Ceramic to Metal Bonding

The demand for ceramic to metal bonding is growing. New applications are continually being innovated which require the specialized properties of these materials working in combination. Sensors, electronic packaging and power electronics require solutions for thermal management, electrically conductive joints, and hermetic seals. Sensor windows of quartz and sapphire require joining to metal housings such as titanium and stainless steel. Aluminum oxide and aluminum nitride are used as insulating bases where high voltages need to be isolated. The unique properties of ceramics and metals make them highly desirable assembly components across many applications and industries.

Unfortunately these unique properties are also what make the bonding of ceramic to metal difficult to achieve. “Mother Nature” has handed engineers a double set of problems. First, ceramics do not like to be directly wetted, which impedes the adherence of molten metal layers and adhesives. Second, ceramics and metals have largely different coefficients of thermal expansion (CTE). These two problems have limited the application of ceramics in combination with metals for many years.

Traditional Methods

Historically, ceramic to metal bonding has been done one of two ways, with the use of adhesives or with a soldering or brazing process.

- Adhesives - Various polymers create adhesive bonds between the ceramic and metal components. Pre-treatment with an adhesion promoter may be necessary. Low joining temperatures are advantageous but limitations exist on bond strength, dimensional control, and thermal and environmental stability.

- Solder or braze attachment - Ceramic components must first have a metal layer applied. This has normally been done via vacuum metallizing processes, Mo-Mn oxide and plating processes, or active brazing. Once this metal layer is applied, the ceramic and metal components are joined by the melting and subsequent solidification of a filler metal.

Solder or braze attachment has been preferred in many cases over adhesives. This is due to the fact that solder and braze filler materials are metals and thus result in connections that are thermally conductive and hermetic. Additionally soldered and brazed joints do not degrade or pass moisture, conditions which can occur in adhesive joints.

811 W. Fifth Street, Lansdale, PA 19446, USA • www.s-bond.com
Tel: (215) 631-7114 / FAX: (215) 631-7115 • Email: info@s-bond.com

The solder or braze attachment process can be further differentiated. When considering braze attachment of ceramics to metals, the issue of CTE is limiting. Brazes melt at temperatures greater than 840°F (450°C) and, upon cooling, the solidified joint stresses can fracture or distort a part. Many times brazed ceramic-metal joints will require the use of a low CTE metal such as Kovar®, Invar® or Molybdenum.

Alternatively, solders by definition melt and join at temperatures below 840°F, and normally closer to 480°F (250°C). As such, soldered joints have proven to be a better solution for the bonding of ceramics to metals. The joining stresses are much lower because solidification occurs from much lower temperatures than those of brazed joints. The caveat with conventional solders remains that an adherent metal layer must first be placed on the ceramic surface and then followed by a solder-flux process. The solder-flux process is necessary to disrupt the oxides that form upon the heating of the metal-coated ceramic and the base metal during the solder joining process.

The Active Solder Solution

S-Bond® active solders are engineered to provide a superior solution for bonding ceramics to metals. S-Bond alloys contain active elements such as titanium and cerium, which are added to Sn-Ag, Sn-In-Ag, and Sn-Bi alloys to create a solder that can be reacted directly with the ceramic and sapphire surfaces prior to bonding. In fact, the active compositions of S-Bond solders enable the direct bonding of ceramics and sapphire to all metals, including steel, stainless steels, titanium, nickel alloys, copper and aluminum alloys.

S-Bond active solders solve many current braze and solder joining issues by:

- Eliminating the solder-flux process
- Eliminating multi-step pre-coating processes
- Preventing distortion and softening of metals
- Preventing ceramic fracture

S-Bond joints are:

- Hermetic, passing < 10^{-9} atm-cc/ sec
- Strong (> 5,000 psi shear)
- Ductile, based on Sn-Ag or Sn-In alloys
- Thermally conductive

811 W. Fifth Street, Lansdale, PA 19446, USA • www.s-bond.com
Tel: (215) 631-7114 / FAX: (215) 631-7115 • Email: info@s-bond.com

S-Bond Processing

Two different processes can be used in S-Bond ceramic to metal joining, producing joints with differing properties.

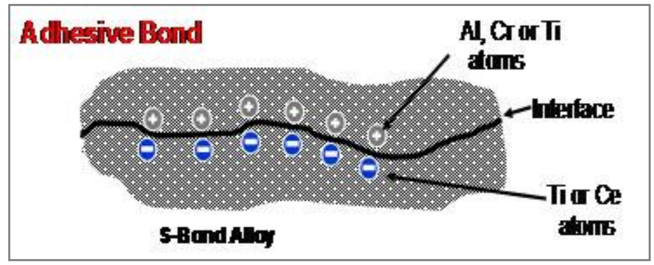

Figure 1 - Adhesive Nature of Mechanically Activated Bond

One method is the 'mechanically activated' joining at the S-Bond solder alloy melting temperature. This is accomplished by heating the component joining surfaces to the solder melting temperature and then spreading, rubbing, or brushing the molten active solder onto the surfaces. This mechanical 'hot' assembly creates agitation within the solder which breaks thin oxide skins that naturally form while molten. The resulting joints are adhesive, with joint strengths nominally below 3,000 psi in shear.

The S-Bond joint shown in the figure to the right illustrates the adhesive bond formed between Stainless Steel and Alumina.

