Low resistance and low temperature bonding between Silver and Indium

Sung-il Cho, Jin-Yu, and Young-Ho Kim

Center for Electronic Packaging Materials,
Department of Materials Science and Engineering,
Korea Advanced Institute of Science and technology,
373-1 Guseong-dong, Yuseong-gu, Daejon 305-701, Korea

Abstract

Conductive adhesives are commonly used for the interconnections of fine pitch, small packages like mobile applications. Since conductive particles connect mechanically with contact pads to give somewhat higher contact resistance, a metallurgical interconnection, which provides both fine pitch and low resistance, was studied using silver ball and indium which can be made at low temperatures. The connection resistance of the In-Ag metallurgical interconnection was lower than that of the Ni/Au-Ag mechanical interconnection and the former showed little dependency on the bonding load in contrast to the latter.

1. Introduction

In electronic products, various components of different materials are assembled to form final products, and several kinds of interconnection techniques are used to join these components. The resulting joints must provide mechanical, thermal, and electrical connections between the joined parts. The solder connection technology using lead/tin alloy has played a key role in various levels of electronic packaging such as flip-chip connection and solder-ball connection in ball-grid-arrays(BGA)[1]. The current solder paste technology cannot handle the very fine pitch interconnection. Another technical limitation of using the Pb-Sn solder is its high reflow temperature, approximately 215°C, which is higher than the glass transition temperatures of the epoxy resins used in most polymeric printed circuit board materials[1]. Another critical issue is its toxicity and environmental incompatibility[2].

Conductive adhesives are used for the fine pitch interconnections between the liquid crystal display(LCD) panels and the driver-IC tape carrier packages(TCPs) and research is under way to use this for flip chip bonding to circuit boards. The main motivation towards the use of conductive adhesives in more general electronic assembly applications is the prospect of achieving extremely fine pitch connections at low costs and low temperatures[3]. Conductive adhesive materials are available containing pure metal particles such as silver, nickel, tin, Ni-Au coated polymer spheres, or copper pillars[4].

The solder bonding is a metallurgical contact which forms intermetallic compounds in the reflow process, which provides strong bonding and low contact resistance. The conductive adhesive bonding is a mechanical contact between the conducting particles and the metal electrode which gives somewhat higher contact resistance but can be used for the flexible packages of finer pitch and also enables low temperature processes. To provide both fine pitch interconnection and low resistance, low temperature metallurgical contact; the interconnection between silver balls and the indium pad, was studied and the connection resistance was investigated. The connection resistance of the Ag ball-In pad was compared with that of the Ag ball-Ni/Au pad.

2. Experimental

A. Materials

Indium was evaporated and Ni/Au was sputter-deposited on the Si/Cr/Cu substrate, and the thicknesses of the In or Ni/Au overlayers were 1000, 400/100nm, respectively. Cr was the adhesion layer and Cu was the conducting layer. The dimension of the Si plates were 20×40×0.7mm and the thickness of Cr and Cu were 40, 2000nm. The interconnection was established by placing the epoxy resin containing Ag balls(2mm in diameter) between the two Si plates and applying thermocompression. An epoxy resin of the fast curing type was selected which provided strong and robust interconnections at low bonding time.

B. Bonding Process

Three Ag balls were placed on the bottom Si plate, and the epoxy resin was applied on the Si plate. Then a flipped Si plate was placed over the Ag balls to make a cross-shaped structure. The metallurgical bonding was accomplished by applying heat and load at the same time and the epoxy between the two Si plates was cured. Applied bonding temperature, load, and time were varied as shown in Table Ⅰ.

C. Contact resistance

The contact resistance between silver balls and the metal pads was measured using the four-point probe method by applying a constant current between the two Cu plates and measuring the voltage drop.

Table Ⅰ. Bonding parameters

154°C		130°C	
Load	Time	Load	Time
10,20,50,100,500g	90sec at each load	10,20,50,100,500g	90sec at each load

3. Result and Discussion

A. Connection resistance with bonding load

Figure 1 shows the relationship between the connection resistance and the bonding load. In the case of the In pad, the connection resistances are almost the same regardless of load change. But in the case of Ni/Au pad, the connection resistance increases as load decreases.

