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Applying of ultrasonic waves on brazing of alumina to copper using Zn-Al filler alloy

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Ultrasonic waves were applied during brazing of alumina to copper, The intensity of ultrasonic wave was 1 kW and 18 kHz and the aim of this work was to study the effect of the ultrasonic wave and brazing temperature on the properties of the braze joint between alumina and copper using Zn-Al alloys as filler metal.

First the alumina was metallized by applying on ultrasonic wave in a Zn-Al braze bath. Then the metallized alumina was brazed with copper using the same filler alloy. The joining mechanism was investigated by measuring the joining strength and analyzing the microstructure at the interface of the joint. The ultrasonic waves improved the wetting in the molten Zn-Al bath by accelerating the removal of bubbles from the interface between alumina and the filler, and this was reflect in improved joint strength.

1. Introduction

Ceramics are becoming increasingly important in engineering applications because of their excellent heat resistance, corrosion resistance, wear resistance, etc. [1]. Ceramic-metal interfaces are a critical feature in many materials systems, and processing of these interfaces is fundamental to fabrication of a wide range of materials and devices [2]. In recent years, brazing has received renewed attention due to its flexibility in stress accommodation and joint production. The brazing methods of ceramic to metals are divided into the Mo-Mn method, active filler metal method, molten aluminum method and oxide utilizing method [1].

Brazing is often the preferred method for joining ceramics to metal because it can provide hermetic seals and the plasticity of the braze accommodates the differential expansion between the ceramic and the metal. But several important problems such as poor wettability and residual stresses due to thermal expansion mismatch between ceramics and the metal still remain unsolved [3]. Applying ultrasonic waves during brazing could help to decrease joining temperature which in turn will reduce the thermal stress in the ceramic/metal joint [4, 5].

2. Experimental

The materials used in the present investigation were alumina (99.62 mass% Al_2O_3, 0.1 mass% SiO_2 and others) of 6 mm diameter and 4 mm thickness, and copper (0.03 mass% O) of 6 mm diameter and 4 mm thickness. The braze filler were Zn-Al alloys, containing Al content from 0 up to 10 mass%, (Fig. 1 show the element phase diagram). Alumina was first metallized by applying ultrasonic waves in Zn-Al filler bath.

The intensity of ultrasonic was 1 kW and 18 kHz. The brazing temperatures were 673, 723 and 773 K. The Alumina was lap-joined to copper that was coated with the same filler by applying the ultrasonic wave for 10 sec (Fig. 2). The joining strength of Al_2O_3/Cu joint was evaluated by fracture shear loading using a cross head speed of 1.67×10^{-2} mm/s. Also the hardness of filler alloys was measured using 100 gf in Vickers hardness tester.

3. Results and discussion

3.1. Effect of ultrasonic applying time and joining temperature

Fig. 3 show the change in joining strength of Al_2O_3/Cu joint with application time of ultrasonic wave using Zn with 5% Al as filler alloy at joining temperatures of 673, 723 and 773 K. Applying an ultrasonic during brazing improves the strength of Al_2O_3/Cu joint at all joining temperatures. For instance, the strength of the joint changes from 18.9 MPa to 65 MPa when the time of application of the ultrasonic wave changes from 10 s to 90 s respectively at joining temperature of 723 K. Moorhead *et al.* [1] reported that ceramic surface low thermodynamic driving force for interface formation (wetting), in contrast to metals which have a higher surface energy surface and hence are wetted. Applying ultrasonic waves removed the macro air bubbles at the interface between filler and alumina, thus increased the wetting of the filler with alumina. Therefore the improvement the wetting of filler alloys against alumina improves the joint strength.

The increase in joining temperature raises the joining strength at a constant applying ultrasonic time. Fig. 4 represents the change in joining strength of Al_2O_3/Cu

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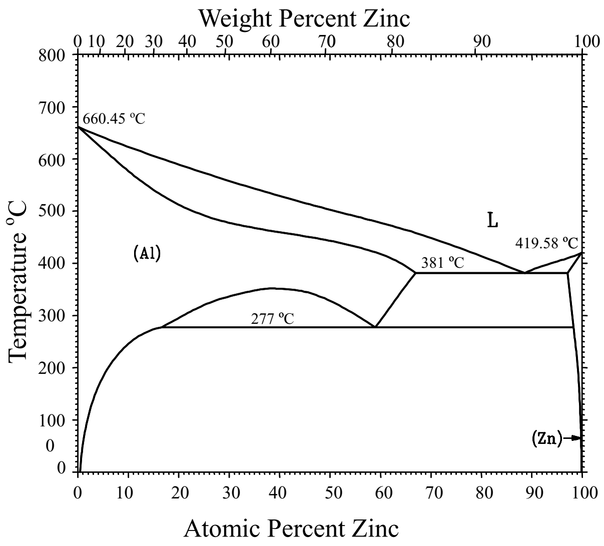


Figure 1 Phase diagram of Zn-Al binary alloys [6].

