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Author(s)	Hafez, Khalid M.; Naka, Masaaki
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Application of Ultrasonic Waves during Brazing of Alumina/Copper Using Zn-Sn Filler

Khalid M. HAFEZ* and NAKA Masaaki **

Abstract

Ultrasonic waves were applied during the brazing of alumina to copper. The aim of this work is to study the effect of ultrasonic waves and filler composition on the properties of the braze joint between alumina and copper using Zn-Sn alloys as filler metal. First alumina was metallized by applying ultrasonic waves to the Zn-Sn 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, hardness and analyzing the microstructure at the interface of the joint. The weight percent of tin in the filler ranged between 0, 30, 60 and 91%. The shear strength and microstructure of the joint strongly depend on the filler composition. The effect of ultrasound was assessed primarily from acoustic cavitations, impact and friction between filler and alumina ceramic, to improve the wetting between alumina and the filler, and reflect improved joint strength. Another ultrasonic advantage causes reduction of the joining temperature and means that thermal stress as in the braze joint are reduced.

KEYWORDS: Alumina, Copper, Brazing, Zn-Sn, (Ultrasonic waves)

1. Introduction

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. However several important problems such as poor wettability, and residual stresses due to thermal expansion mismatch between ceramics and the metal still remain unsolved [1].

Ultrasound has a role to play in resolving this problem; the use of ultrasonic vibrations during brazing makes it possible to greatly improve the joint quality [2-4].

2. Experimental

The materials used in the present investigation were Alumina and copper of 6 mm diameter and 4 mm thickness. Braze filler were Zn-Sn alloys. Alumina surfaces were first metallized by applying ultrasonic waves in the Zn-Sn filler bath. The intensity of ultrasonic was 1 kW and 18 kHz. The brazing temperature was 723 K. Then alumina was lap-joined to copper that was coated with the same filler by applying ultrasonic for 10 sec. The joining strength of Al_2O_3/Cu joint was evaluated by fracture shear loading using a cross head speed of 1.67 X 10^{-2} mm/s.

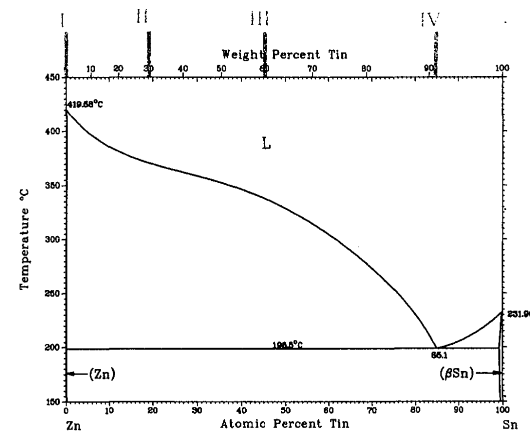

Fig.1 Binary phase Diagram of Zn-Sn

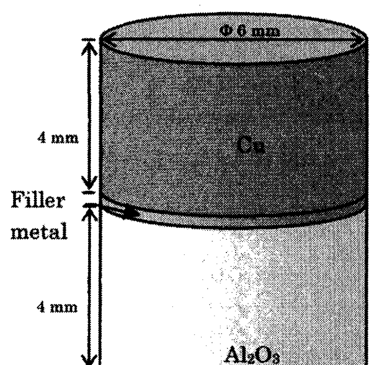

Fig. 2. Specimen after joining.

† Received on January 31, 2003

*Ph.D. Student

** Professor

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3. Results and Discussion

3.1 Interfacial structures

Brazing of Al_2O_3 to Cu was performed at a temperature of 673 K for various Zn-Sn filler alloys 30, 60 and 91 wt% Sn respectively, No voids were observed at the interface, suggesting that the molten brazing alloy adequately wet the surfaces of Al_2O_3 and Copper. When joining was performed using a 30%Sn-70 Zn as a filler alloy, a wide interface could be observed, containing three reaction layers. As can be seen from the SEM micrograph of 'Fig.3' and EPMA analysis 'Fig. 4 ', the first reaction layer (I) with a 30 μm thickness of a gray color was formed just in contact with the copper side and could be a γ solid solution between Cu and Zn, the next layer is white containing large gray clusters (II) from EPMA analysis the gray clusters contain 1.3 at% Cu and 98.7 at% Zn while the white areas contains 1.8 at% Cu, 18.9 at% Zn and 89.4 at% Sn. From the ternary diagram of Cu-Zn-Sn the gray clusters could be Zn plus 1.3% Cu while the white area could be β solid solution of Sn with excess Zn[5]. The third layer near the alumina surface within 2~3 μm had no chemical reaction with ceramic and was only mechanical reaction due to ultrasonic application.

