Effects of Ag and Pd Addition on Mechanical Property and Ion-migration Tolerance in Low Temperature Sintering Bonding Using Ag_2O Paste

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ABSTRACT

A new bonding process using Ag_2O paste composed of Ag_2O particles mixed with reduction agent of triethylene glycol (TEG) has been proposed. Ag nanoparticles formed at around 130℃ to 160℃ through the reduction process. Such formed Ag nanoparticles were immediately sintered each other and bonded to a metal substrate. A Au coated Cu specimen was successfully bonded using the Ag_2O paste. The joint had superior strength than that using the conventional Pb-rich solders. To improve ion-migration tolerance, Ag_2O paste was mixed with Au and Pd microparticles to form sintered Ag-Au and Ag-Pd layers, respectively. While both Au and Pd additions improved the ion-migration tolerance, Au addition had somewhat higher effectiveness. As for the mechanical property of the joints, mixing of the second metals resulted in decreasing joint strength. To meet the basis of the joint strength of conventional Pb-10Sn solder, limitations of mixing ratio for Au and Pd were estmeted to be approximately 16vol% and 7vol%, respectively. In each case, the ion-migration tolerance was about 3 times and 2 times as much as that of pure Ag, respectively.

Keywords: Silver oxide, Silver nanoparticle, Bonding, Ion-migration

1 INTRODUCTION

There has been no alternative bonding process for Pb-rich high-temeperature solders that have been applied to assembly of power electronics deveices. To this end, the authors developed a new bonding process using Ag mettalo-organic nanoparticles as a bonding material [1-7]. The metal-to-metal bonding has been successfully achieved via this bonding process at a bonding temperature of around 300 ℃ , which can be alternative to the current microsoldering in electronics assembly using the Pb-rich solders. However, the organic matter around nanoparticles disturbed the bonding at a lower temperature. To improve the bondability at a bonding temperature below 300℃ furthermore, the authors have proposed a novel bonding process through in-situ formation of Ag nanoparticles using Ag_2O paste composed of Ag_2O particles mixed with reduction agent [8, 9]. In the first part of this paper, the bonding process using the Ag_2O paste was described. In applying this bonding process to fine pitch electronics assembly, an attention should be paid to ion-migration tolerance of the circuit because of pure Ag bonded layer. Thus, in the last part of this paper, to improve ion-migration tolerance of the bonded layer, Ag_2O paste was mixed with Au and Pd microparticles to form sintered Ag-Au and Ag-Pd layer, respectively, and the ion-migration tolerance of the sintered layers and tensile strength of the joints were evaluated.

2 EXPERIMENTAL PROCEDURE

Ag_2O particles having 1 to 3μm in size were mixed with TEG to form Ag_2O paste. Au particles having 620nm in average size and Pd particles having 217nm in average size were blended with Ag_2O particles and then were mixed with TEG to prepare Au-added and Pd-added Ag_2O pastes, respectively. Ion-migration tolerance of sintered Ag layer using each paste was evaluated with the water-drop method as shown in Fig. 1. Each paste was supplied on a glass substrate and sintered at 250℃ for 5min. A distilled water droplet of 10μl was dropped on a gap between the sintered samples and then 3 volts were applied between the samples. Under the electric voltage Ag ions migrated from the anode to the cathode and Ag dendrites grew toward the anode. An arrival time for the Ag dendrites reaching anode was measured. Bondabilty of each paste to a metal was also evaluated. Ni/Au plated Cu tensile samples were used. Each paste was supplied on a lower sample of 5mm diameter and

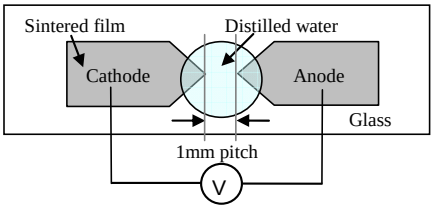


Fig. 1 Water-drop method for evaluating ion-migration tolerence.

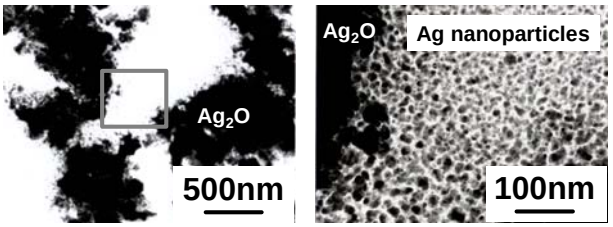
15mm length, and then pre-heated at 120℃. After that an upper sample of 10mm diameter and 25mm length was put on the lower sample and bonded at 250℃ for 5min under a pressure of 5MPa. After the bonding the sample was subjected to a tensile test using a cross-head speed of 1mm/min.