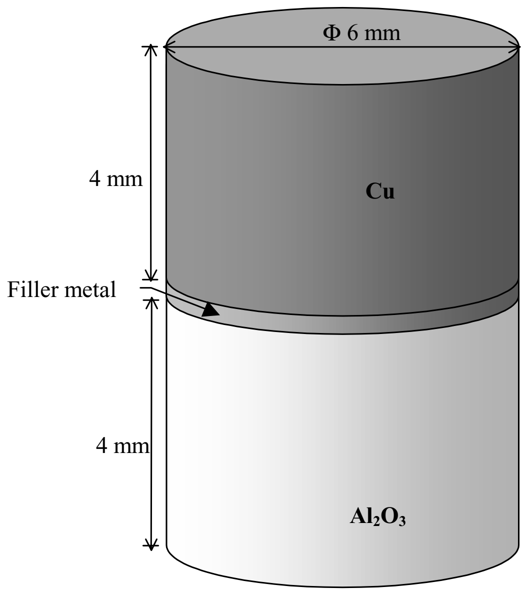


Figure 2 Specimen after joining.

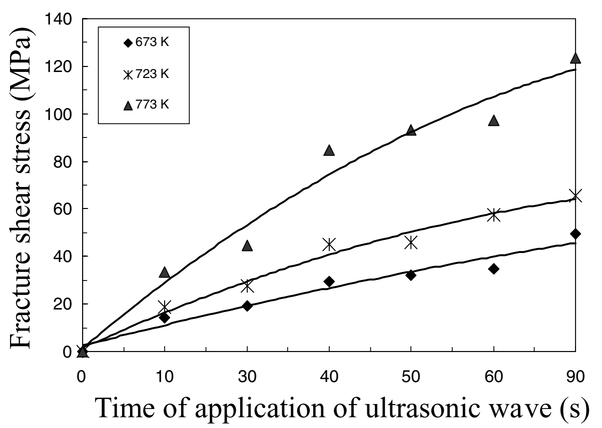


Figure 3 Change in joining strength of Al_2O_3/Cu joint using 5%Al Filler with application time of ultrasonic waves.

joint using Zn-5% Al filler with joining temperature at the constant applying time of 40 s. It can be seen that the strength of joint changes from 30 MPa at 673 K to 85 MPa at 773 K.

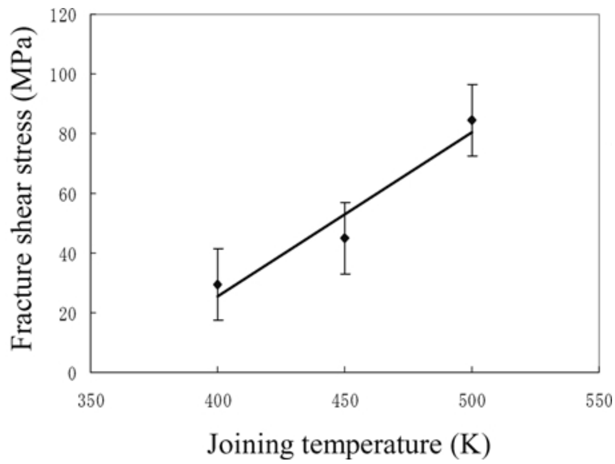


Figure 4 Change in strength of Al_2O_3/Cu joint using Zn-5Al filler with joining temperature at applying time 40 s.

From Figs 3 and 4 it is noted that the increase of the ultrasonic applying time almost has the same effect as increasing of joining temperature. This means that we can obtain same joining strength at low temperatures which will reduce the thermal stress in ceramic/metal joint.

3.2. Effect of filler alloy composition

Fig. 5 shows the dependence of joint strength of Al_2O_3/Cu with Al content in Zn-Al filler in joining condition of 723 K and 40 s. The addition of 5% Al to Zn filler improves the strength of the joint. With further addition of Al up to 10% decrease the joint strength. The increasing of joint strength has two factors. First the wetting of molten Zn-Al filler against alumina, up to 5% Al, molten aluminum definitely wets alumina, because the aluminum in Zn-Al filler reacts with alumina. This leads to enhance the wetting of filler against alumina [4].

