Aluminum Bonding with Active Solders

Aluminum is the material of choice for many components and applications today. However the bonding of aluminum presents a challenge due to its naturally forming oxide skin. This nascent oxide skin, Al2O3, exists on all aluminum alloys and serves as a natural barrier to corrosion. Unfortunately it also serves as a barrier to metallic bonding. Soldering, brazing and even welding all must have means to disrupt this thin aluminum oxide skin before wetting and metallurgical adherence can be generated.

Conventional Methods

Several methods are employed in the oxide removal process and vary in accordance with the bonding method used. In welding, AC high frequency pulses on a DC arc will alternate polarity and disrupt the oxide, cleaning the aluminum as it welds. In brazing, chemical fluxes, typically fluoride-based acids, can be used to remove the oxide skin, and are applied via in-process sprays or on the surface of immersion dip brazing baths. Brazing may also be accomplished by fluxing in controlled atmospheres or by brazing in a vacuum with Mg present to getter the oxide molecules. These methods are all used to disrupt aluminum oxide layers just prior to the molten braze filler flowing on the cleaned aluminum joint surfaces.

In aluminum soldering, very aggressive fluoride-based acidic fluxes are used to disrupt the oxide layer and allow the solder to wet and adhere to the freshly cleaned aluminum surface. Alternatively, nickel plating can be applied, covering the oxide skin with a metallic layer that will subsequently form an oxide that is less stable than that of the aluminum. The less tenacious nickel oxide that forms on the plating can then be disrupted with less aggressive fluxes, allowing the molten solder to wet, flow and adhere to the nickel-plated surface.

A Better Bonding Alternative – Active Soldering

Recently developed active soldering technology provides an alternative to both traditional fluxing and high-temperature brazing processes. Active solder filler materials contain additions of active elements which react with and through the aluminum oxide surface layers. These active elements then react with the underlying “fresh” aluminum surface to create reaction zones, resulting in the formation of strong chemical bonds with the aluminum surface.

S-Bond Technologies has engineered various active solder alloys, including Sn, Sn-Al, Sn-Zn, Sn-Ag, Sn-Ag-Bi, Sn-Ag-In and even Pb-Sn based solders. Patented S-Bond® active solders have been formulated using highly active elements such as Ti, Mg, Ga and rare earth metals. Figure 1 illustrates the chemical

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bonds formed in the active soldering process. Figure 2 is a metallographic image of an aluminum / S-Bond interface showing the reaction bond zone where Al-Ag phases have chemically formed.

Figure 1 - Illustration of Metallurgical Bond Formation


Figure 2 – S-Bond - Aluminum Bond Interface

S-Bond® solder alloys bond to a range of metals, ceramics and composite materials without the need for fluxes or pre-plating. In particular, these active solder alloys have an affinity for joining aluminum to itself as well as to other metals and ceramics. The result is that S-Bond active soldering technology has simplified the aluminum soldering process.

Advantages of S-Bond Aluminum Soldering

- Reduces thermal expansion mismatch issues. Lower bonding temperatures are in the range of 120 – 250°C.
- Provides the ability to solder to copper and other metals and ceramics, provided thermal expansion mismatch is managed in the component design.
- Produces metallic joints for thermally conductive bonded interfaces.
- Eliminates metal plating requirements, lowering preparation costs.
- Assures nearly 100% bond areas, eliminating aggressive acid fluxes and creating cleaner work environments
- Eliminates post-bond cleaning to remove flux and associated waste water.
- Affords repair and re-manufacture advantages since solders melt at temperatures far below aluminum alloy melting temperatures.

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Applications that highlight the advantages of S-Bond active solder joining include a wide range of thermal management components, such as finned heat exchangers, cold plates, and heat spreaders. Figures 3 – 6 illustrate a selection of the many successful examples.

