SCHOTT

Glass and ceramics in implantable device packaging

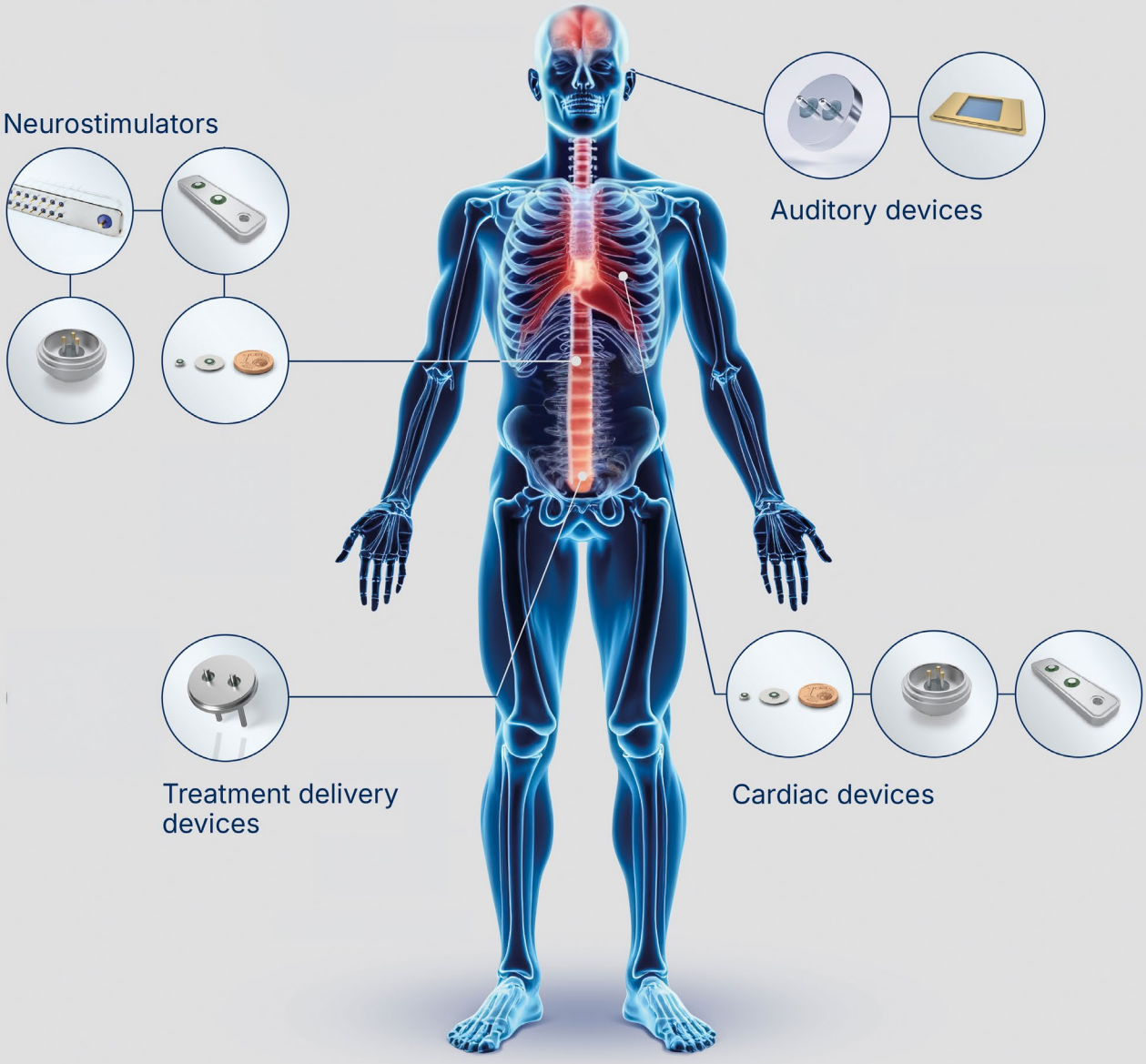
How materials for customized feedthrough components can affect reliability, miniaturization, and scalability