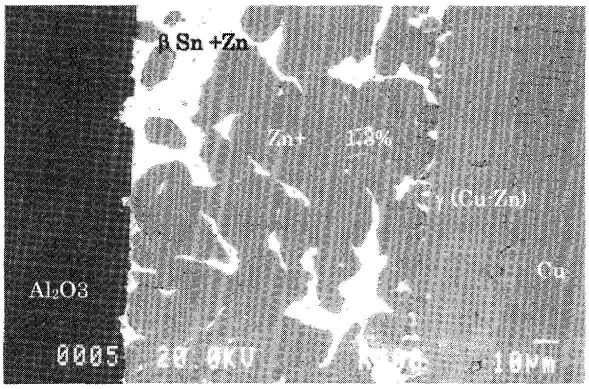

Fig. 3 SEM micrograph of Al_2O_3/30Sn-70Zn/Cu interface

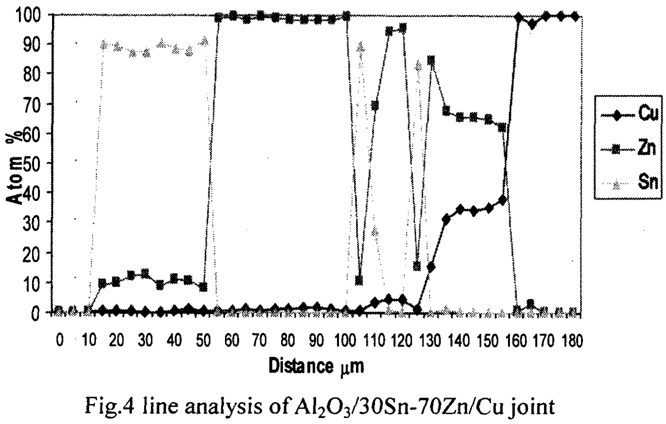

Fig.4 line analysis of Al_2O_3/30Sn-70Zn/Cu joint

The observation of the joint performed using 60%Sn, 40%Zn as a filler alloy shows only two layers, as can be seen from the SEM micrograph and EPMA at Fig. 5 and Fig. 6 respectively. The first reaction layer just in contact with the copper side, could be γ solid solution between Cu and Zn like the previous joint. The next layer close to the ceramic is rich with zinc but the loss of tin is strange and it may be because the metallizing and joining occur at 673 K while the melting temperature of tin is 255 K.

