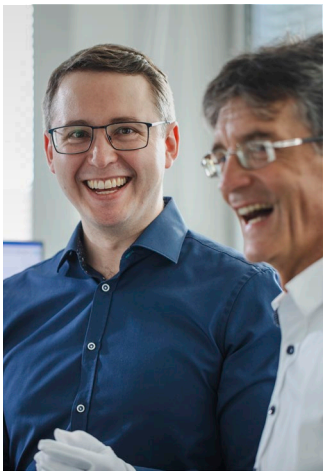
Reduced need for compensation and calibration
- Limits drift mechanisms at the system level.
- Reduces dependence on calibration routines and correction algorithms.
- Supports stable signal performance over time.











6. Summary: System-level trade-offs & selection criteria

The choice between polymer and hermetic packaging is a system-level decision that influences cost, design flexibility, and long-term performance.

Key trade-offs

- Initial cost: strongly depends on volume, automation level, and reliability requirements
- Design flexibility: polymer higher, hermetic moderate
- Initial performance: comparable
- Long-term stability: polymer limited, hermetic higher
- Maintenance effort: polymer higher, hermetic lower

Selection should be based on lifecycle requirements rather than initial test results alone.

Where hermetic packaging is commonly applied

Hermetic solutions are widely used in applications that require stable internal conditions and predictable long-term behavior, including:

- industrial and process sensors exposed to humidity, corrosive substances, thermal cycling, or high-pressure conditions
- automotive environments with high stress and limited maintenance access
- medical devices requiring stable calibration over time
- aerospace systems operating under pressure variation or vacuum conditions
- optical and electronic systems sensitive to moisture and dielectric changes

When hermetic packaging adds value

Hermetic packaging becomes particularly relevant when:

- performance targets require low drift over a long service life
- calibration is limited or not feasible
- environmental exposure includes high humidity, condensation, aggressive media, or pressure variation

In these scenarios, hermetic packaging supports stable operating conditions, reduces lifetime risk, and enables more predictable system behavior.



About SCHOTT

Pioneering the impossible since 1884

We are a global technology group focused on specialty glass, glass-ceramics, and advanced material solutions across demanding applications including electronics, healthcare, automotive, industrial, energy, and aerospace. With around 17,000 employees in 30+ countries, we combine deep material, design, manufacturing and application expertise with a global infrastructure to support customers worldwide.

About SCHOTT's hermetic packaging portfolio

SCHOTT's hermetic feedthroughs and packaging components have been used by leading sensor manufacturers for decades. Applications range from harsh-environment automotive or industrial settings to mission-critical aerospace and aviation systems and high-precision optoelectronics. With exceptional in-house glass and processing expertise, SCHOTT provides a broad variety of standardized hermetic seals and fully customized packaging solutions. The team tackles complex reliability challenges, boosts cost-effectiveness, and enhances performance to meet the most demanding industry requirements.

Why SCHOTT is the preferred supplier of reliable hermetic (sensor) packaging components

80+ years
Experienced pioneer of hermetic glass-to-metal sealed components

2,000 +
hermetic products for more than 30 markets

1.2 – 600 mm
Range of product diameters

Flexibility
From standard to complex and hundreds to millions

Quality you can trust

Application expertise

Manufacturing scalability





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