1. Key drivers

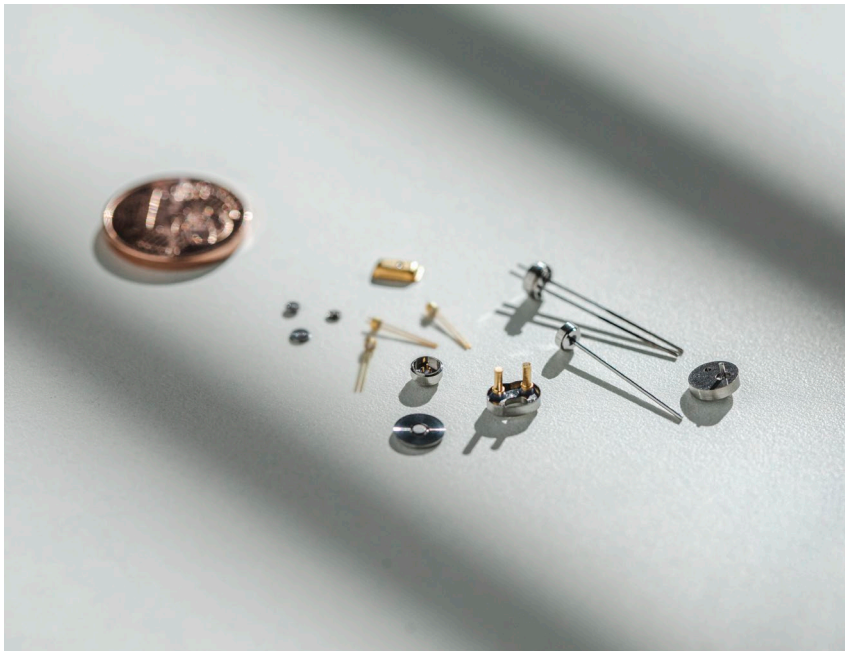
The evolution of implantable medical devices is driving a new generation of packaging requirements. These trends define some of the key technical challenges that packaging and feedthrough technologies must address to support future implant generations:

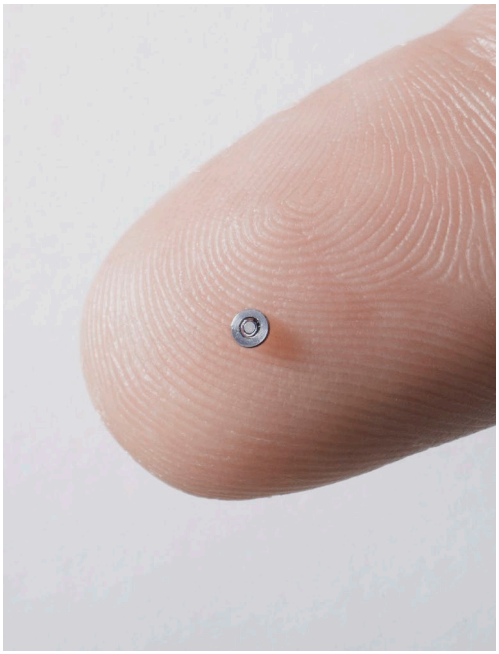
- Electrical stimulation therapies have moved beyond the heart to the spine, brain, and a variety of positions along the Vagus nerve.
- Expanded stimulation applications can, depending on the case, create more challenging electrical performance requirements: Higher current flows, recharging requirements, remote powering, and increased monitoring and control communication.
- Lifetime requirements for implants have increased dramatically, from a few years to more than 15. Longer service life expectations may also be a development target depending on the device and use case.
- At the same time, there is a push for smaller and smaller devices so that the implants can be placed using minimally invasive surgical techniques that can reduce surgical risk and shorten recovery time for the patient.



















2. Core considerations in implant packaging

Implant packaging must typically balance electrical, mechanical, environmental, and design requirements within a constrained geometry. These requirements are closely interconnected and can define the design limits of the device.