3 RESULTS AND DISCUSSION

3.1 Bonding Process using Ag_2O

In the bonding process using Ag_2O paste, TEG was acted as a reduction agent for Ag_2O. Ag nanoparticles formed at around 130℃ to 160℃ through the reduction process of Ag_2O particles with TEG as shown in Fig. 2. Such formed Ag nanoparticles were immediately sintered each other and bonded to a metal substrate due to a great surface energy per volume. A Au coated Cu specimen was successfully bonded using the Ag_2O paste as shown in Fig. 3. The joint had superior strength than those using the metallo-organic nanoparticles and conventional Pb-rich solders [9]. The superiority of the joint strength using the Ag_2O paste was found to be caused by low-temperature sintering performance of Ag_2O-derived Ag nanoparticles and less organic remnant that inhibits sintering.

Figure 4 (a) and (b) show back-scattered electron (BE) images and corresponding element mappings by electron probe micro analysis (EPMA) of cross-sections of the joints



(a) General view (b) Magnified view of (a)

Fig. 2 TEM images of Ag_2O paste heated to 130℃.

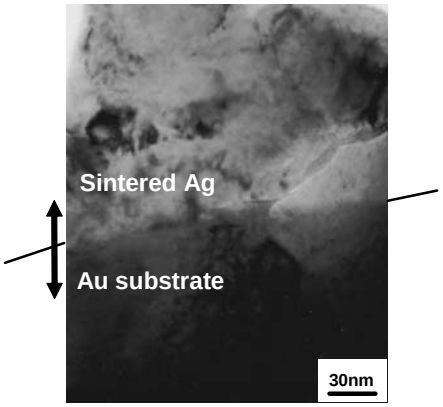
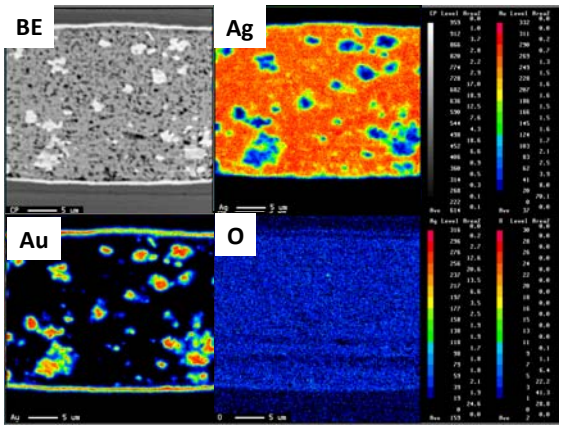
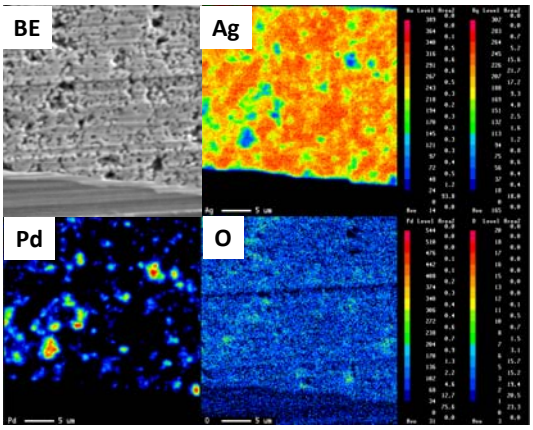


Fig. 3 TEM image of Ag/Au substrate interface bonded using Ag_2O paste at 160℃.



(a) Ag-9vol%Au sintered layer.



(b) Ag-9vol%Pd sintered layer.

Fig. 4 BE images and corresponding EPMA mappings of cross-sections of joints bonded using Au and Pd-added Ag_2O pastes.

bonded using Au and Pd-added Ag_2O pastes, respectively. While sintering and bonding were successfully achieved in these joints, both Au and Pd were separately concentrated in the sintered Ag layers. This suggests that Au nor Pd was completely alloyed to Ag during the formation and sintering process of Ag nanoparticles.

3.2 Ion-migration Tolerance

Figure 5 shows arrival time of Ag dendrites from cathode to anode potted against volume fraction of Au or Pd in the sintered layer. In both cases of Au and Pd additions arrival time was monotonously increased with volume fractions of additive metals. Thus, both Au and Pd additions were found to improve the ion-migration tolerance of sintered Ag layers. The results shown in Fig. 5