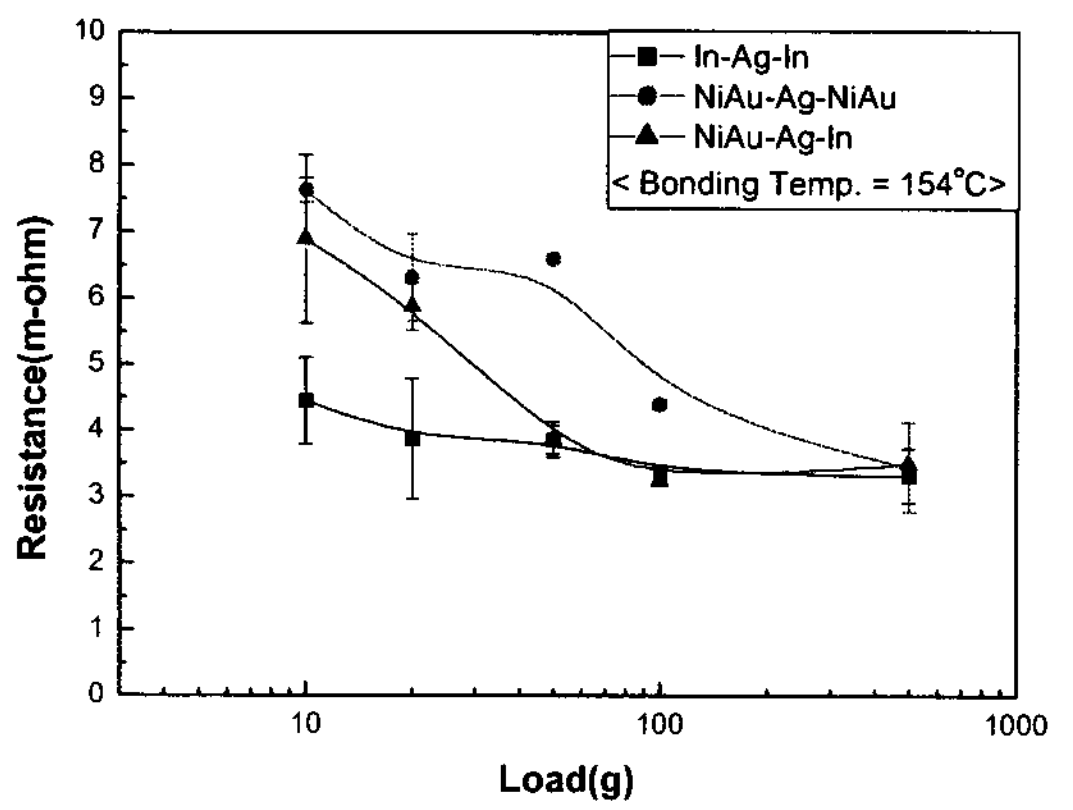

Fig. 2. Connection resistance plotted as a function of bonding load. Comparison of connection resistances between indium pad and Ni/Au pad.

The bonding temperature of 154 °C was chosen to facilitate the bonding by the Ag-In eutectic reaction under the melting point of In which is 156.4 °C. The Ag-In phase diagram[5] is shown in Fig. 3 and it can be seen that the eutectic reaction occurs at 97 wt.% of In at the eutectic temperature of 144°C. At 154 °C which is above eutectic temperature, there exists a mixture of liquid phase L with $AgIn_2$ so $AgIn_2$ is formed easily at the In-Ag contact area by liquid-solid interdiffusion mechanism.

