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New Process of Self-organized Interconnection in Packaging by Conductive Adhesive with Low Melting Point Filler

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1. Introduction

The electric conductive adhesive which can be applied at low temperature is paid to attention to overcome the problem for low heatproof assembly such as opto-electronics packaging [1,2]. For the diversification of the electronics assembly, the adhesive joining is promising and its practical use is developed to realize the low temperature packaging with low-cost. In Ag filler adhesives, electric conduction between electrodes is achieved through the conduction path by the contact of the fillers, and joint strength is obtained by curing resin. However, since electric conduction is obtained by the mechanical contact, consequent low reliability due to the unstable state of conduction, limited electric current by concentrated resistance with oxide film, and the migration become serious problems [3].

In this research, we propose the process in which conduction path with metallic filler is formed, whose diameter is smaller than the gap of the electrodes, with lower melting point than the curing peak point of the resin.

2. Concept of the process

In the curing process as shown in Fig. 1, materials are maintained at the initial bonded state at room temperature with constant gap. Afterwards, fillers are heated up to the temperature range below the curing peak point of the resin, and are melted. The material to be bonded is made close. The motion of filler occurs in the joint due to resin flow. Then, the adjoining fillers contact, and partly cohere and even grow to be a huge sphere blob. The joint is maintained at the temperature over the curing peak point of the resin, until the resin is cured completely, and the joining process ends. In the joint by this process, two kinds of conduction path can be created by selecting proper material characteristic of the resin and filler. For the conduction path (Type I), filler adjoins with the adjacent filler and the morphology is isotropic. On the other hand, when the cohering filler size exceeds the gap distance between the electrodes, conduction path (Type II) forms and gets wet on the copper surface. Though large conduction path is formed, the direction of the connection is unidirectional normal to electrodes and anisotropic. Arrayed conduction path can be achieved by combining materials which can form Type II only in the direction to the small electrodes. Among the horizontal electrodes the insulation is also possible with its self-organizing characteristics.

3. Experimental

In the experiment, two kinds of epoxy thermosetting resin (single liquid no filler type) were used. Resin A consists of the mixture of both bisphenol A and bisphenol F system. Resin B is the epoxy resin normally used as under-fill material having reductive characteristics against the surface oxide. Sn-In eutectic alloy powder (globular type with diameter ϕ 42μm) was supplied as the metallic filler which melting point (390K) is lower than curing peak point of the resin. The oxygen-free copper plate (10mm×10mm×1mmt) was used as electrode. Specimen was heated in the infrared oven in air with the temperature profile. The formation of the conduction pass was observed with cross-sectional samples by the optical laser microscope. The DSC curve was acquired to investigate the curing profile for each resin material, the Sn-In powder, and the compound of those.

4. Results and discussion

Conduction path formation of the fillers

To investigate the influence of the resin performance of oxygen reductivity on the filler cohesive behavior, the specimens were prepared for both resin A and B (gap:

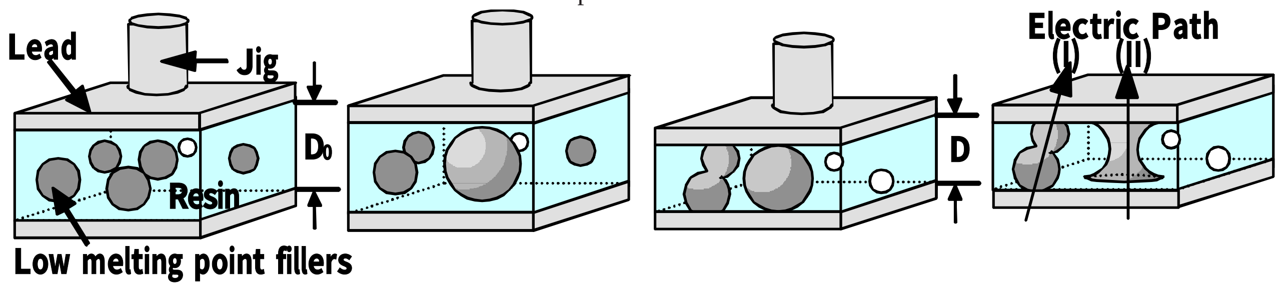
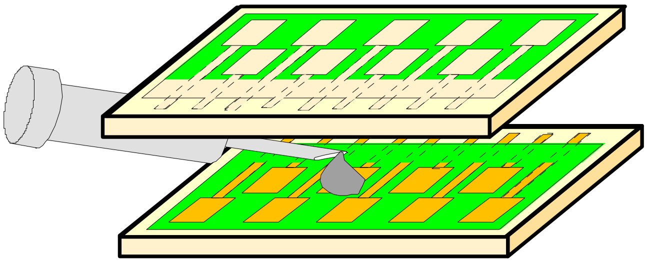
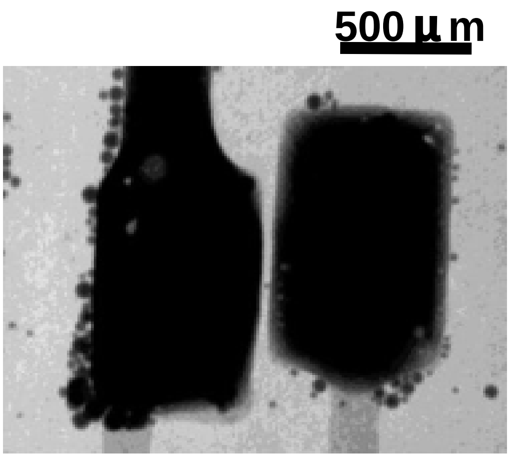