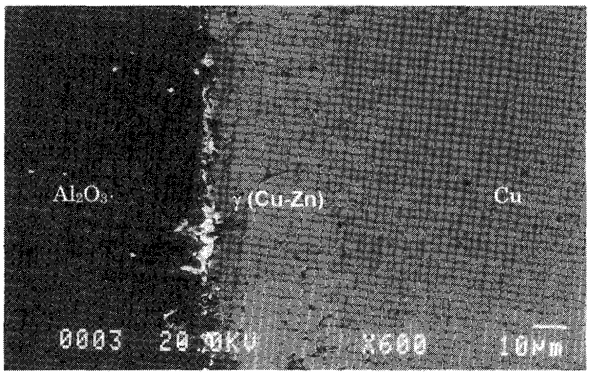

Fig. 5 SEM micrograph of Al_2O_3/60Sn-40Zn/Cu interface

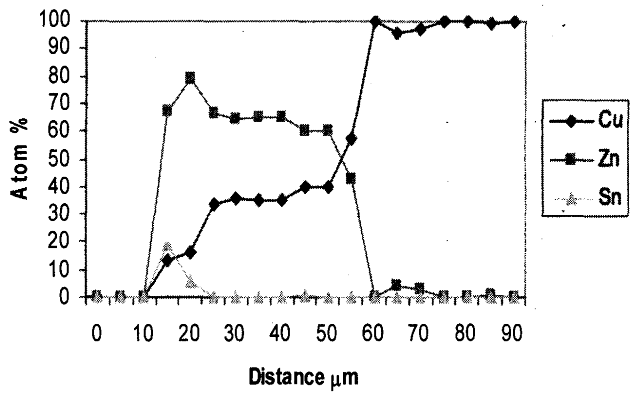

Fig.6 line analysis of Al_2O_3/60Sn-40Zn/Cu joint

The joint that was made using 91%Sn, 9% Zn as a filler alloy shows an interface containing two layers, the first reaction layer just in contact with the cooper side is highly concentrated with gray clusters and the chemical composition 58.6 at% Cu, 30.4 at% Zn and 11.1 at% Sn. From the ternary diagram it could an intermetallic component Cu_5Zn_8. The next layer the concentration of Cu_5Zn_8 decreases and a white area which is rich with Sn exist Figs (7,8).

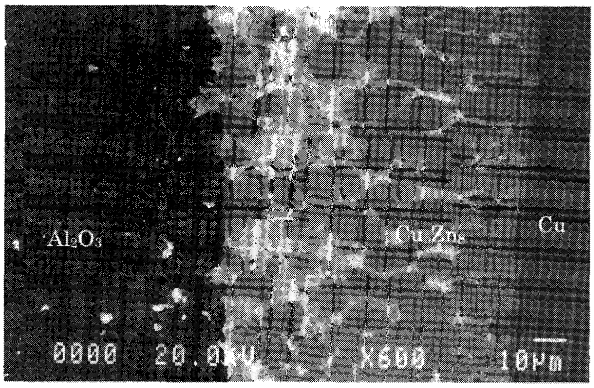

Fig. 7 SEM micrograph of Al_2O_3/91Sn-9Zn/Cu interface

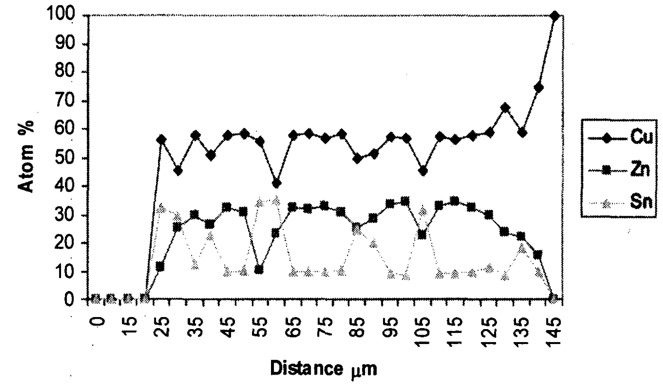

Fig.8 line analysis of Al_2O_3/91Sn-9Zn/Cu joint

3.2 Bond strength

3.2.1 Effect of ultrasonic applying time

Figure 9 show the change in joining strength of Al_2O_3/Cu joint with increasing time of the ultrasonic wave, using 30 %Sn-70 %Zn as filler alloy at a joining temperature of 673 K. Applying ultrasonic waves during brazing improves the strength of the Al_2O_3/Cu joint. For instance, the strength of the joint changes from 26 MPa to 43 MPa when the application time changes from 10s to 90s at a joining temperature of 673 K. Moorhead *et al.* [6] reported that a ceramic surface has no thermodynamic driving force for interface formation (wetting), as would be the case of metals in which a higher surface energy surface was available. Applying ultrasonic waves removes the macro air bubbles at the interface between filler and alumina, thus increase the wetting of the filler with alumina. Therefore the improvement in wetting of filler alloys against alumina improves the joint strength. The ultrasonic waves applied during metallizing have many effects, collapsing cavitations bubbles near ceramic surface, impact of the ceramic surface by filler atoms and friction between filler and ceramic surface, all these effects will combine into improve the wettability and therefore enhance the bond strength[7].

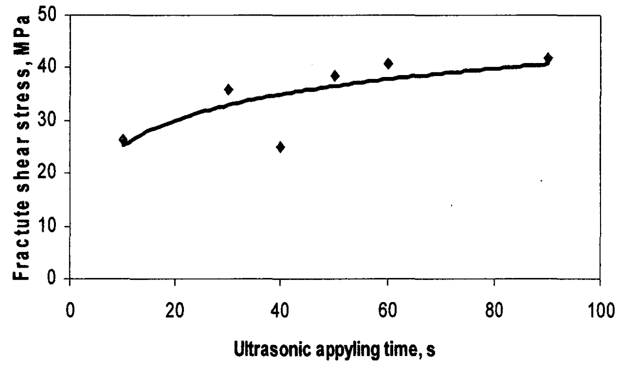

Fig. 9 Relation between ultrasonic applying time and fracture shear stress of joints

