The Future Is Now:
How Glass Micro Bonding Enables A New Era of Ultra-Reliable Wafer Level Chip Scale Packaging

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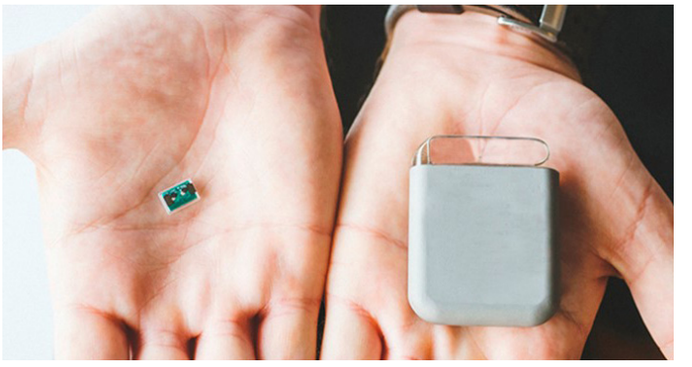
As advancements in technology accelerate by the day, a world is on the horizon in which almost every electronic device, from televisions to household appliances, will be connected to the internet. This will add enhanced functionality and convenience, including over-the-air software updates, information notifications to users, and interactions with other devices. Smartwatches are already an example of a powerful connected accessory that offers a glimpse into the future: biometric monitoring and health problem detection are built into many newer models. Medical devices and active medical implants are joining this trend as well. Connected capabilities allow them to send important, real-time information straight to computers and smartphones for an enhanced level of health awareness and patient care.

With increased connectivity comes a need for electronic components that can be unobtrusively incorporated into devices and everyday items. For medical applications, low-profile components enable smaller devices that are more comfortable and less invasive for patients. These trends toward miniaturization and connectivity can pose challenges for traditional approaches to hermetic packaging, which is used to create a long-term, vacuum-tight seal that protects sensitive electronics from potentially damaging elements such as moisture, heat, vibrations, and pressure.

A sealing technology known as Glass Micro Bonding is expanding hermetic packaging capabilities while enabling unprecedented miniaturization and wireless signal transmission.

The wafer level process allows the direct bonding of two or more glass wafers without any interface materials, enabling transparent all-glass wafer level chip scale packaging (WLCSP) in a wide range of applications. These include medical implants, microelectromechanical systems (MEMS) devices, and other reliability-critical electronic and optical devices. In addition, thanks to the room temperature laser-sealing process, the technology can be used to package electronics and sensors that previously couldn't withstand the environmental heat emitted in standard wafer bonding processes, opening new possibilities for ultra-reliable and fully connected chip-size devices.



A side-by-side comparison showing a typical medical implant (right) and a SCHOTT Primoceler all-glass implant (left).