Fig. 1 Schematics of joining process using electrically conductive adhesives (ECA) with low melting point fillers.



(a) Dispensing method



(b) MXT photograph of the joints

Fig. 2 Self-organized interconnections by ECA with low melting point fillers.

D=300μm and V_f = 30%). Particle size distribution was measured for 100 fillers using cross-sectional micro laser photographs. In the specimen with resin A, Average diameter (39.6μm before the filler melting) is almost the same (39.7μm) even after melting. The number of fillers which coalesces during melting was very few. For the specimen with reductive resin B, fillers are growing up over 200μm in diameter. As for resin A, the adjacent filler unites mutually; necking phenomena between fillers, namely conduction path (Type I) was seen. Oxide film is destroyed only at contact area with the adjacent fillers and they get wet locally. On the other hand, in resin B the Sn-In filler cohered mutually in the molten state, globular Sn-In filler was growing up to a huge domain, and conduction path (Type II) was formed. In addition, fillers in resin B were excellently wet at the surface of the copper plate. Melting body tends to be a huge liquidus ball or wetting blob in the joint due to the reductivity of the resin. Oxide film on the Sn-In filler surface can be removed by reductive resin B, consequently filler surface melts at about 390K. It unites with the adjacent filler which came in contact during flowing, and becomes huge globular filler under the external pressure of a liquid resin and the intrinsic surface tension of melting filler.

Effect of the volume fraction on the formation of conduction path

Though conduction path is not observed with low volume fraction (V_f = 30%) of resin A, uniting the adjacent filler is seen for higher fraction (60%) and Type I is formed. On the other hand, in resin B with low volume fraction Type II is formed so that fillers get wet to upper and lower copper plate. Type II was observed with considerably wide area wetting at upper and lower electrode with high volume fraction. Moreover, for the horizontal distribution of filler observed by X-ray images, fillers remain as initial shape for low volume fraction in resin A. For high volume fraction, a lot of fillers get contact in the direction normal to the plates meaning the existence of type I. In resin B on the other hand, the filler as large as gap of 100μm is observed (V_f = 30%), and Type II was formed. Moreover with high volume fraction, fillers were distributed as large land on the plate. From these results, although partial necking is generated, conduction path in resin A is not formed when the volume fraction is small, while conduction path can be formed in resin B even when the volume fraction is smaller than general conductive adhesives. Since joint strength increases as the amount of resin area increases, an excellent joint can be expected to be obtained by selecting the characteristics and the volume fraction of the resin according to the performance demand of the joint.

Electric resistance of the joint

In order to compare with the resistance of non-melt filler, specimen of resin which was cured below filler melting point was prepared by heating for 300s at 353K as resin C. Very low electric conductivity was shown meaning mechanical contact between fillers. On the other hand, specimen made of resin A and B showed a very high conduction, by 3 to 6 order of magnitude higher than non-melting one since fillers unite mutually by melting and conduction path forms. Low resistance was obtained even at the range of volume fraction low enough (V_f = 30%).

5. Conclusions

In summary, joining process using conductive adhesive with low melting point alloy was proposed. Filler joint morphology, the formation of conduction path, and the electric resistance were examined. In the conductive adhesive joint which used the Sn-In filler, it was clarified that different morphology of conduction path can be formed according to the reductivity of the resin used. In the case of reductive resin, fillers cohere and get wet at the interface. Conduction path which has a complete alloy layer is formed. With little reductivity, fillers were adjoined with the initial diameter preserved; the conduction path with the necking shape type was formed. The formation of conduction path can be controlled significantly by varying 1) resin property, 2) the gap of the joint, and 3) the volume fraction.

References

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