3.2.2 Effect of filler alloy composition

Figure10 shows the relation between the tin content in the filler alloy and the mechanical properties of the brazed joint. It is clear that increasing the percentage of tin in the filler reduces the bond strength of the joint. Naka and Hafez [4] reported that when using the same filler, the fracture shear stress will increase with an increase of the remaining filler on the ceramic surface after fracture. Although it is clear from the fracture surface in Figure 10 that the remaining filler increases with increasing the tin content in the filler alloy, but on the other hand the mechanical properties of the filler alloy (which is represented by hardness in Figure 11) fall when increasing the percentage of tin in the filler alloy. This could be the reason for the deterioration of joint shear stress. The formation of brittle intermetallic components at high level of tin content could also have the same effect.

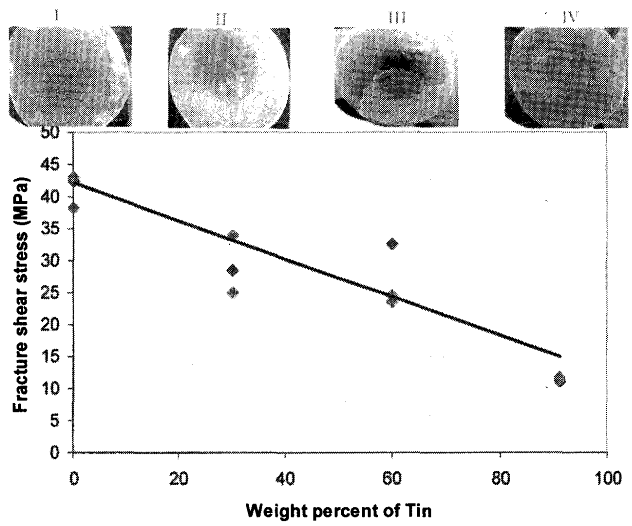

Fig. 10 Relation between weight percent of tin and fracture shear stress of joints

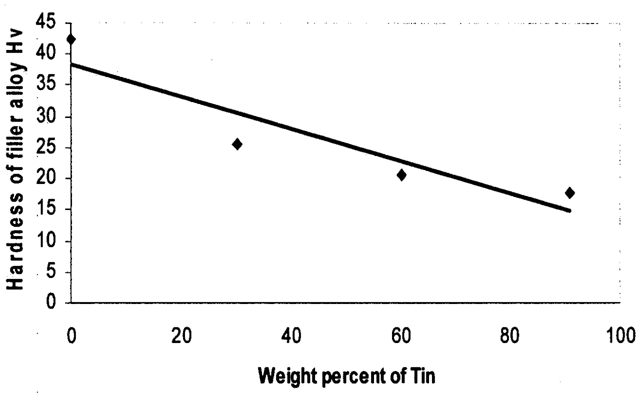

Fig. 11 Relation between weight percent of tin and hardness

4. Conclusions

Brazing of alumina to copper by using a Zn-Sn filler alloy was performed at 673 K for different filler alloy compositions and the following conclusions could be obtained;

1. By applying ultrasonic sound joint interfaces free from voids could be obtained.
2. Different reaction layers could be observed at the interface, containing solid solution compounds and intermetallic components.
3. The fracture shear stress increased with increasing the application time of ultrasonic waves and decreased with increasing the tin content in the filler alloy.

References

[1] M.G. Nicholas and D.A.Mortimer Material Science and Technology, (1985), Sep., pp. 657-665.

[2] Masaaki NAKA, Michimasa MAEDA and Ikuo OKAMOTO, Transactions of JWRI, (1989), vol. 18 No.1, pp75-79.

[3] M. NAKA and I.OKAMOTO, Metal-Ceramic Joints, (1989)., vol 8, pp.79-84.

[4] Masaaki NAKA and Khalid M. HAFEZ, submitted to Journal of Material Science.

[5] ASM Handbook, Alloy Phase Diagram, (ed. Huge Baker et al.), 1992, Vol. 3.

[6] A.J.Moorhead and W.H. Elliott, ASM Handbook, ASM International,(1993), V6, pp.948-958.

[7] Khalid M.HAFEZ and Masaaki NAKA, transaction of JWRI, vol. 31, No. 2, pp177-180, (2002)