Joining Al_2O_3 to Al_2O_3 by Brazing †

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KEY WORDS: (Brazing) (Joining) (Ceramics) (Alumina) (Amorphous Filler Metals) (Copper-Titanium)

Alumina is one of the most commonly used oxides in ceramics. Construction of ceramic structures provides more complex shapes. The joining of ceramics by metal is often quantitated in terms of wettability. The wettability is expressed by the product of the surface tension of liquid and the contact angle formed by the tangent to the liquid surface at a point of contact with the solid in sessile drop technique.

The object of the work described in this paper is to evaluate the joining strength of Al_2O_3/Al_2O_3 joint made with amorphous $Cu_{50}Ti_{50}$ filler metal, and to relate the strength to the wettability of the alloy to alumina.

The composition of alumina in this work was 99.6 wt% Al_2O_3, 0.1 wt% SiO_2 and others. Alumina of 15 mm diameter and 3 mm thickness, and alumina of 6 mm diameter and 3 mm thickness were used to make a lap joint. Prior to joining the surface of the specimen was polished mechanically with silicon carbide paper to No. 1000. The heating rate up to brazing temperature was 20°C/min in 10^{-5} torr, and the cooling rate after brazing was 19°C/min down to 600°C and then about 1°C/min down to room temperature. Joint strength was measured by fracture shear loading using a special fixture at a cross head speed of 1 mm/min. The microstructures of brazed specimens were determined by optical and scanning electron microscopy. The sessile drop technique was used to evaluate wetting behavior by measuring contact angle of liquid alloy on alumina ceramics. The contact angle was obtained after cooling down to room temperature. The contact angle of liquid drop on alumina surface is schematically shown in **Fig. 1**.

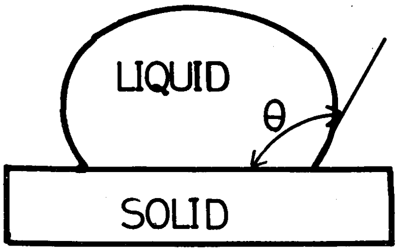

Fig. 1 Schematic of contact angle of liquid drop on solid surface.

The contact angles between alumina and copper-titanium alloys containing 34 to 57 at.% titanium at 1025°C for 30 min are presented in **Fig. 2**. The contact angles markedly decrease from 33° for $Cu_{66}Ti_{34}$ alloy to 5° for $Cu_{43}Ti_{57}$ alloy. The contact angle of $Cu_{50}Ti_{50}$ alloy significantly decreases with an increase in temperature and time as shown in **Figs.** 2 and **3**.

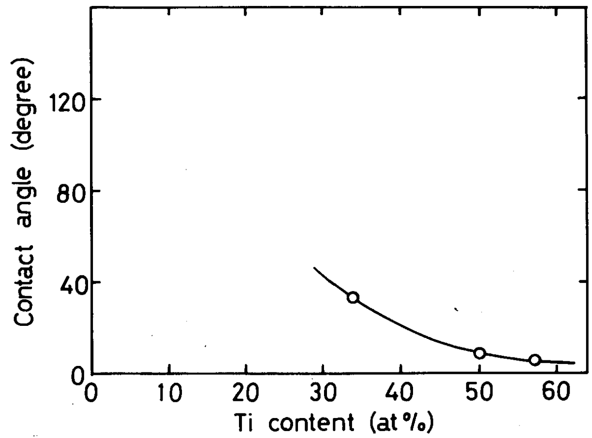

Fig. 2 Effect of titanium content on contact angle of Cu-Ti alloys on Al_2O_3 at 1025°C for 30 min.

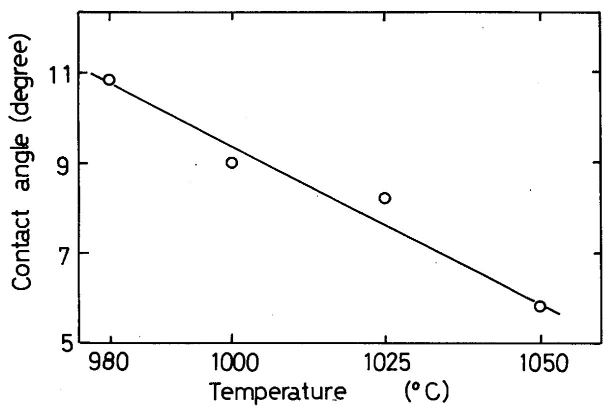

Fig. 3 Change in contact angle of $Cu_{50}Ti_{50}$ alloy on Al_2O_3 with temperature for 30 min.

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The contact angle of $Cu_{50}Ti_{50}$ liquid at constant brazing time of 30 min decreases from 11° at 980°C to 6° at 1050°C. At the constant brazing temperature of 1025°C the angle lowers markedly from 11° to 1° at brazing time of 120 min **(Fig. 4)**.