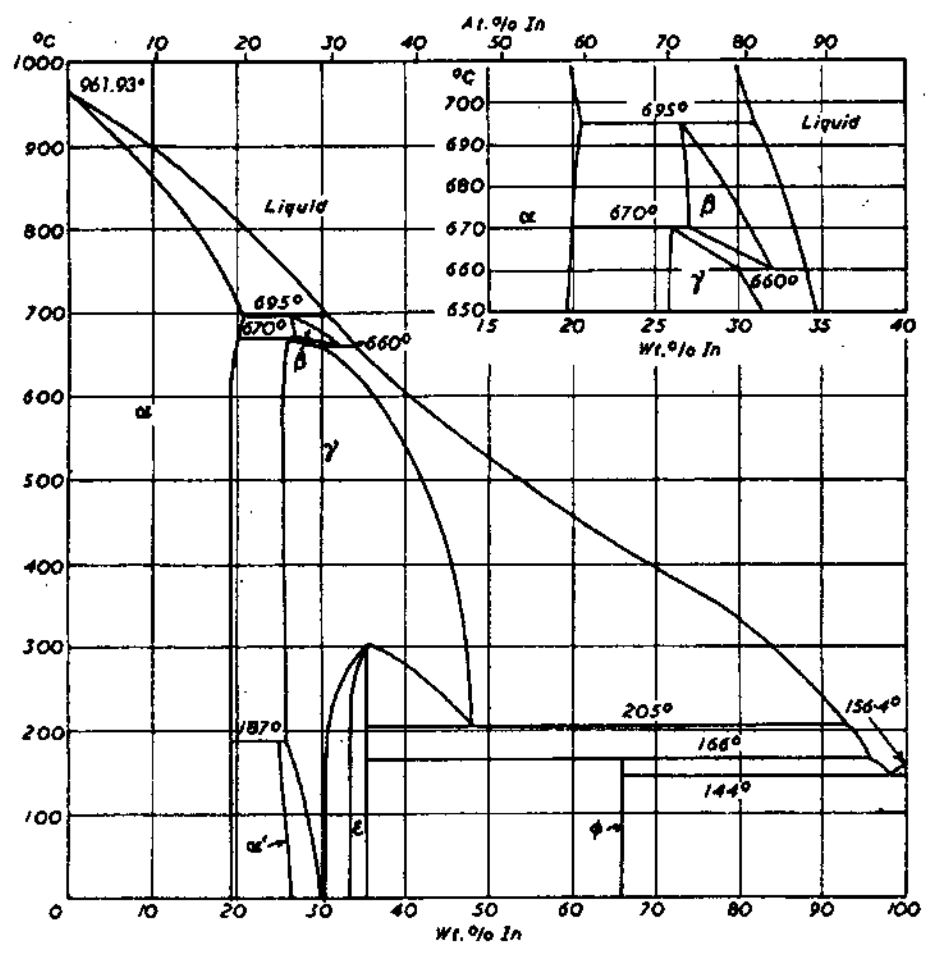

Fig. 3. Indium-silver binary phase diagram[5]

Liquid indium wets perfectly all of the In-Au contact area and forms the intermetallic compound $AgIn_2$ so the contact area does not seem to be changed significantly with bonding loads, which shows the relative independence of the contact resistance of the In pad from the bonding load. But in the case of Ni/Au pad, Au cannot react with Ag and is harder than In. Therefore the contact area will increase as the bonding load increases which could explain the load dependency of the connection resistance. When one plate has an In pad and the other has a Ni/Au pad the connection resistance shows the intermediate values between two cases: two In pads and two Ni/Au pads.

At the low temperature of 130°C, it can be seen that the resistance is comparable to that of 154°C as shown in Fig. 4. This result could enable indium to be used for applications which require very low temperature processes. Cross sectional view of Ag ball-In/Cu/Si plate interconnection is shown in Fig. 5.