Electrical performance

- Stable insulation across feedthroughs
- Reliable signal and power transmission
- Controlled dielectric behavior under physiological conditions

Environmental stability

- Chemical stability in body fluids
- Resistance to corrosion and ion diffusion
- Thermal behavior and coefficient of thermal expansion (CTE) matching

Mechanical behavior

- Resistance to static and cyclic mechanical loading
- Fracture behavior under stress concentration
- Stability under assembly and operational loads

Feedthrough integration and miniaturization

- Feedthrough pitch is often limited by creepage and electrical isolation distance
- Increasing pin count can directly increase package size
- Interfaces between materials can concentrate stress and affect reliability

These requirements are often tightly coupled. Electrical isolation can limit achievable feedthrough density, while mechanical and material behavior typically define how stress is transferred within the package.

Key implication:
Feedthrough integration is often a primary design constraint and can define both the minimum package size and the achievable level of functional integration.



3. Hermetic packaging as a key requirement

Hermetic technology is utilized to protect the body from implantable medical devices while enabling electronic signals to monitor, sense, and stimulate nerves and organs as part of a medical therapy.
Glass-to-metal sealing and ceramic-to-metal sealing technologies provide a protective function for packaging and feedthrough components using inorganic materials that show virtually no aging over time.

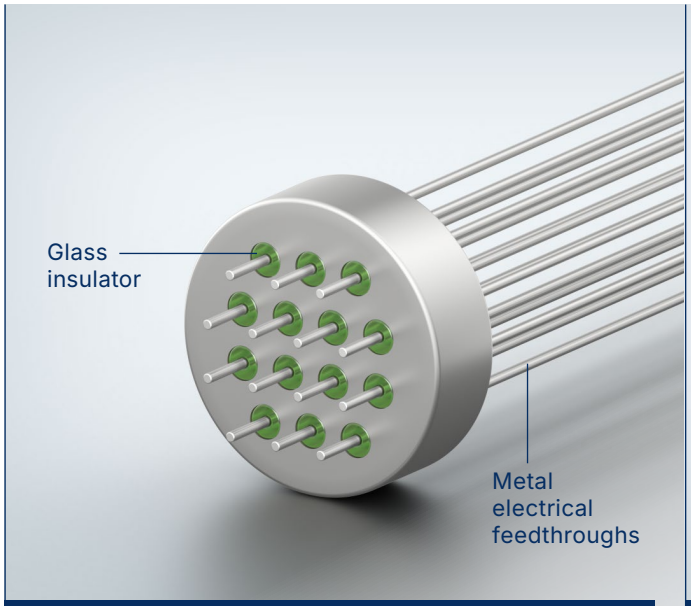
These materials work in the following way:

- The enclosure materials must be biocompatible and must not harm or irritate the bodily tissues.
- The enclosure materials must be resistant to attacks or damage by bodily fluids.
- The inorganic materials are designed to keep moisture and/or bodily fluids from reaching the electronic circuitry of the medical implant and potentially causing failure.
- The materials must also enable sterilization of the medical device prior to implantation.

The hermetic feedthroughs:

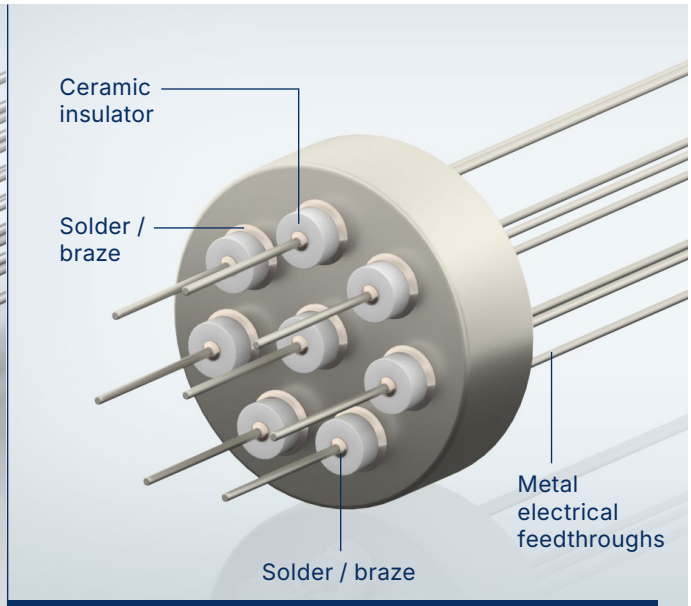
- Allow electrical signals to pass in and out of the medical implant for operation of the device.
- Use glass or ceramic materials as insulators around the feedthrough conductors.
- The glass-to-metal seals or braze ceramic seals create the critical barriers that are intended to prevent liquids and vapors from passing into the enclosure.

