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SHORT COMMUNICATION

Solid state metal-ceramic reaction bonding applications to transistor packages and advanced materials

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With the rapid development in the semiconductor industry, solid state devices are now being produced which are capable of generating high power and operating at elevated temperatures. Package design, in particular thermal properties, is playing a key role in furthering this development. With this in mind, a ceramic package, suitable for high-power transistor devices, has been developed using solid state reaction bonding of BeO to Cu.

Reaction bonding is a direct solid state process involving no intermediate layers and is suitable for joining a wide range of metals (e.g. Pt, Au, Cu, Ni, Co) to various ceramics (e.g. Al_2O_3, BeO, ZrO_2, MgO, $LaCrO_3$). The process was developed following observations of De Bruin, Moodie and Warble.[1,2,3] with patents being held in several countries jointly by the Commonwealth Scientific Industrial Research Organization and the Flinders University of South Australia.[4]

Recently our research has been mainly directed towards exploring applications of this process for solving technological problems. The versatility of the technique lends itself to a wide range of applications. One such application is the bonding of BeO to Cu in constructing a high-temperature transistor heat sink package. An example of a strip-line style package is shown in Figure 1. (Figure 1(a) is an exploded view and Figure 1(b) an actual construction). BeO is used because of its excellent thermal and dielectric properties.

Existing methods for attaching Cu to BeO generally involve metallizing or brazing, such as the Mo/Mn process or the use of an active metal capable of wetting the ceramic surface. These methods involve elaborate bonding procedures, generally at high temperatures, with a suitable atmosphere provided throughout the process. If this intermediate metallizing layer could be eliminated and a direct bond be made, then the thermal contact should be greatly improved.

The method used to produce the bonds involves heating the components to approximately 900°C for about 2 hours in an atmosphere of argon, under a light holding pressure to maintain intimate contact. Being a solid state bond, maximum bond strength is attained by ensuring that the maximum surface area is in contact between the metal and ceramic. For the type of bond shown in Figure 1 this is achieved by polishing the copper base screw and alumina retaining ring to optical flatness prior to bonding. The BeO is not polished, but is used as received from the manufacturer, due to the hazards involved in machining BeO. The copper leads are also not polished, but are simply flattened between optically flat steel platens before bonding.

High temperature testing of various bond combinations has shown that the bonds generally retain their high strength at elevated temperatures, there being only a slight reduction compared to the room temperature strengths. A range of materials that have been successfully bonded using the reaction bonding technique are shown in Table I, together with typical strength data.

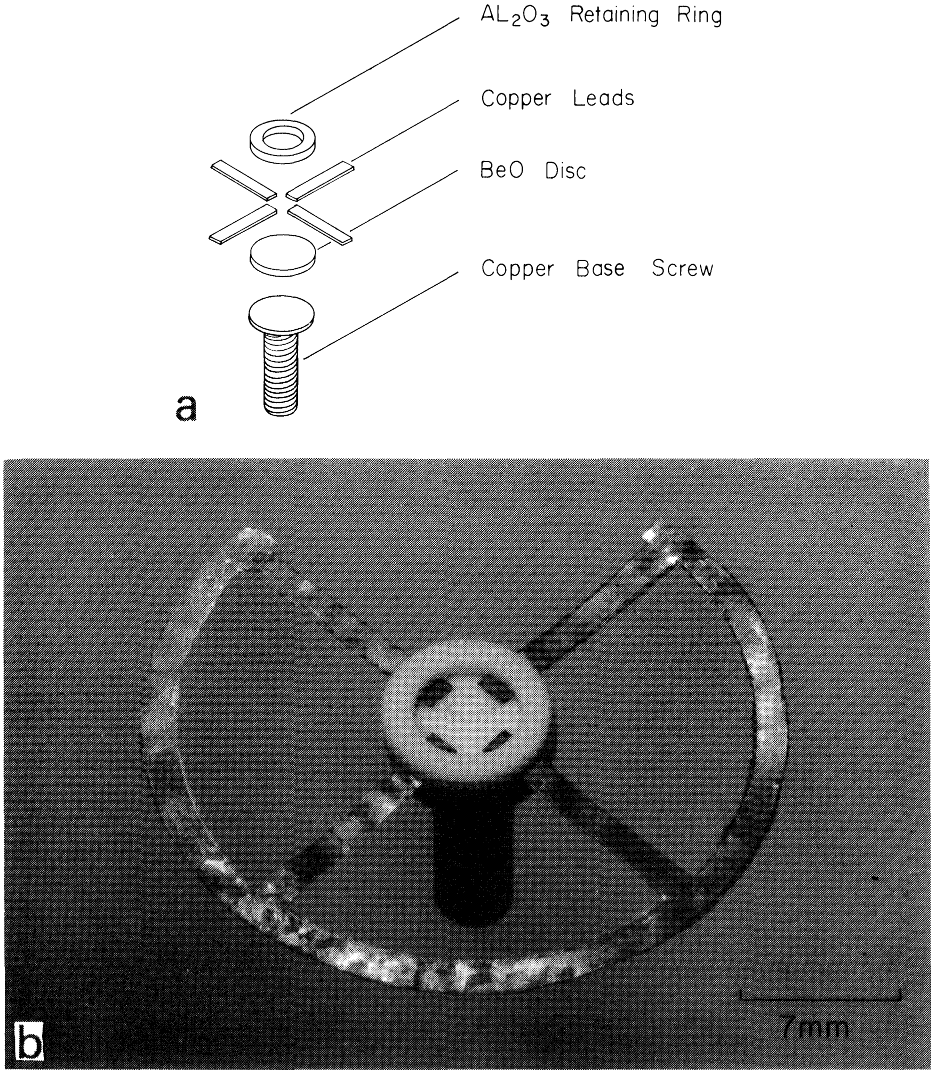

FIGURE 1 "Strip line" style heat-sink package. (a) Exploded view. (b) Actual construction

TABLE I
A sample of bonds made by reaction bonding. Strengths by 4 point bend test (modulus of rupture)

Bond	Strength (MPa)
BeO-Cu	36
ZrO_2-Cu	100
Al_2O_3-Cu-Al_2O_3	44
Al_2O_3-Pt-Al_2O_3	200
ZrO_2-Pt-Al_2O_3	130
Al_2O_3-Ni-Al_2O_3	30
Al_2O_3-Au-Al_2O_3	100

Test bonds are generally formed in a sandwich construction, i.e. ceramic-metal-ceramic, however, if the application requires, one sided bonds can be constructed.

Currently, the bonding process is being evaluated in oxygen sensing probes, body implant packages, fast response thermocouple sheaths, automobile gas sensors and discharge lamp housings.[5]

Possible applications of metal-ceramic reaction bonding could include electrodes for MHD generators, fuel cells, ceramic engine components and cutting tools. Using the reaction bonding technique, most bonds formed are helium leak-tight making it a possible application for vacuum leadthroughs.

The versatility of the reaction bonding technique, together with the high bond strengths obtained, and the retention of these strengths at elevated temperatures, suggest the technique as a means of solving many technological problems in fields of high temperature and advanced materials.

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