# EFFECT OF INTERMETALLIC COMPOUND ON MECHANICAL PROPERTIES OF Al-Cu DISSIMILAR BRAZING JOINT

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**ABSTRACT**

Brazing of Al to Cu using Al-Si-Mg-Bi brazing alloy has been carried out in the vacuum furnace. In the bonded interlayer, there were two kinds of intermetallic compounds. One of these intermetallic compounds was $\theta$ phase and the other was $\delta$ phase. The growth of $\delta$ phase was controlled by diffusion Al into Cu. Deformation behavior of Al-Cu brazing joint was brittle without deformation of the base metal. Shear strength of the joint was only about 20MPa. The shear specimen broken in the intermetallic compound, which was mainly $\theta$ phase. Shear strength did not depend on the bonding temperature.

**KEYWORDS**

Aluminum, Copper, brazing, Intermetallic compounds, Fracture strength

## 1. Introduction

Dissimilar bonding is very important technology in almost all industrial products. Especially, Al-Cu combination is effective for weight reducing in thermal control equipments. For Al-Cu combination, there are many investigations about solid state bonding (diffusion bonding, friction bonding, etc.)[1][2][3] but there is little information about application of brazing for Al-Cu dissimilar bonding.

In this paper, brazablity of Al-Cu dissimilar joint using vacuum brazing technique was developed. And the control factor of fracture strength of the dissimilar joint was investigated.

## 2. Materials used and experimental procedure

### 2.1 Materials used

JIS A1050 and JIS C1020 are used as base metal. Brazing sheet is Al-Si-Mg-Bi alloy equivalent JIS 4104. This brazing sheet is generally used for vacuum brazing of Al alloy. Chemical compositions of each material are shown in Table 1;

**Table 1** Chemical compositions of materials

| | Chemical compositions (mass%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Si | Fe | Cu | Mg | Zn | Ti | Bi | Al |
| A1050 | <0.25 | <0.40 | <0.05 | <0.05 | <0.05 | <0.03 | | >99.50 |
| C1020 | | | >99.96 | | | | | |
| 4104 | 10 | | | 1.5 | | | 0.1 | Bal. |

### 2.2 Experimental procedure

The size of specimen which used for observation of microstructure of a bonded interlayer is 10×10×3mm as shown in Fig.1. Shear test of a lap joint was performed with the specimen size of 20×52.5×3mm. Thickness of brazing sheet is 100$\mu$m. A couple of specimen was loaded 0.1MPa by spring and was brazed in the vacuum furnace with a brazing temperature range from 783 to 823K and a brazing time for 0.06 to7.2ks.

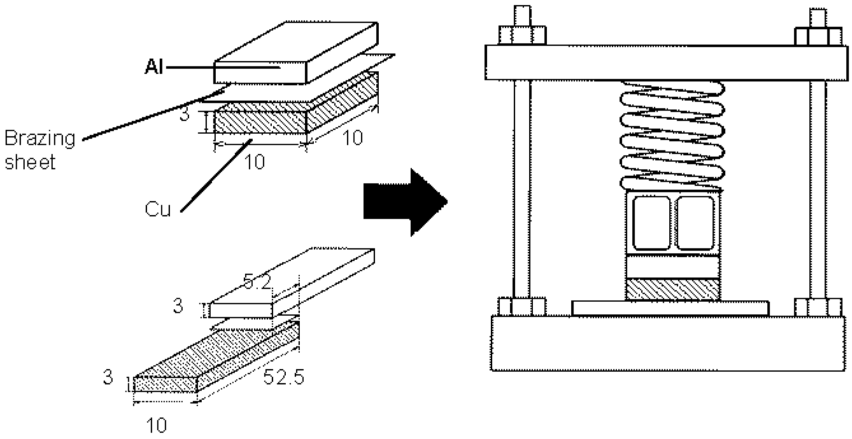



**Fig.1** Schematic illustration of setting specimen

## 3. Results and discussions

### 3.1 Microstructure in the bonded interlayer

A typical microstructure of the bonded interlayer is shown in Fig.2. Brazing condition is 803K×0.06ks. A layered reaction phase (Phase I ) and a wavy phase (Phase II) are mainly at the interface between Cu and the brazed interlayer as shown in Fig.2.