Hermeticity describes the ability to maintain a gas-tight enclosure over time.
Polymer-based materials, even if initially gas-tight, allow gradual diffusion of moisture and gases and are therefore generally not considered hermetic for long-term implant applications. For this reason, packaging solutions for high-reliability class III medical implants are usually based on fully inorganic material systems.



Glass-to-metal sealing

- Glass-to-metal sealing has a decades-long track record in implantable devices
- Integrated design combining glass insulation and feedthrough(s), directly joined in a furnace process
- No additional joining interfaces / materials needed
- Can enable higher integration density and miniaturization



Ceramic-to-metal sealing

- Stable insulation and an established industry approach
- Requires solder or braze joints between electrical feedthroughs, ceramic insulator, and outer housing, resulting in increased design complexity
- Feedthrough spacing defined by creepage and electrical isolation requirements
- Increased spacing limits achievable pin density

Both approaches provide hermetic performance, but differ in how they support miniaturization, integration, and scalability.

4. Ceramic vs. glass sealing: engineering comparison

Material selection helps determine how device requirements can be realized in practice. The following table maps material behavior to key design constraints, particularly feedthrough integration, miniaturization, and long-term stability.

Parameter	Glass-to-metal seals (GTMS)	Ceramic-to-metal seals	Conclusion
Electrical performance	▪ Provides stable dielectric insulation with low signal loss. ▪ The homogeneous structure can also support efficient and controlled RF transmission, enabling integration of wireless data and inductive power transfer. ▪ Easy customization to match impedance requirements. ▪ Defined filtering and blocking of RF-signals is possible by adding a filter component on one or both sides of the feedthrough.	▪ Provides stable insulation. ▪ Conventional dry pressed ceramic cylinder with metallization on the ID and OD can work well for RF transmision. ▪ Including a filter in the ceramic feedthrough can allow RF signals to be blocked while DC signals may pass.	→ Both approaches meet insulation requirements, while glass can support simpler integration of high-frequency functionality. → Filtering of RF-signals is inherent to the ceramic insulator material or available as an add-on to glass-to-metal seals
Feedthrough integration and miniaturization	▪ Continuous hermetic design structure that integrates feedthrough and sealing in one component. Only three components for single pin feedthrough: metal housing, insulator glass preform, conductor pin. Multiple pins can be placed in one glass preform to reduce pitch and the overall footprint. ▪ Since glass flows in to fill the open space and make the seal, there can be more flexibility with preform dimensions and tolerance.	▪ Discrete feedthrough design with ceramic insulator and individual pins. ▪ Ceramic insulators require metallization and a metal braze for sealing. ▪ Tight tolerances must be maintained when making metal components and ceramic preforms. ▪ Pre-metallization of the ceramic preform becomes more challenging as part size is miniaturized.	→ Glass-to-metal sealing can enable higher feedthrough density and more compact implant architectures compared to ceramic-to-metal sealed components.
Mechanical and interface behavior	▪ Glass and metal are joined in an integrated structure with engineered thermal expansion matching. This supports controlled stress distribution and reduces localized stress concentrations. Oxide formation can be precisely controlled or significantly reduced.	▪ Requires metallization and solder or braze joints between pin and eyelet. Multiple interfaces introduce potential stress concentration points and must be carefully managed. ▪ Insufficient wetting at non-metallized surfaces or incomplete braze flow, often caused by loose tolerances due to tolerance stack-up, may introduce inhomogeneities in the solder seal, which may act as stress concentration points.	→ Glass can reduce interface complexity and supports more predictable mechanical behavior.
Long-term stability	▪ Glass-to-metal sealing technology can support robust long-term reliability through an integrated structure with fewer interfaces and potential failure points.	▪ Multi-component structures introduce additional interfaces, which can act as stress concentration points.	→ Glass can provide more consistent long-term performance due to its monolithic sealing architecture.
Integration and scalability	▪ Combines sealing, insulation, and feedthrough in a single structure. Controlled processing can enable consistent performance from prototyping to high-volume production.	▪ More components can lead to increasing complexity at higher integration levels.	→ Glass can support scalable integration with reduced design complexity.