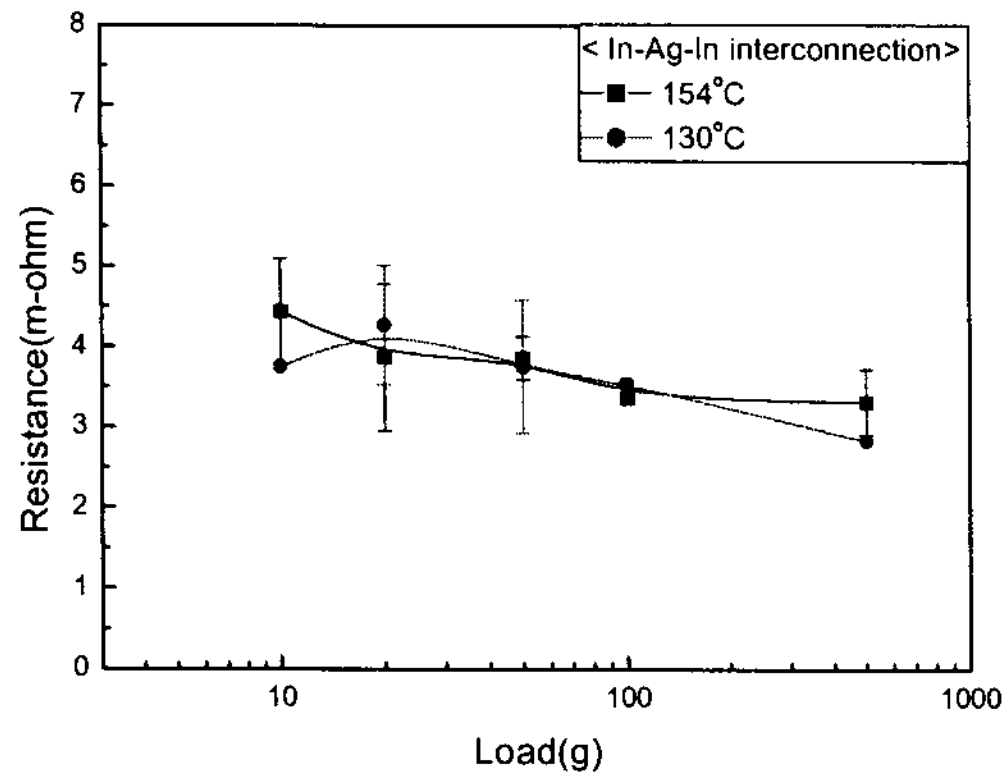

Fig. 4. Comparison of connection resistances at different bonding temperatures, 154°C and 130°C.

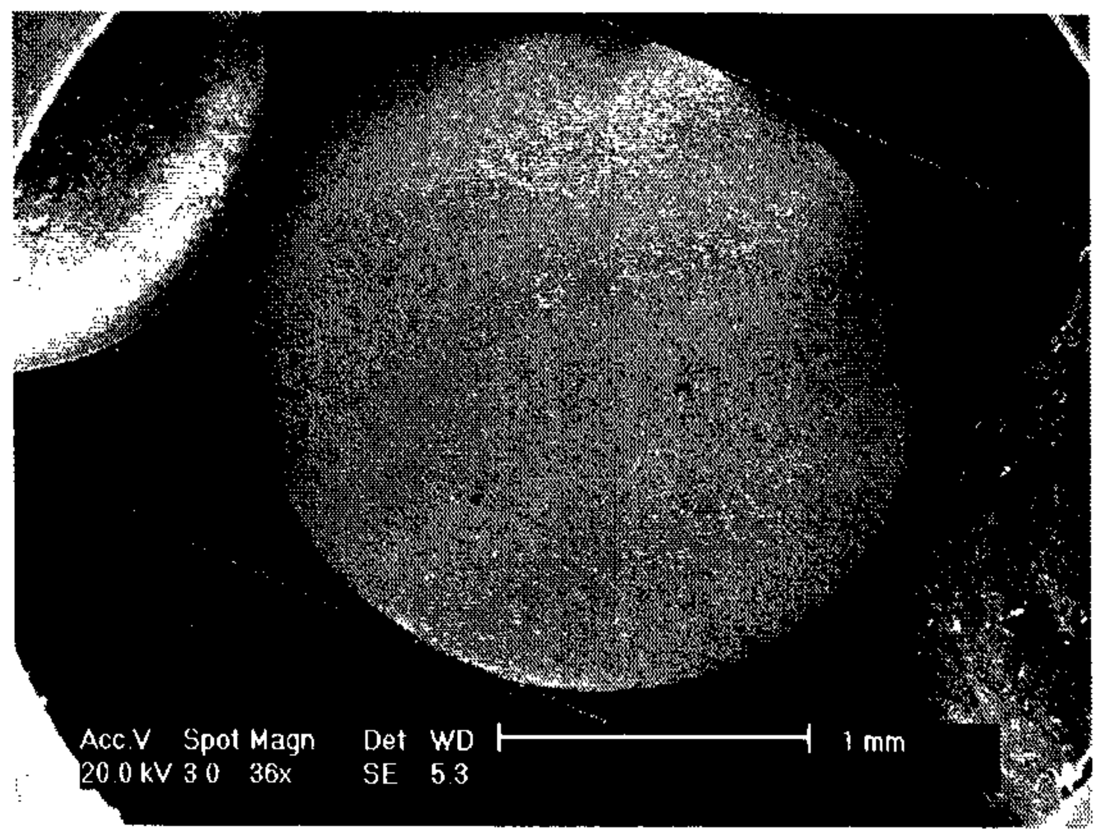

Fig. 5. Cross section of Ag ball-In/Cu/Si plate interconnection.