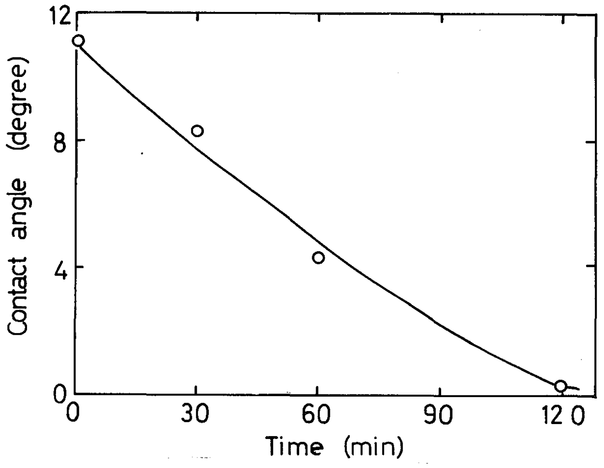

Fig. 4 Change in contact angle of $Cu_{50}Ti_{50}$ alloy on Al_2O_3 with time at 1025°C.

The work of adhesion is the energy required to separate a unit area of solid-liquid interface into two surfaces. An increase in titanium content in copper-titanium alloy decreases the contact angle, and probably enhances the adhesion work of the liquid alloy.

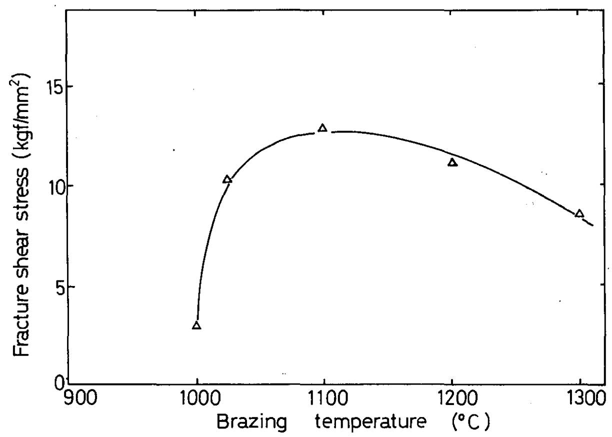

Fig. 5 Brazing temperature dependence of room temperature fracture shear stress of Al_2O_3/Al_2O_3 joint brazed with $Cu_{50}Ti_{50}$ filler.

The brazing temperature dependence of fracture shear stress of Al_2O_3/Al_2O_3 joint at constant brazing time of 30 min is shown in **Fig. 5**. The stress exhibits a maximum at 1100°C, and then decreases with higher brazing temperature. The reaction at the interface between the Cu-Ti alloy and alumina increases with an increase in temperature. This is may supported experimentally from the decrease in contact angle in Fig. 3. On the other hand, the damage of alumina in the interface owing to the reaction leads to the weakening of the joint of alumina and Cu-Ti alloy. These give rise to the maximum of joining strength of $Al_2O_3/CuTi/Al_2O_3$ joint.

Fig. 6 shows the microphotographs of Al_2O_3/Al_2O_3 joint brazed with $Cu_{50}Ti_{50}$ filler at 1025°C for 30 min, and the line analyses of Ti, Cu and Al in the joint. Though the microphotographs at the interface do not show the intermediary phase, X-ray photoelectron spectroscopy analysis reveals the presence of titanium oxide at the interface between alumina and the filler alloy. The formation of titanium oxide is attributable to the joining of alumina to the filler alloy.

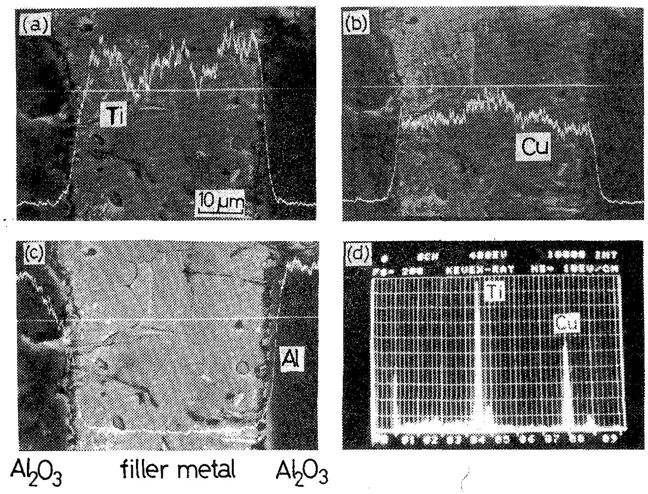

Fig. 6 Microphotographs and line analyses of Ti, Cu and Al (a, b, c) in joint interface, and spot analysis of filler metal (d) made at 1025°C for 30 min.