Second, the strength of Zn-Al filler is improved by alloying Zn with Al. The relation between Al content and hardness of filler alloys is presented in Table I, alloying Al with up to 10 wt% increases the hardness of the filler from 42.5 Hv to 73.6 Hv. This would tend to enhance the joining strength. But increasing Al content up to 10% raises the viscosity of molten fillers, and high

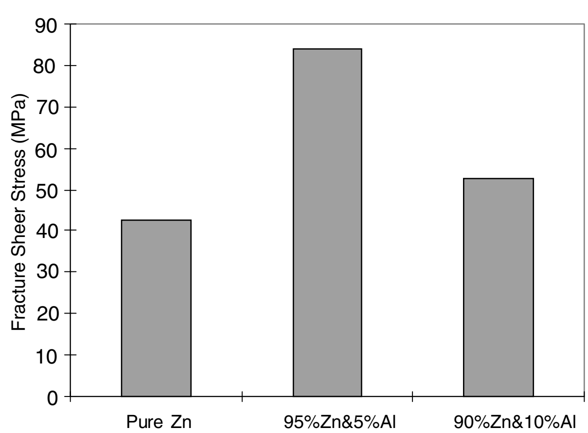


Figure 5 Dependence of Al_2O_3/Cu joint strength with Al content in Zn-Al filler in joining condition of 723 K and 40 s.

TABLE I Relation between Al content and Hv hardness of filler alloy

Alloy	Hardness (Hv.)
Pure zinc	42.5
95% Zn & 5% Al	54.3
90% Zn & 10% Al	73.6

viscosity of the filler results in a lowering of the joining strength.

3.3. Fracture surface observation

In all brazed joints, the fracture occurs at the filler/alumina interface. Observing the fracture surface area (Fig. 6) can give an idea of the effect of ultrasonic waves on the wetability of filler to ceramic. Fig. 7 shows effect of ultrasonic applying time on the percentage of wetted area on fracture surface. It can be shown that by increasing of ultrasonic applying time the area of wetted part increase. The applying of ultrasonic waves accelerate the wetting of the filler metal, and increase the wetted area of the alumina and filler metal.

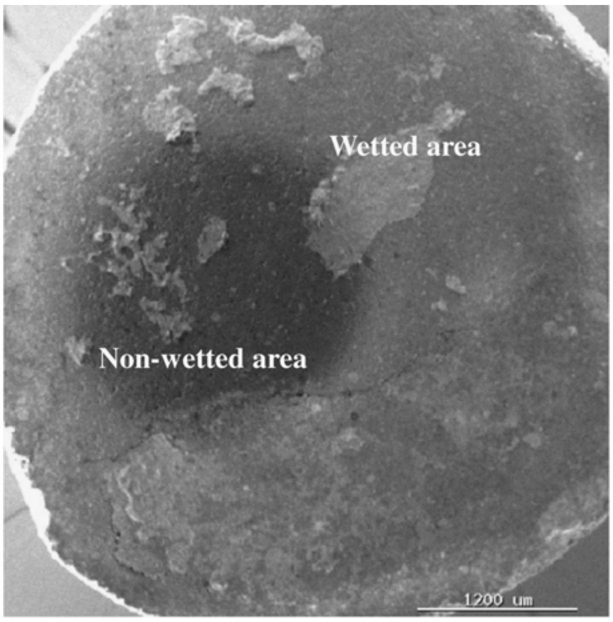


Figure 6 Fracture surface of Al_2O_3 joint using Zn-5% Al filler, (Al_2O_3 side).

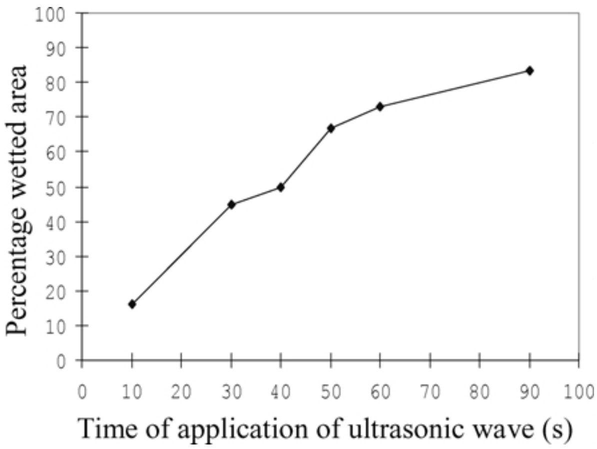


Figure 7 Effect of ultrasonic applying time on the fracture surface area.