B. Connection resistance with bonding time

Figure 6 shows the connection resistances of In and Ni/Au pads at low loads(0g, 10g) with bonding time variation(5, 15, 55, 90sec)and it can be seen that both the resistance of the In pad and the Ni/Au pad does not change significantly as the bonding time increases. The connection resistance of the In pad specimen is still somewhat lower than that of the Ni/Au pad. In the case of the In pad specimen, the bonding is made by the liquid In-solid Ag contact mechanism and so the connection resistance does not change with bonding time.

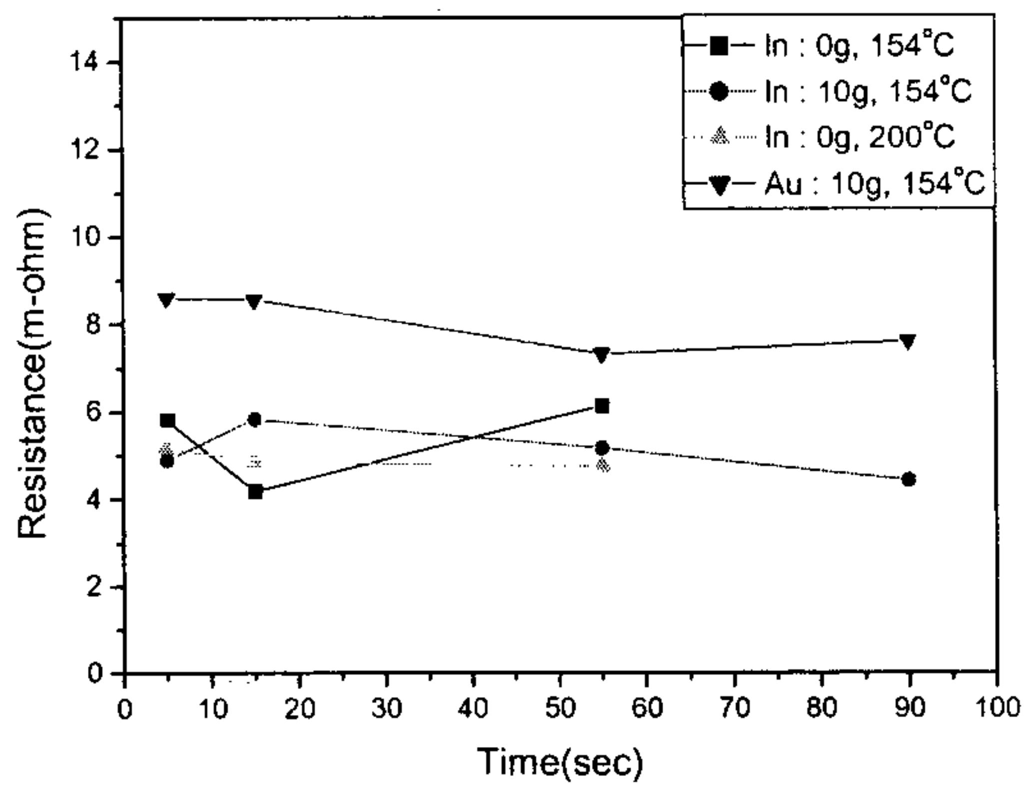

Fig. 6. Connection resistance plotted as a function of bonding time. Standard deviation is ommited for clear distinction of points.

There is also another reason which is responsible for the relationship between the connection resistance and the bonding time. By applying heat to the specimen for bonding, the epoxy is cured and the volume of epoxy is shrunk which gives the effect of applying some loads to the specimen. As seen in Figure 6, even in the case of no load(0g), the connection resistances have almost same values of resistance with bonding time.

4. Conclusion

In order to provide both low resistance and low temperature processes, interconnection between Ag balls and In pads were studied. The connection resistance of the In-Ag interconnection was lower than that of the Ni/Au-Ag interconnection which was just mechanical. The In-Ag interconnection could be formed at very low temperatures maintaining low connection resistance and did not show much dependence on the bonding load and bonding time. Therefore it can be applied to the low temperature, low cost process. The development of applications using the In-Ag interconnections are currently underway.

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