PROTECTING ELECTRONICS FROM HARSH ENVIRONMENT CONDITIONS

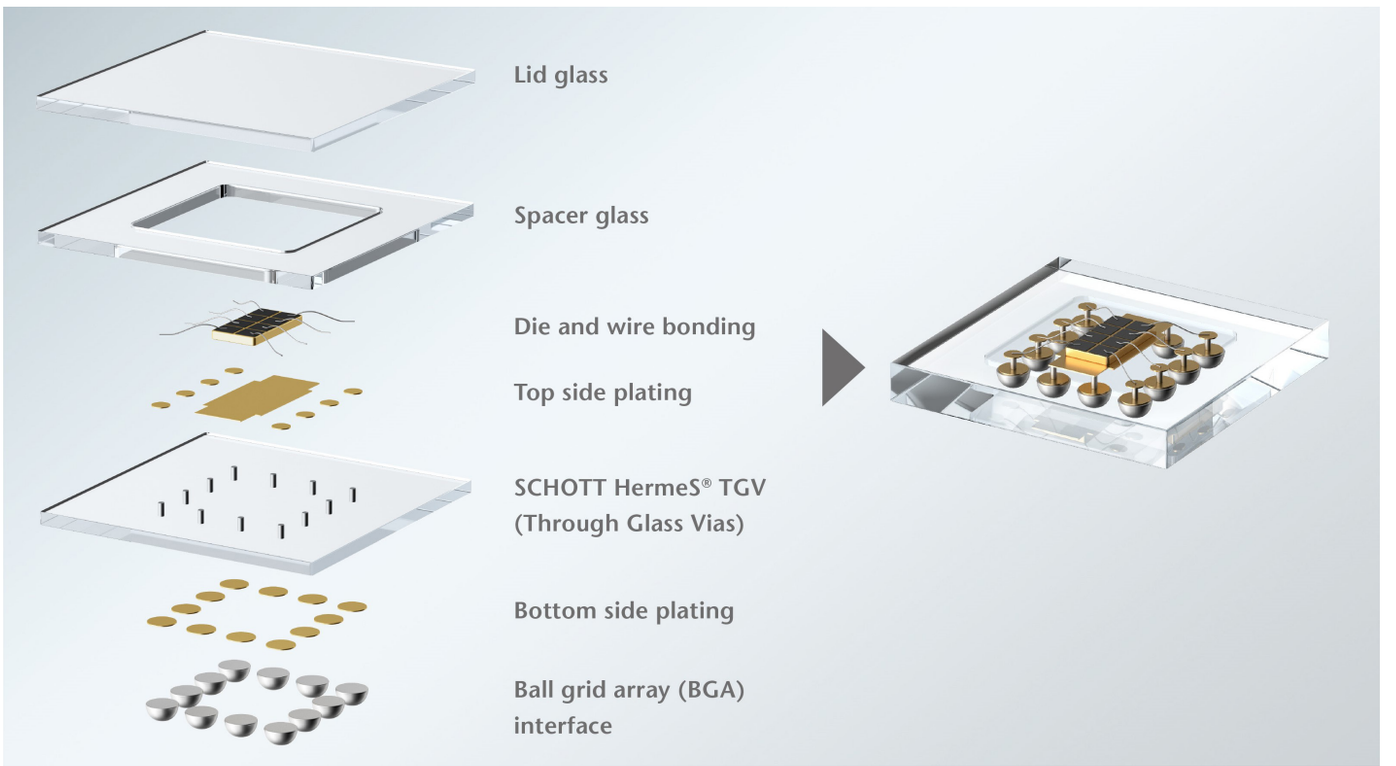
In the current industry landscape, there are two main approaches for sealing of electronic assemblies: adhesive-based bonding and direct hermetic bonding. Adhesive-based bonding uses glue or epoxy to create a seal and can be done at room temperature. However, the organic nature of these materials makes them non-hermetic and, therefore, unsuitable for long-term protection as they wear out over time. This breakdown process can be exponentially accelerated if exposed to harsh environment conditions, ultimately making adhesive-based bonding unsuitable for reliability-critical medical applications.

In contrast, direct hermetic bonding offers a true hermetic and vacuum-tight seal, delivering the best possible protection for electronics in reliability-critical applications. This makes it the ideal choice for complete electronics protection. Only inorganic materials are used — such as glass, metal, and ceramic — which offer durable seal integrity and remain reliably intact, even under extraordinarily harsh environmental surroundings. Direct hermetic bonding offers significant advantages; however, commonly known hermetic sealing technologies such as glass-to-metal or ceramic-to-metal sealing technologies have certain size limitations. While they can be made in very small form factors (as small as a few millimeters), new demands in cutting-edge devices for extreme miniaturization as well as radio frequency (RF) functionality pose a challenge as the boundaries of miniaturization continue to be tested.

Glass Micro Bonding is an innovative process that opens new doors for wafer-scale sealing of electronics with all-glass hermetic electronic packages. The hermetic seal is formed using an extremely precise laser to fuse glass-to-glass by melting only the cross section where the glass meets — an area of just a few microns — while leaving all other surfaces untouched. This one-step manufacturing process does not require any type of adhesive or additive materials and forms a true direct hermetic seal between the glass wafers.

The extremely small and isolated area heated by Glass Micro Bonding to form the seal allows even the most heat-sensitive electronics and sensors to be vacuum-sealed in an all-glass hermetic package at room temperature. This opens new doors for Glass Micro Bonding to be used for hermetic sealing in microfluidic devices or sensors that may contain a sensitive organic layer or coating applicable to their specific function.

Glass Micro Bonding is a simple, straightforward process that does not require any additive materials and can be performed with new glass types that offer excellent biocompatibility. This makes it an ideal technology for medical applications in which biocompatibility is of paramount importance — particularly for implantable devices. There is also a decreased likelihood of reactions with other materials. Such a reaction could cause materials to break down, leading to device malfunction. In addition, the extremely



An explosion view diagram of a device encapsulated with Glass Micro Bonding.

small and precise seal areas add negligible bulk to the electronic components.