Figure 3

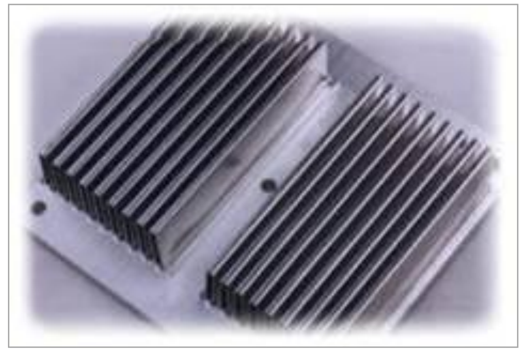

Figure 4

Figure 6

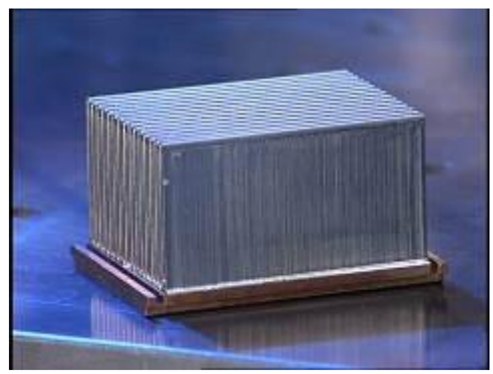

Figure 5

Mechanical Activation in the Soldering Process

Highly active S-Bond solders require mechanical activation in the bonding process. The use of mechanical means in the spreading of the solder material serves to disrupt the natural oxides that form on the molten S-Bond layer. As the active solder melts, cerium oxide modified films form on the surface of the S-Bond. These films are more tenacious and thus more stable than the tin oxides that form on conventional Sn-Ag solders. The mechanical activation disrupts these thin oxides to facilitate active solder wetting and adherence.

Mechanical activation can be achieved through a variety of means. Once the active solder is melted, it can be mechanically spread on faying surfaces via brushing or rubbing, or via ultrasonically activated spreaders. This layer provides a base for bonding, often termed 'pre-tinning'. In a subsequent step, the molten pre-tinned faying surfaces are joined via pressing or sliding together, activating a strong solder bond.

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Figures 7 and 8 illustrate typical methods used in S-Bond solder application. The figures illustrate the rubbing and brushing that can be used to spread and wet S-Bond to aluminum surfaces in preparation for bonding.

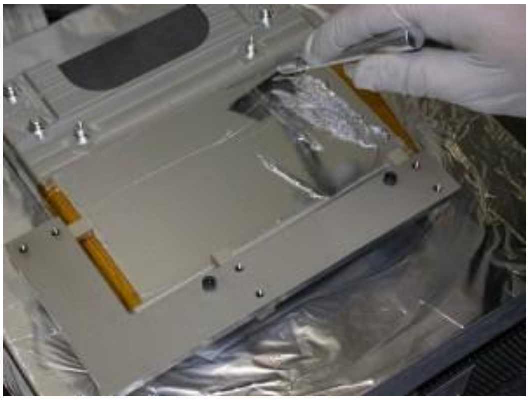
Figure 7


Figure 8

In summation, S-Bond alloys are a new class of solder filler metal requiring new processing methods for effective aluminum soldering. The soldering process involves mechanical activation or agitation of the S-Bond solder as it is pre-placed on the aluminum joining surfaces. The molten pre-placed layers are then joined to each other with mechanical activation to complete the bonding. Figure 9 illustrates ultrasonic spreading of the molten active solders onto large aluminum surfaces prior to joining. Figure 10 shows the bonding of heat exchanger components, joining S-Bond pre-tinned molten surfaces via sliding. This action eliminates air from the large interface, producing a joint with no voids to maintain low thermal resistance – a requirement for an assembly designed to cool automotive electronics.


Figure 9


Figure 10

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An important distinction in S-Bond alloys is that these active solders do not flow into joints via capillary action or flow over surfaces that have not been pre-tinned. S-Bond active solders stay where they are placed. As such, they are not compatible with a conventional solder reflow process. Solder joining techniques that integrate mechanical disruption must be incorporated into S-Bond aluminum bonding processes. For some processes this may be a limiting factor. However, in many applications, a molten solder that will not flow into adjacent surfaces provides a major advantage. The bonding of enclosures, metallic foams and intricate surfaces may be more successfully accomplished in the absence of undesirable excess solder flow.

S-Bond Aluminum Soldering Adds Superior Value When…

- Thermally conductive, low void joints are needed.
- Fluxing causes contamination.
- Excess solder flow affects part function.
- Dissimilar materials are being joined.
- Reworkable joints are preferred.
- Higher joint strengths are not required.

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 aluminum 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.

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