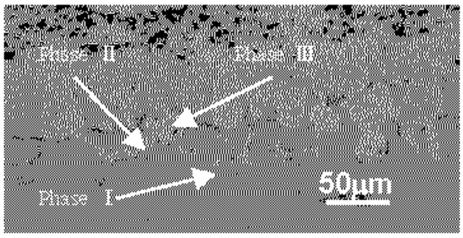
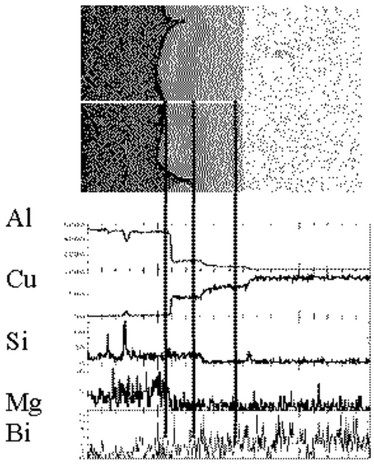
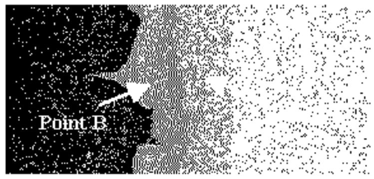



**Fig.2** Microstructure of Al-Cu dissimilar brazing joint : 803K× 0.06ks

Chemical compositions of these reaction phases were analyzed by EPMA and then these phases were identified as shown in Fig.3. It was cleared by EPMA analysis that Phases I and II were intermetallic compounds, $\theta$ and $\delta$ , respectively.




(a)Results of line analysis; 803K× 7.2ks




| Element | Atomic percent | |
|---|---|---|
| | Point A | Point B |
| Al | 39.00 | 67.10 |
| Cu | 61.00 | 32.20 |
| Si | 0.00 | 0.72 |
| Mg | 0.02 | 0.19 |
| Bi | 0.00 | 0.00 |
| Phase | $\delta$ | $\theta$ |

(b) Results of quantitative analysis;803K× 7.2ks

**Fig.3** Results of EPMA analysis

Fig.4 shows Vickers hardness of both intermetallic compounds comparing to the base metal. The hardness of both $\delta$ and $\theta$ phases are Hv620 and Hv470, respectively. These values are much more lager than that of base metal.

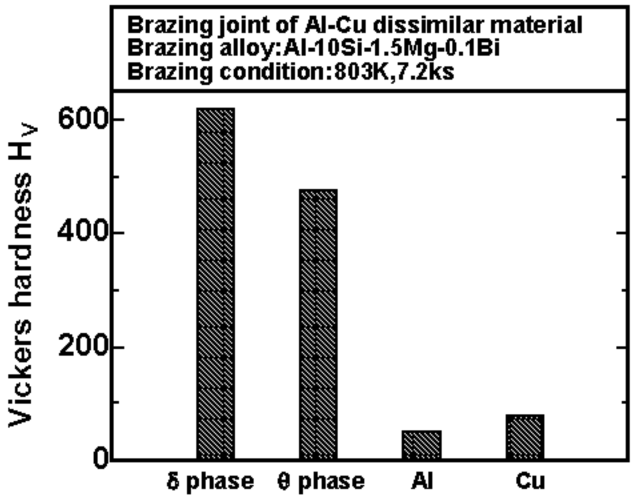



**Fig.4** Vickers hardness of each phase

**3.2 Effects of a bonding temperature on a width of intermetallic compound**

Fig.5 shows the relation between width of intermetallic compound and brazing time. Width of $\delta$ and $\theta$ phases increases with the increase in a brazing time. Width of both $\delta$ and $\theta$ phases increase linearly with the increase in bonding time. The gradient of line of $\delta$ phase is almost 0.5. It means that $\delta$ phase grows as a function of square root of brazing time and the growth rate probably is controlled by diffusion of Al to Cu. On the other hand, Fig.6 shows the relation between width of an intermetallic compound and a brazing temperature. Width of $\theta$ phase increases with an increase in a brazing temperature and that of $\delta$ phase is almost constant regardless of the brazing temperature.