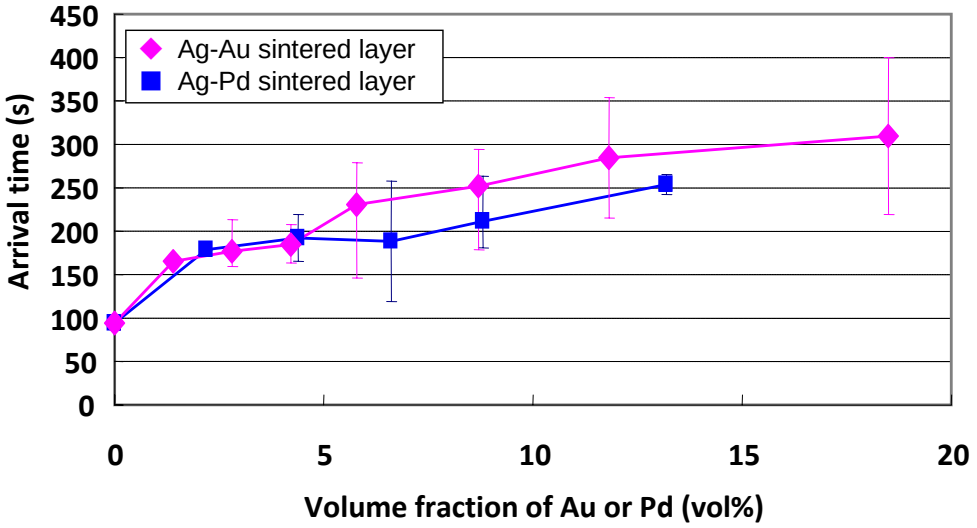


Fig. 5 Arrival time of Ag dendrites from cathode to anode potted on water drop test against volume fraction of Au or Pd in sintered layer.

also suggest that Au addition has somewhat higher effectiveness for ion-migration tolerance than Pd addition.

3.3 Joint Strength

Figure 6 shows the tensile strength of the joints bonded using Au or Pd added Ag_2O paste. Additions of Au and Pd resulted in decreasing joint strength. This may be caused by agglomeration of the second metals particles as shown in Fig. 4 disturbing the sintering of Ag layer. In the case of Pd addition, Ag nanoparticles may insufficiently sinter to Pd particles because of oxide layer around the Pd particles. This can cause lower strength of Ag-Pd joints than that of Ag-Au joints, because Ag nanoparticles can be more likely to sinter to Au particles having no oxide layer. To meet the basis of the strength of conventional Pb-10Sn solder, which was around 40MPa, limitations of additive fractions for Au and Pd were estimated to be 16vol% and 7vol%, respectively. In these cases, the ion-migration tolerance was about 3 times and 2.0 times as much as that of sintered pure Ag, respectively as presented in Fig.6.

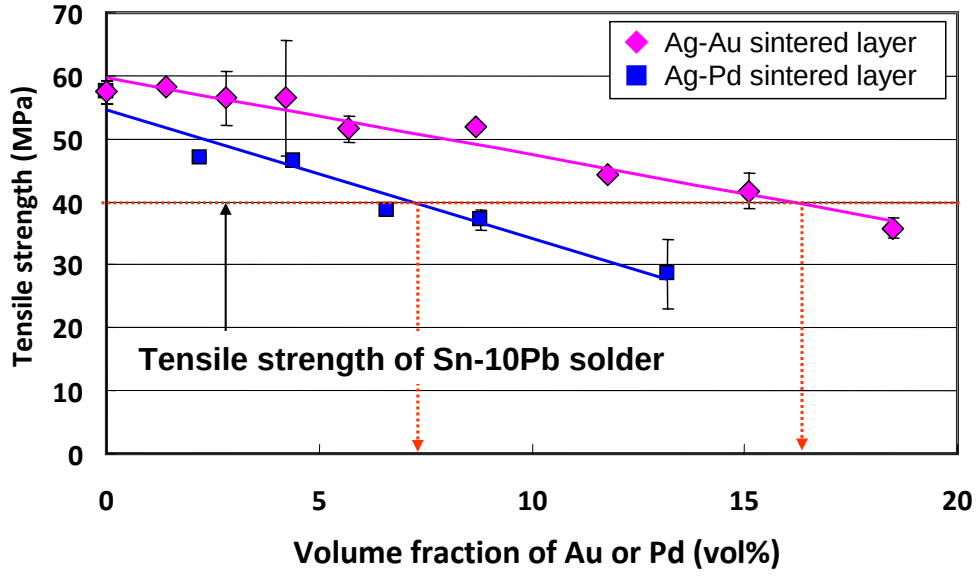


Fig. 6 Tensile strength of joints bonded using Au or Pd added Ag_2O paste plotted against volume fraction of additive metal.

4 CONCLUSIONS

In this study to improve ion-migration tolerance of sintered Ag layer using Ag_2O paste, Au and Pd microparticles were mixed with Ag_2O paste to form sintered Ag-Au and Ag-Pd layers. Although Au nor Pd was sufficiently alloyed to sintered Ag, ion-migration tolerance of both sintered Ag-Au and Ag-Pd layers were improved with increasing volume fraction of additive elements. On the other hand, the tensile strength of the joints bonded using Au and Pd added Ag_2O pastes decreased. The limitations of additive fractions for Au and Pd were estimeted to be 16vol% and 7vol%, respectively from the basis of the strength of conventional Pb-10Sn solder. The durations of ion-migration life for Ag-16vol%Au and Ag-7vol%Pd sintered layers were about 3 times and 2.0 times as much as that of sintered pure Ag, respectively.

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