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Transient Liquid-Phase Sintering using Tin and Silver Powder Mixture for Die Bonding

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Abstract

In this research, we develop transient liquid-phase bonding using Sn-Ag system. The Sn-Ag system was designed by Sn-Ag paste and optimized the proportion. As result, die shear stength of Si and Cu bonding using 50 wt% Ag proportion of paste was more than 40 MPa at 280 °C.

1. Introduction

Recently, power electronics devices are applied SiC or GaN as next generation power semiconductor devices instead of conventional Si power devices. These new power semicondutcors are expected to improve power efficiency, miniaturization of devices, and high reliability at high temperature. Therefore, high reliability packaging at high temperature (higher than 200 °C) is also required for these devices.

Ag nanoparticle adhesive bonding is one of the high reliability bonding technology at high temperature [1]. This process requires more than 300 °C for sintering process.

On the other hand, transient liquid phase (TLP) process is one of the diffusion bonding method, that bonding temperature can lower under melting point of base metal. For example, at Ag-Cu-Ag sandwhich joint structure, Ag-Cu was sintered at 820 °C less than melting point of both metal [2]. Also Al-Cu, Al-Zn, Al-Ag, Pb-Sn, and other systems were investigated. Especially, TLP bonding for Ni base system was developed for bonding of heat-resistance alloys [3, 4, 5, 6]. Furthermore, in order to lower sintering temperature of lead-free solder such as Cn-Sn system with TLP sintering proess is investigated [7]. Likewise, TLP bonding is also avalilable for Sn-Ag system for interlayer interconnect in multilayer substrates[8].

Hence, we develop the TLP bonding of Sn-Ag system for die bonding. In Fig.1, a schema of TLP bonding using Sn-Ag system that we develop. At first, Sn-Ag paste is printed on Cu substrate, then Si chip is mounted on the paste. After applying load and heat, Sn in the paste is transformed liquid-phase, and Ag particle should solve into liquid-phase Sn. After cooling, Ag_3Sn as eutectic alloy of Sn-Ag should be sintered. In this research, we investigate the mechanism of TLP bonding using Sn-Ag system, and optimize this bonding system for die bonding.

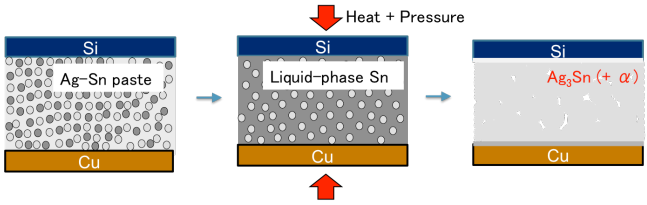

Figure 1 Schema of TLP bonding using Sn-Ag system

2. Purpose

In this research, we investigate mechanism of TLP bonding using Sn-Ag system for die bonding. And TLP bonding condition and Sn-Ag system should be optimize for die bonding.

3. Experimental Procedure

In Fig.2, the die bonding structure was shown. Sn-Ag paste was printed c.a. 90 μm height on Cu substrate and Au/Ni/Ti sputtered Si chip was mounted in ambient air. We prepared several types of Sn-Ag paste in Table 1. Sn-Ag paste was processed to a paste of the solution that mixture powder of Sn (grain size: c.a. 3 μm) and Ag (grain size: c.a. 0.2∼0.3 μm) dissolved in terpineol. Sintering profile is as follow: At first, preheating at 125 °C for 10 min., then heating to 260 or 300 °C at 30–40 °C/s, and also 5 MPa laod is also applied simultaneously. Heat and load are held for 1 min.

The bonded dies were observed by cross sectional SEM and EDX, and also die shear test was performed.

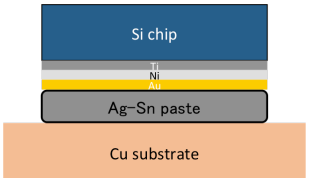

Figure 2 The structure of bonding specimens

4. Result

The cross sectional SEM images of each Sn-Ag paste sintered at 260 °C was shown in Fig. 3. When the proportion of Sn was increased in paste, sintered structure becomes dense.