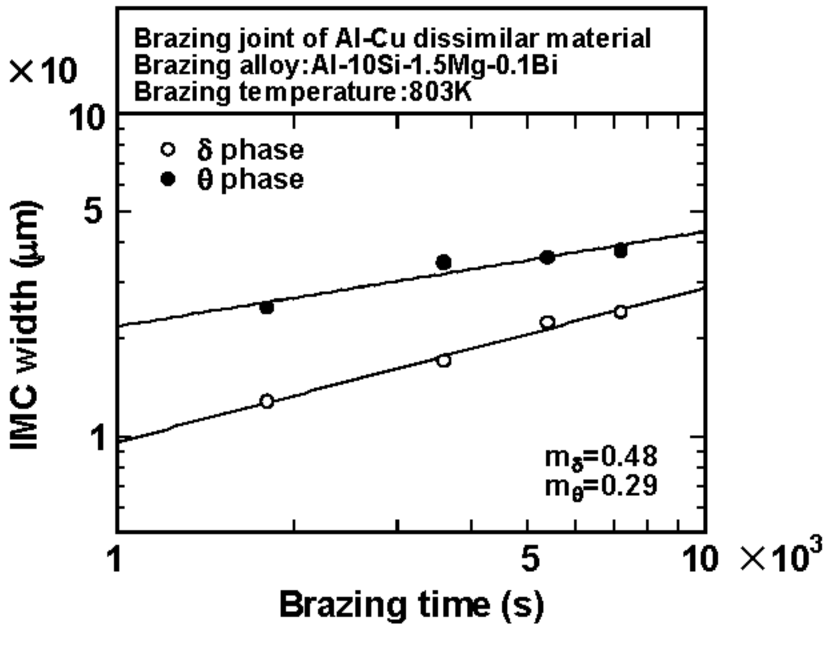



**Fig.5** Relation between width of intermetallic compound and brazing time

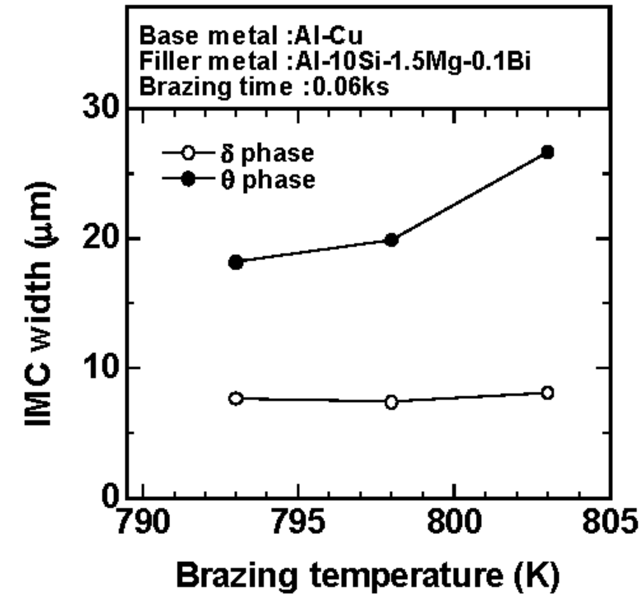



**Fig.6** Relation between width of intermetallic compound and brazing temperature

### 3.3 Relation between shear strength of Al-Cu dissimilar brazing joint and intermetallic compound of bonded area

Fig.7 shows fracture surfaces of brazed joints with different brazing conditions at the shear test. The all fracture surfaces seem to be brittle.