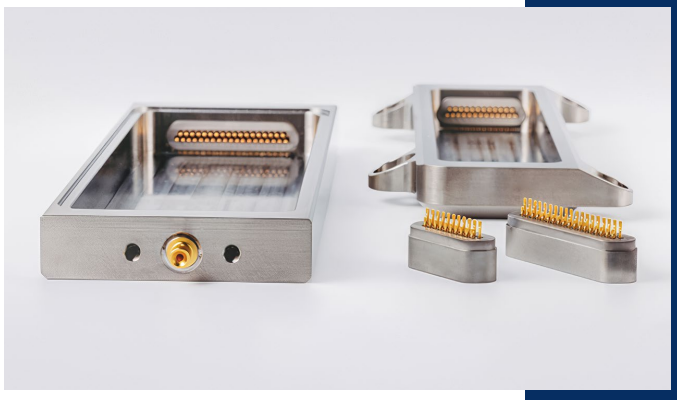












Three things you probably didn’t know about glass

1. Glass can be transparent to radio waves

Glass is often perceived only as an optical material.

Yet glass can act as an RF-transparent window, allowing wireless communication through an otherwise hermetically sealed implant housing.

Why it matters:
More telemetry options. Can support better patient monitoring. Fewer design limitations.

2. Glass can be stronger than some steels

Glass is often perceived as fragile.

But when used in a „compression seal“, glass is placed under compressive stress — the condition in which glass exhibits exceptional strength, exceeding that of some steels. Compression glass-to-metal seals specifically utilize this property to create robust hermetic connections.

Why it matters:
Smaller components. High robustness. Can support long-term performance.

3. Glass can help protect electronics for years and years

Glass is often perceived as brittle.

Yet specialty glass is trusted to protect electronics inside life-sustaining implants from moisture and body fluids over many years. Hermetic glass-to-metal seals are specifically used to create a durable barrier against environmental ingress.

Why it matters:
Can support longer implant lifetime and higher reliability.

5. Summary: Material selection considerations

Material selection should be driven by system requirements that are defined and discussed early in the design process, particularly when feedthrough integration and miniaturization are critical.

Practical checklist

- ✓ Define required feedthrough density early
- ✓ Evaluate creepage distance and electrical isolation constraints
- ✓ Align material system with target package size
- ✓ Consider interface design as a key reliability factor
- ✓ Validate material behavior under application-specific conditions (mechanical, thermal, environmental)

Common material choices in implant packaging

✓ Body	– Titanium, Stainless Steel, Glass, Ceramic
✓ Glass	– Borosilicates, Boroaluminates, Fused Silica
✓ Ceramic	– Alumina, Zirconia
✓ Conductors	– Platinum Iridium, Tantalum, Tungsten
✓ Braze	– Gold

Conclusion

Implant packaging is a system-level design challenge where material selection can directly influence achievable performance, size, and reliability. Glass and ceramic solutions each provide stable hermetic performance, but differ in how they support miniaturization, integration, and scalability.

For engineering teams, the key is not selecting a material in isolation, but understanding how material behavior interacts with geometry, interfaces, and long-term operating conditions. A structured evaluation of these factors can support robust and scalable implant designs.

Disclaimer: This document is provided for informational purposes only. The statements and comparisons presented reflect general engineering considerations and may not apply to all applications. Actual performance, reliability, and suitability depend on device-specific design, operating conditions, manufacturing processes, and validation. SCHOTT supplies hermetic packaging components, including customized feedthrough solutions, and does not manufacture implantable medical devices.

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 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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