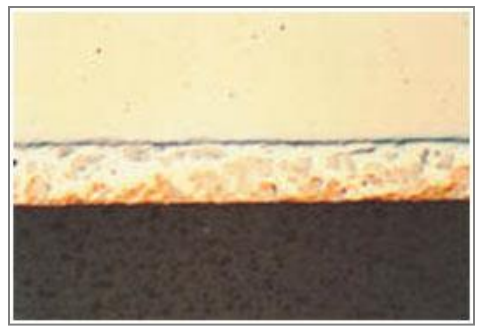

Figure 2 - Stainless Steel - Alumina Joint Indicating Adhesive Bond

A second S-Bond joining method begins with a thermally-activated proprietary process, which prepares the ceramic and sapphire surfaces for bonding. S-Bond alloy is placed on the ceramic surfaces to be joined, after which the components are processed at an elevated temperature in a protective atmosphere furnace. At the elevated process temperature, the active elements in S-Bond react with the ceramic to develop a chemical bond.

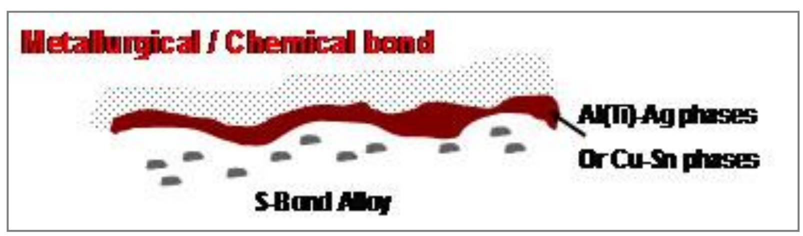

Figure 3 - Chemical Nature of Thermally Reacted Bond

The chemically bonded ceramic surfaces are then bonded to the metal surfaces in a subsequent joining step. The components are heated to the S-Bond active solder melting temperature, spread with molten S-Bond active solder and joined via mechanical activation.

811 W. Fifth Street, Lansdale, PA 19446, USA • www.s-bond.com
Tel: (215) 631-7114 / FAX: (215) 631-7115 • Email: info@s-bond.com

S-Bond joint micro-structures shown in the figure to the right illustrate the chemical bond created between Alumina (Al_2O_3) and S-Bond alloy.

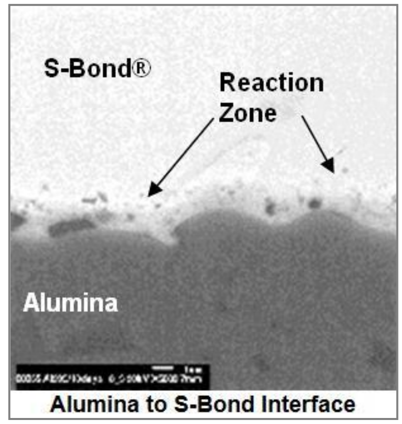

Figure 4 - Alumina - S-Bond Joint Indicating Chemical Bond

This joining method, employing the elevated temperature S-Bond metallization process, results in a chemical bond with a much higher level of joint strength than the adhesive bond. The resulting ceramic-metal joints are better than most brazed sapphire and ceramic to metal joints made by the multi-step Mo-Mn and plating processes. High performance joint properties include shear strengths that exceed 7,000 psi and resistance to thermal cycling from -50° – 150ºC.

Additionally, the S-Bond active solder joining process is highly tolerant of joint variations due to the high surface tension inherent in the solder alloys. Joining with S-Bond eliminates the risks associated with the use of fluxes, such as voids, metallic component etching, and cosmetic defects. No secondary post-bonding cleaning processes are required.

The figures below illustrate several applications joined with S-Bond. Many more applications and industries have been served, including thermal management and heat sinks, C:C composites to aluminum, Si-die attach, quartz to brass sensor housings, MEMS sensors on BeO to brass and foamed metals.

S-Bonded Sapphire and Ceramic Metal Components

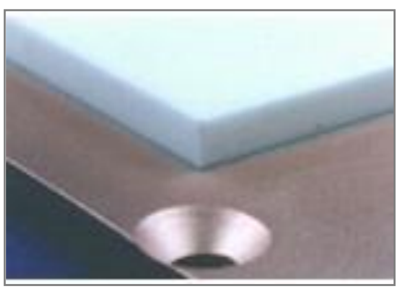

Figure 5 - Ceramic Sputter Target

Figure 6 – Sapphire – Titanium Detector Housing

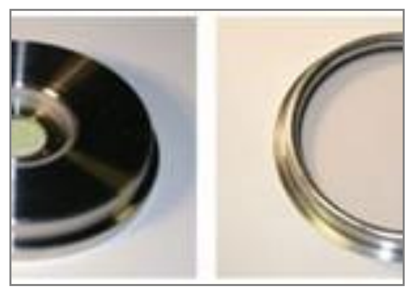

Figure 7 – Sapphire – Metal Window Assemblies

To Learn More

S-Bond Technologies has been developing breakthrough materials and joining solutions for more than two decades. To learn more about S-Bond ceramic to metal bonding solutions, go to www.S-Bond.com and explore our comprehensive knowledge base of application notes, white papers and videos prepared by our own engineers and materials professionals. You may contact us over the internet or directly at (215)631-7114.

811 W. Fifth Street, Lansdale, PA 19446, USA • www.s-bond.com
Tel: (215) 631-7114 / FAX: (215) 631-7115 • Email: info@s-bond.com