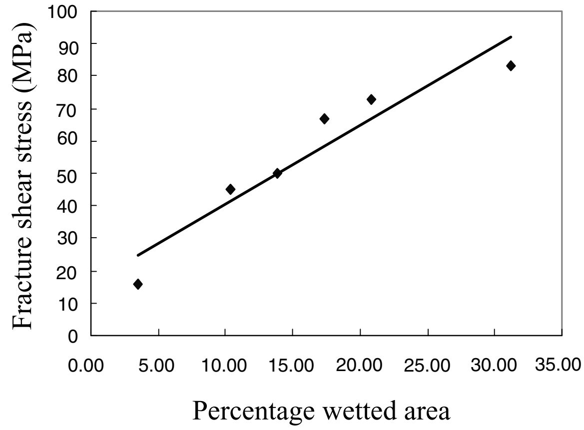
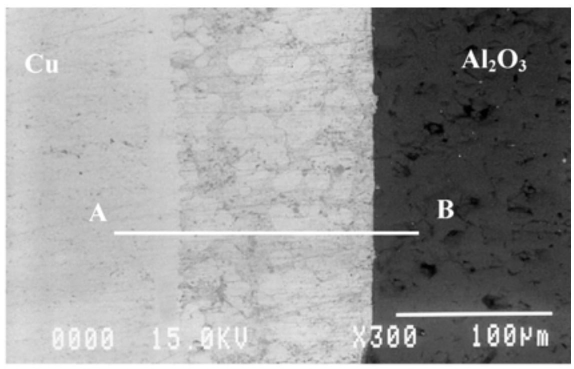


Figure 8 Effect of fracture surface area on the joint strength.

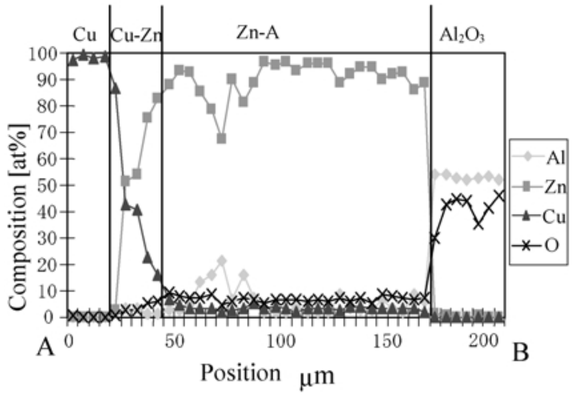
Fig. 8 show the relation between percentage of wetted area at alumina fracture surface and the shear fracture stress of Al_2O_3/Cu joints, using Zn-5% Al as filler metal. It can be shown that increasing of fracture strength is due to increasing of percentage of wetted area, For instance, the strength of the joint changes from 33.3 MPa to 123.5 MPa when the percentage of wetted area change from 16% to 83.4% respectively.

3.4. Microstructure of joint interface of Al_2O_3/Cu joint

Fig. 9 shows the microstructure and EPMA line analysis of Al_2O_3/Cu joint with Zn-5% Al filler brazed at



(A)



(B)

Figure 9 Interface structure of Cu/Al_2O_3 joint at 723 K with applying ultrasonic wave of 40 s.

723 K for 40 s. Filler well wets Al_2O_3, and no defect are observed at the interface between Al_2O_3 and filler. Filler Zn-5% Al has solidified as primary Zn in a matrix of eutectic mixture. At the interface beside Cu, Cu-Zn (β) solid solution is formed as Cu dissolver into filler to a distance of about 25 μm.

4. Conclusions

The joining of Al_2O_3 to Cu using Zn-Al as filler alloys containing Al content up to 10 mass% was conducted using ultrasonic waves with the intensity of 1 kW and 18 kHz. The joining mechanism was investigated by measuring the joint strength, filler hardness, qualification of fracture surface and observation of the microstructure of the interface of Al_2O_3/Cu joint.

Applying ultrasonic during brazing of ceramic to metal can give an interface free from defects. The brazability of Zn-Al filler alloys were improved by applying ultrasonic waves. The applying time of ultrasonic waves from 0 to 90 s promoted the wetting of filler alloy against alumina and raises the joining strength. The addition of Al to Zn filler improve the wettability, and raises the joining strength up to 5% Al. Increasing the applying time of ultrasonic waves increased the percentage of wetted area on the ceramic side, which enhances the joint strength. Increasing the ultrasonic applying time improved the wettability between filler and alumina as did by increasing the brazing temperature.

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