RETRACTION

The following article was withdrawn by the Editorial Board of Transactions of The Japan Institute of Electronics Packaging on February 28, 2017, because it had a copyright problem.

Retraction: Development of a Ag/glass Die Attach Adhesive for High Power and High Use Temperature Applications

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1. Introduction

Advances in the electronic, optoelectronic, and semiconductor industries have driven the need for high performance adhesives. In particular, devices that have high use temperatures require adhesives that show excellent heat dissipation, while maintaining long-term reliability at service temperatures up to 300°C or more.

Typical organic adhesives that contain epoxy, thermoplastic, and/or other polymer components are not suitable for these high performance applications. Thermal stability of the organic component shows degradation/decomposition as use temperatures approach 300°C. Eutectic solders are used for some high temperature applications, but solders such as AuSn are also not applicable because of the re-melt temperature of 280°C.

Dietz et al.,[1, 2] US Patent No. 4,933,030 (Low temperature glass composition, paste and method of use) and US Patent No. 5,334,558 (Low temperature glass with improved thermal stress properties and method of use) have shown Ag/glass adhesives for use in die attach applications at elevated temperatures.

For example, a vitreous-type Ag/glass adhesive employs a vitreous glass which was designed for low temperature processing, but does not perform well at 300°C due to the low Tg of the glass. A crystallizing-type Ag/glass adhesive contain a crystallizing glass component that results in a robust structure, with good reliability and temperature-cycling resistance. However, the relatively low crystalline re-melt temperature results in poor performance at 300°C.

Described in this paper is the development of a unique Ag/glass adhesive for high temperature applications. The new Ag/glass adhesive has a crystallizing glass component that is designed for high temperature applications. The Ag/glass adhesive shows excellent thermal conductivity, and long-term reliability for 300°C continuous use applications.
2. Experiment

2.1 Glass development

An extensive study of glass formulations has been conducted with high AgO content glass formulations.[3] The experimental glass formulations were prepared by blending various oxides; which were placed into an alumina crucibles, then melted in a glass melting oven at 700°C and then the molten glass was quench by pouring into a 2-roll mill. Then the glass cullet were powderize using mortar and pestle and classified through -325 mech. Glass formulations were evaluated using differential scanning calorimetry (DSC) to determine the glass properties, focusing on glass transition, crystallization peak, glassy range and re-melt temperature. We were targeting to develop a crystallizing glass with the re-melt temperature of 350°C and the crystal peak that forms above 300°C. Figure 1 shows a typical DSC curve for the glass component of the Ag/glass adhesive. DSC of the glass shows crystallization peaks at low temperatures, followed by re-melting of the crystallized glass at about 350°C. During cooling, the glass melt re-crystallizes above 300°C to form a robust crystalline material that is stable for high temperature die attach applications.

2.2 Ag/glass paste development

Over 100 Ag/glass pastes have been formulated and evaluated for die attach applications.[3–5] The Ag/glass pastes were formulated by blending Ag powders with the crystalizing glass frit, metal oxide(s) and solvent; the above mixture was milled through a 3-roll mill 3 times to create a homogeneous paste. Paste development focused on determining the best Ag powder combination (Ag particle size and shape), glass frit content, and metal oxide additions (e.g. ZnO) to enhance the overall performance of the adhesive. The adhesive performance criteria included high thermal conductivity, low interfacial resistance (Rth), and high temperature stability/reliability at 300°C.

2.3 Ag/glass paste evaluation

Die attach parts were prepared by dispensing the paste onto the substrate and attaching the die with minimal pressure. Parts were fired in air at about 10°C/minute to 370°C, and held for 10 minutes; no pressure was required during processing. During the die attach process, the glass component first crystallizes and then re-melts at about 350°C, wetting the surfaces of the die and substrate, creating excellent interfacial bonds. During the cool down of the die attach process, the melted glass component re-crystallizes creating a robust adhesive structure; the recrystallized glass component is stable to temperatures greater than 300°C.

3. Results and Discussion

The bulk adhesive, and die attach properties of the Ag/glass adhesive were evaluated. Reliability tests were conducted to determine the high temperature stability for 300°C continuous use applications.

Die shear strength (DSS) was measured using a bond tester for various bare and metallized die-substrate combinations as shown in Fig. 2. Parts for DSS were prepared by attaching 2.5 mm × 2.5 mm Si or SiC die (bare and Au-metallized) onto various bare and Ag-metallized ceramic sub-
strates, including Al\textsubscript{2}O\textsubscript{3} and BeO. In all cases, the die shear strength was excellent. In particular, high die attach bond strengths for bare die-substrate combinations open up opportunities for use of the Ag/glass adhesive with non-metallized surfaces.

Hot DSS at 300°C was evaluated for AuSiC die on AgAl\textsubscript{2}O\textsubscript{3}. Die attach parts were placed on a preheated hot plate on the bond tester to obtain adhesion data at 300°C. Figure 3 shows the DSS data for 25°C vs. 300°C. While a small decrease in DSS was observed, the die adhesion value of 33.5 MPa at 300°C is excellent.

