

Leak-tight Ceramic-to-Metal Joints

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Introduction

We know ceramics as hard, chemical-resistant, and high-temperature-resistant substances. The range of available ceramics spans from common window glass to the engineering ceramics used in extreme environments where high temperatures and/or harsh wear-conditions prevail. Many modern electronics and advanced-energy products use unique combinations of materials to achieve optimum performance. As a result, manufacturers must find ways to bond these material combinations to meet customer demand. Ceramic-to-metal joints are most common, and require advanced joining processes due to significant differences in their thermal and mechanical properties.

The Influence of Ceramic Type on Material Properties

Atomic bonds in ceramics are typically ionic or covalent. Ionic compounds transfer electrons to form positive and negative ions, while covalent compounds share valence electrons. Many ceramics exhibit a mix of these two bond types, and properties vary depending on the ratio present. The ionic radius and charge influence strength and melting point, as does the number of shared electrons. For example, aluminum oxide (melting point = 2050°C) is characterized by approximately 37% covalent bonding and 63% ionic bonding, while silicon carbide (melting point = 2800°C) contains 89% covalent bonds and 11% ionic bonds. Silicon dioxide (melting point = 1715°C), includes roughly an equal mix of ionic and covalent bonds.

In addition, ceramics can be crystalline or amorphous. Crystalline ceramics, which exhibit a repeating atomic structure, deform by slip (relative movement of atoms along preferred planes) whereas amorphous ceramics have no repeating structure and deform by viscous flow (similar to a high-density liquid). The same compound can

take on either of these two forms. For example: quartz is made of crystalline silicon dioxide, while window glass is an amorphous form of the same compound.

The Importance of Hermeticity

In engineering applications, ceramics are invariably joined to other materials, most often metals. Many service conditions involve the use of high-temperature gases or aggressive liquids, and assemblies must be sealed to prevent loss of fluid or intrusion of the external environment. Leak-tight (hermetic) seals are most commonly sought in electronics packaging applications. Early vacuum assemblies required sealing against external atmosphere intrusion under widely varying conditions of temperature and humidity, and were expected to remain effective for years. Today's electronics packages must also maintain a long-term seal between metallic leads and glass or other ceramic components. Figure 1 shows a hermetic electronic feed-through device used on many motor-driven devices such as air-conditioner compressors.

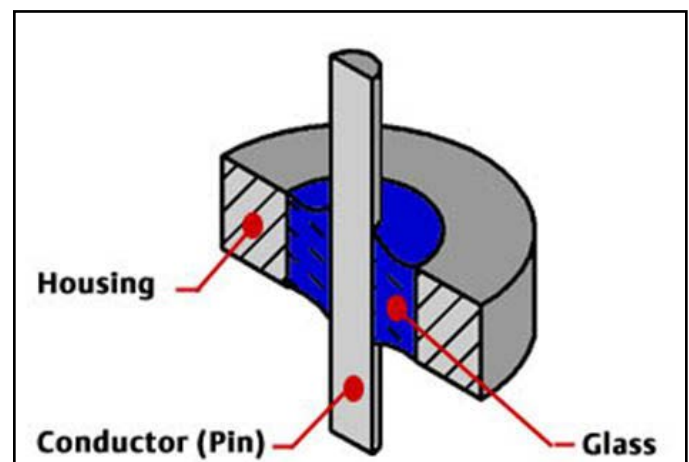


Figure 1: Cross-section of a glass-to-metal seal for an electronic feed-through device (courtesy of Fusite, a division of Emerson Electric)

Techniques for Achieving Hermeticity

Hermetic joint designs must account for the different thermal-expansion properties of the ceramic and metallic components being joined. Apart from glass-to-metal compression seals, common approaches to achieving hermetic seals include active metal brazing, diffusion bonding, and combinations of these methods. For example, partial transient liquid phase (PTLP) bonding has been used to join carbide ceramics to nickel-base alloys for high-temperature energy applications. A brazed joint between two silicon carbide components is shown in Figure 2, where an Al-Si alloy acted as an active braze filler metal.

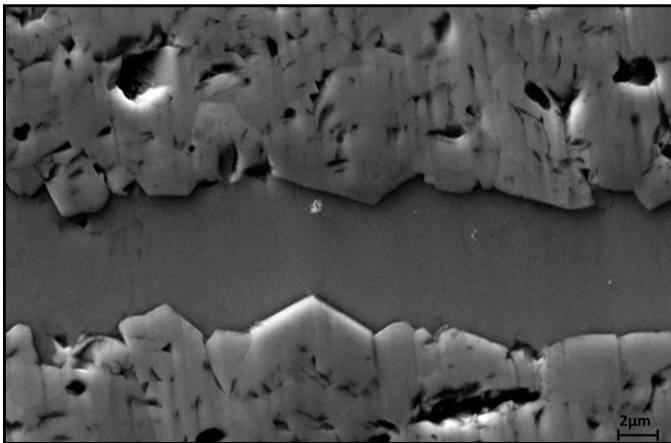


Figure 2: SiC/SiC joint vacuum furnace-brazed with Al-70%Si alloy.

How EWI Can Help

EWI's experts have developed methods of modeling the thermal excursions which occur during joining and service, as well as the resulting stresses and strains. In addition, EWI has three high-temperature furnaces which are used to join ceramics and metals at temperatures up to 1500°C, in either a vacuum or inert gas environment. Our hot-press furnace can impart up to a 50-ton load on assemblies during joining, a key enabler to diffusion brazing and related processes. Inspection of ceramic-containing joints at EWI includes non-destructive examination using helium leak testing, radiographic, electromagnetic, and ultrasonic techniques. Joint sectioning and microscopic examination are also used. Our experience with ceramic-to-ceramic and ceramic-to-metal joint fabrication includes joint design, joining process selection and process development.

Kirk Cooper is a Senior Engineer with EWI. His background includes a wide variety of materials engineering and joining endeavors spanning multiple industry sectors over 29 years. His focus has been on failure analysis, brazing and soldering, product design for ferrous and non-ferrous systems, and materials and process selection and troubleshooting. He has conducted research on diffusion bonding, and has experience in torch, vacuum furnace, controlled atmosphere, and induction brazing. He has also done work in conventional and ultrasonic soldering.