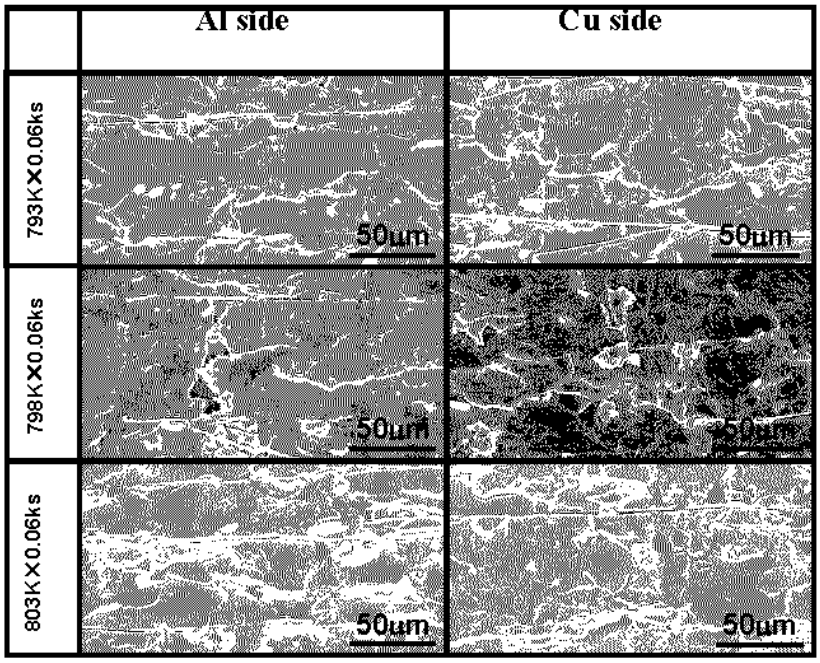



**Fig.7** SEM image of fracture surface of Al-Cu dissimilar brazing joint specimen

Relation between shear strength of the joint and brazing temperature is shown in Fig.8. The shear strength is about 20MPa, which is about 30% of the Al brazed joint independent of brazing temperature. According to EPMA analysis for fracture surface, fracture seemed to occur in the intermetallic compound layer. Moreover, by observing cross section of fractured specimen, fracture seemed to occur in $\theta$ phase (Type I ) and at the interface between $\theta$ phase and $\delta$ phase (Type II). In particular, fracture mainly occurred in $\theta$ phase as shown in Fig.9.

T.Enjo has been reported that the tensile strength of Al-Cu dissimilar diffusion bonding joints depended on the intermetallic compound and was lower comparing with that of Al base metal [1]. From the results of Fig.8 and Fig.9, the shear strength of Al-Cu dissimilar brazing joints is also considered to be controlled by strength and shape of the intermetallic compound layer.

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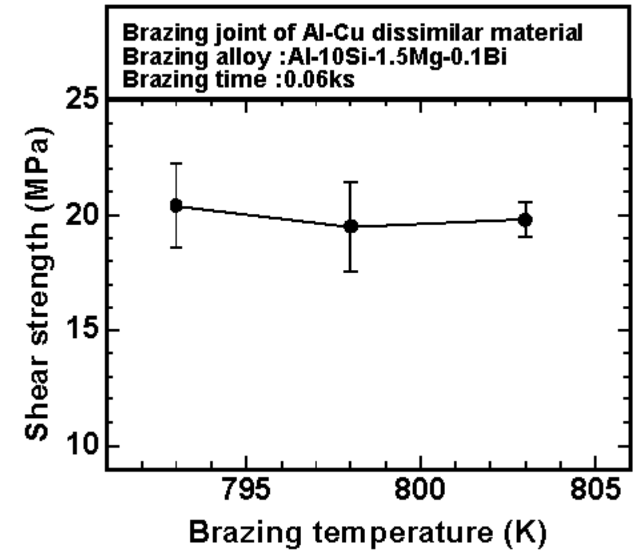


**Fig.8** Relation between fracture strength of Al-Cu dissimilar brazing joint and brazing temperature

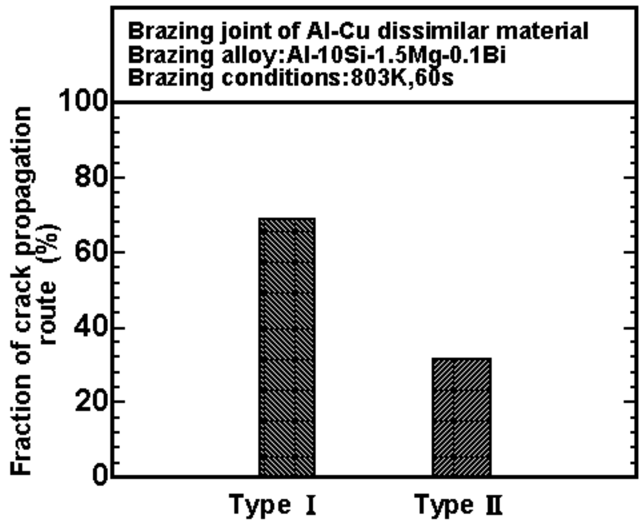


**Fig.9** Fraction of fracture propagation

## 4. Conclusions

The Al-Cu dissimilar joint was brazed using a commercial brazing sheet of Al-Si-Mg-Bi alloy. Two kinds of intermetallic compound, $\theta$ and $\delta$ phases, were mainly seen in the bonded interlayer. The layered $\delta$ phase was at the interface between Cu base metal and the bonded interlayer. The wavy $\theta$ phase grew by adjoining the $\delta$ phase. The hardness intermetallic compound was much more higher than those of Al and Cu base metals.

Width of $\delta$ phase increased linearly with an increase in square root of brazing time independently of brazing temperature.

The shear strength of brazed joint is about 20MPa, which is about 30% of the Al brazed joint independent of brazing temperature. Fracture seemed to occur in $\theta$ phase and at the interface between $\theta$ phase and $\delta$ phase. In particular, fracture mainly occurred in $\theta$ phase. The shear strength of Al-Cu dissimilar brazing joints is considered to be controlled by strength and shape of the intermetallic compound layer. Therefore it was important to control the growth of intermetallic compound layer for improving the strength of these joints.

## References

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