While the technology allows for the use of wafers with hermetically sealed-in through-glass vias, a notable advantage of Glass Micro Bonding is that its transparent glass encapsulation can even eliminate the need for wired connections — RFs can travel through the all-glass package. This can reduce both bulk and complexity in device designs while also allowing devices to be internet-connected by emitting and receiving over-the-air data signals. This is extremely intriguing in medical device and implantable applications, as RF can be used for live monitoring as well as reprogramming or updating a device without removing it from its existing setting. Glass Micro Bonding also enables sealed electronics to be combined with chip-based optical components to create optical devices for sensing, imaging, or telecommunications applications.

Components sealed with this new technology can be as small as a few cubic millimeters. The technique is very flexible and can be performed on a chip-scale all the way up to wafers as large as 12 inches, making it simple and cost-effective to scale up for high-volume manufacturing.

REVOLUTIONARY STEPS ALREADY BEING TAKEN IN MEDICAL AND AEROSPACE SETTINGS

Glass Micro Bonding creates an extremely robust and reliable seal that encapsulates sensitive electronics, supporting long-term reliable electronic device operation. The technology is quickly becoming established in applications where failure is not an option and ultra-miniaturization is an advantage or requirement, particularly for medical devices and implants as well as aerospace settings.

Israel-based Nano Retina is using Glass Micro Bonding to seal and protect electronics in a retinal implant device designed to help restore vision in individuals with blindness from retinal degenerative disease. It was key that the sealing technology not only be clear so it can be used in the eye, but also extremely low profile while maintaining strength and reliability. The implantable device, which works with a set of eyeglasses worn by the patient, replaces the functionality of damaged photoreceptor cells in the eye and creates electrical stimulation that activates remaining healthy retinal cells.

Further adding to a reputation of reliability is the use of Glass Micro Bonding in electronic components onboard satellites, where repair or replacement processes of any kind are typically not an option due to inaccessibility in space. Glass Micro Bonding can support the longevity of key components for the lifetime of the satellite and also withstand the extreme conditions present during launch and orbit. The European Space Agency is using Glass Micro Bonding for robust packaging of an optical sensor with sealed-in electrical feedthroughs, which has already seen success in several test projects.

WHAT DOES THE FUTURE HOLD?

Today, most medical diagnostic tests require a blood test at a doctor's office, which is then sent to a lab for analysis. Results can take anywhere from a few hours to several days or even weeks for non-standard tests. Extremely small implantable sensors are an innovation that could remedy this less-than-ideal reality: by continuously gathering data and monitoring blood status in the body, trips to the doctor can be reduced, and safety can even be enhanced with real-time alerts of any abnormal readings. Glass Micro Bonding could help push these developments forward and make such sensors an everyday reality with ultra-miniaturized biocompatible glass packages that enable RF transmission and even potential wireless charging capabilities.

Environmental sensing is another application area that could benefit from this new technology. Glass Micro Bonding could be combined with high-quality optics to make small devices that provide images or analytical information by continuously monitoring the environment. Examples of this include light detection and ranging (LiDAR) for automotive applications, such as autonomous driving, and a variety of other applications requiring high-performance micro-optics components.