Reliability testing of die attach parts included high temperature storage at 300°C in air, and thermal cycling tests at −55°C/+175°C for up to 1,000 cycles.

The DSS data for high temperature storage of die attach parts are shown in Fig. 4. Hot storage at 300°C for 1,000 hours shows a small decrease in DSS; however, 30 MPa DSS shows very good die adhesion. These data show that the Ag/glass adhesive performs very well at 300°C, and is a good candidate for 300°C continuous use temperatures.

The thermal cycling test (−55°C/+175°C) was conducted for up to 1,000 cycles for AuSiC–AgAl\textsubscript{2}O\textsubscript{3} and Si–Al\textsubscript{2}O\textsubscript{3} die-substrate combinations. Parts were evaluated for delamination via C-SAM, DSS, and interfacial resistance (R\text{th}) measurements. Figure 5 shows the C-SAM images of die and substrate interfaces for bare and metallized die-substrate parts subjected to up to 1,000 cycles. The C-SAM images show no indication of delamination for the bare Si chip and minimal delamination for the AuSiC chip.

Figure 6 shows the DSS data for bare and metallized die attach components used for the thermal cycling test. Both groups of parts show excellent adhesion, with no degradation in bond strength after 1,000 cycles of −55/+175°C. We observed an unexpected increase in the DSS after 500 cycles; yet we did not find the reason for such increase.

Figure 7 shows the interfacial thermal resistance data.
Fig. 4 Die shear strength for 300°C hot storage test for 1,000 hours.

Fig. 5 C-SAM evaluation of bare and metallized die-substrate parts for \(-55^\circ C/+175^\circ C\) thermal cycling test up to 1,000 cycles.

Fig. 6 Die shear strength of Si-Al2O3 and AuSiC-AgAl2O3 subjected to thermal cycling test at \(-55^\circ C/+175^\circ C\) for up to 1,000 cycles.
for AuSi-AuSi die-substrate parts used for the thermal cycling test. Rth values were very low, and remained constant after 1,000 cycles of −55°C/+175°C. The low Rth values (~0.01 Kcm²/W) for the thermal cycling test indicate an excellent reliability of the Ag/glass adhesive interfaces.

Thermal conductivity measurements were performed using the xenon flash method as shown in Fig. 8. Thermal conductivity measurements of the bulk adhesive (1-layer) were made using the Ag/glass paste. The Ag/glass paste samples were cured/fired at standard curing conditions of 370°C for 10 minutes hold; the sample thickness ranged from 0.5 to 1.0 mm. Thermal conductivity values of about 100 W/mK were measured for the 1-layer adhesive samples.

The effective thermal conductivity ($k_{eff}$) of Ag/glass die attach parts was also measured using the Flash Method shown in Fig. 8. The $k_{eff}$ data (also called 3-layer thermal conductivity) includes the impact of the interfacial bonding of the adhesive with the die attach parts. In this case, $k_{eff}$ was measured for AuSi-AuSi die-substrate parts. Effective thermal conductivity values of about 83 W/mK were measured for die attach parts.

Figure 9 summarizes the thermal conductivity data for the Ag/glass adhesive. The new Ag/glass adhesive for high temperature applications demonstrates excellent bulk thermal conductivity and effective thermal conductivity. These data are consistent with the very low interfacial resistance measurements made for die attach parts. High effective thermal conductivity for Ag/glass die attach parts is essential for providing rapid heat dissipation for high temperature die attach applications.

Table 1 provides a summary and comparison of the high performance, high temperature Ag/glass adhesive with
eutectic solders, and commercially available Ag/glass adhesives. The new high temperature Ag/glass adhesive offers several advantages over other die attach materials. In particular, the bulk thermal conductivity of about 100 W/mK (and low electrical resistivity) far surpasses that of the other die attach materials shown in Table 1.

In addition, the new Ag/glass adhesive offers advantages for die attach applications including:

1. Processing in air, with no additional die pressure required.
2. New opportunities for bonding to bare die-substrate combinations.
3. Thermal stability for 300°C continuous use.
4. Pb-free adhesive for RoHS compliance.

4. Conclusions

An Ag/glass die attach adhesive was developed for use in high power, high temperature applications. The adhesive shows excellent thermal properties, with bulk thermal conductivity of about 100 W/mK and effective thermal conductivity of about 83 W/mK. The high heat flow through the die attach part is ideal for thermal management of high temperature devices.

The Ag/glass adhesive also demonstrated very good results for reliability tests. Reliability test data indicates that the die attach parts have low-stress, excellent interfacial bond strength, and good heat flow. The die attach parts showed excellent mechanical and thermal stability at 300°C. The high temperature stability and performance of the Ag/glass adhesive makes it an excellent candidate for high power, high temperature applications.

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References


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