Table 1 Ag-Sn solder paste

Paste Type	Ag proportion (wt%)	Sn proportion (wt%)
Ag-30Sn	70	30
Ag-40Sn	60	40
Ag-50Sn	50	50

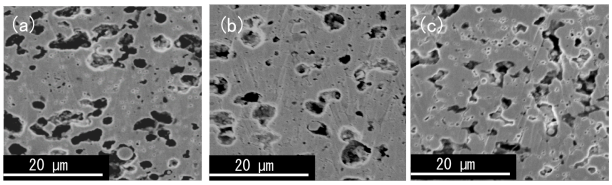

Figure 3 Cross section SEM images of (a) Sn-30Ag, (b) Sn-40Sn, and (c) Sn-Ag50Sn sintered at 260 °C.

And Fig.4 and Fig.5 show the cross sectional analysis of Sn-50Ag sintered at 260 °C and 300 °C by SEM and SEM. At 260 °C sintering, it is seen that Sn is unevenly distributed in sintered structure, hence, Sn was not dissolved. On the other hand, at 300 °C sintering, Sn and Ag was exixt homogeneously, and it is considered that eutectic Ag_3Sn was formed.

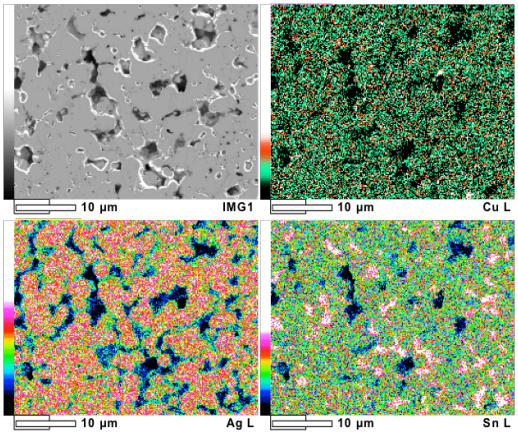

Figure 4 Cross section SEM and EDS images of Sn-50Ag sintered at 260 °C.

Die shear strength of each type of Sn-Ag paste at 260, 280, 300 °C is shown in Fig.6. The die shear strength increased when the proportion of Sn in the paste increased. Especially, die shear strength of Ag-50Sn was more than 40 MPa.

5. Conclusion

TLP bonding using Sn-Ag system was developed for die bonding. As result, in this bonding process, using 50 wt% Ag proportion of paste was more than 40 MPa, and Sn-Ag was fomred homogeneous eutectic alloy at 300 °C bonding temperature.

Acknowledgement

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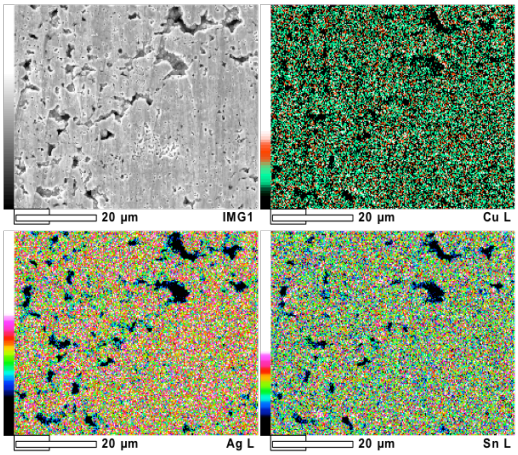

Figure 5 Cross section SEM and EDS images of Sn-50Ag sintered at 300 °C.

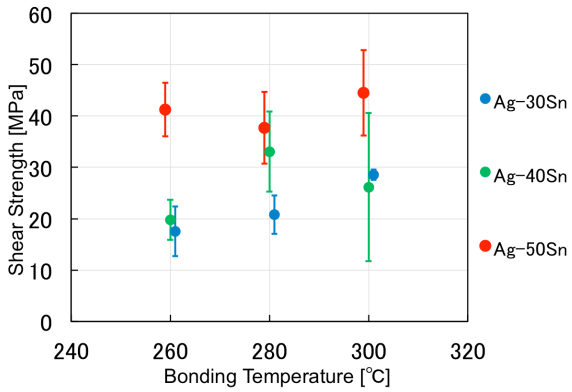

Figure 6 Die shear strength of each type of paste at 260 °C, 280 °C, and 300 °C.

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