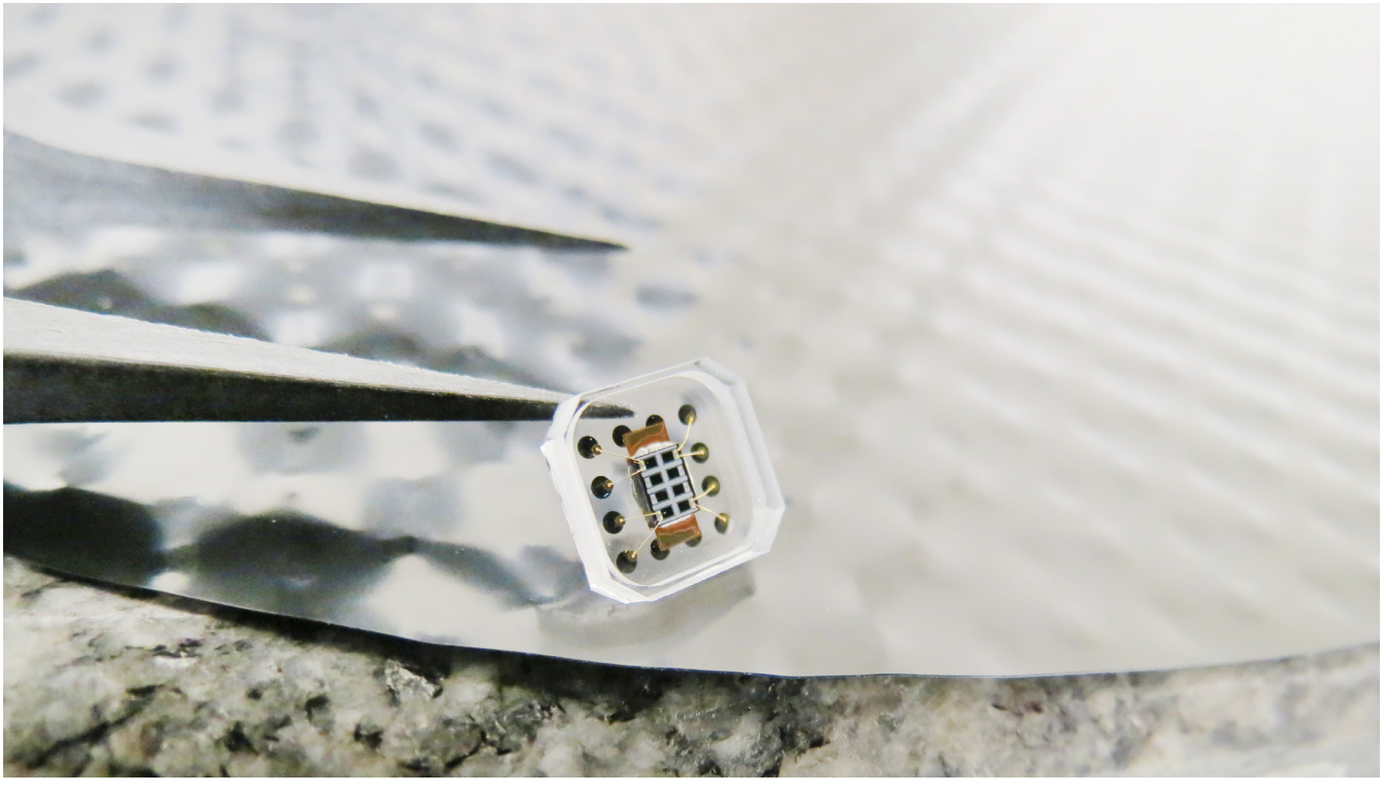
FROM CONCEPT TO COMPLETION

Glass Micro Bonding is a specialized and proprietary technology that is helping overcome hurdles in hermetic packaging limitations that have previously seemed insurmountable. SCHOTT Primoceler Oy uses a highly collaborative process to work with customers incorporating this new hermetic sealing technology into products. From concept development to prototyping, testing, and manufacturing scale-up, the com-

pany's in-house experts can help make innovative application ideas a reality.

This pioneering hermetic sealing technology can be performed with a wide variety of glass types, including borosilicate, fused silica, quartz and soda lime glasses, and silicon. It may seem counterintuitive to use what is often thought of as a breakable material for protection, but the glass assemblies maintain integrity because of their inorganic complexion that is non-porous, non-aging, and resistant to drastic environmental changes. Application-specific testing is performed to validate that the assembly will remain durable and intact under the extreme stress. Testing processes include temperature cycling, moisture resistance, high-temperature storage life, mechanical shock and vibration, and leak-tightness.

Glass Micro Bonding is helping to create new types of ultra-miniaturized devices that are reliable and well-tested while also offering connectivity through RF transmission. The hermetic seals created with this technology will hold up for the lifetime of the device and have proven reliability in extreme environments. In the discussion of what's next for advancements in hermetic packaging technology, Glass Micro Bonding is bridging the gap between today's ideas and tomorrow's advancements in an increasingly connected global landscape.



Ultra-miniaturization is a key benefit of components sealed with Glass Micro Bonding.

About SCHOTT

SCHOTT Electronic Packaging is part of the global technology group SCHOTT and a leading developer and manufacturer of hermetic housings with over 75 years of experience in hermetic sealing for harsh environment, high-reliability applications. SCHOTT's experts work directly with customers, including medical device designers and manufacturers, to formulate customized hermetic sealing solutions based on individual application needs. SCHOTT also offers customizable and fully hermetic Solidur® LED modules and Eternaloc® connectors that can reliably withstand extremely harsh environments, such as typical sterilization conditions in autoclaves. SCHOTT Primoceler Oy is a wholly-owned subsidiary of SCHOTT that offers Glass Micro Bonding, a revolutionary laser-based process that enables ultra-miniaturized hermetic packaging for highly sensitive electronics in demanding applications.