Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.566-567

P2-10

Numerical Study of the Self-Interconnection Assembly Method Using Resin Containing Solder Fillers

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1. Introduction

Electronic devices have achieved high integration due to trade-off needs against products fitted with the devices, multi-functionalization and miniturization. Now, after the integration of the devices, more-reliable, higher-density, and lower-cost assembly method than existing methods is demanded.

In the self-interconnection method using resin containing solder fillers as shown in Fig. 1[1], melted fillers during the curing process of the thermosetting resin coalesce with each other, get together on the lands which are more wettable than substrates, and shape conductive paths by themselves between the opposing terminals. Because of the self-interconnection property, this process has possibility of high reliability and flexibility for design change.

2. Experiments

A pair of FR-4 glass fabric epoxy substrates with cupper area array pattern were used as substitutes for the device and substrate. Reductive and no-filler-type epoxy resin was used as the adhesive to eliminate oxide film from the fillers. Tin–indium eutectic, spherical, and average particle diameter 42 [μm] solder powder was used as the fillers.

The resin containing the solder fillers was sandwiched between these substrates. Fig. 2 (a) is a transmitted optical photograph of the sample. The substrate and the resin appears bright, larger black circles are the terminals, and smaller and evenly distributed black spots are the fillers.

During heating, the reflow-furnace temperature exceeded the melting point of the fillers (390 [K]), and was maintained at 403 [K] to melt the fillers and to reduce the resin viscosity. Downward movement of the upper substrate caused the horizontal outward resin-flow helping the filler coalescence. Enough huge filler, formed gradually through the coalescence, wetted both the substrate and the terminal, move towards the terminals, and formed a conductive path due to the difference of wettability between the substrate and terminal. Fig. 2 (b) is an X-ray photograph of the sample after the process. The fillers which collected on and the terminals are appears dark in this photograph.

The resin was cured to hold the shape of the conductive paths and to adhere between the device and the substrate by rise in temperature to 463 [K], and the joining process was completed. Fig. 3 is cross-section of the conductive path. These pictures confirm the Self-interconnection.

3. Numerical analysis and evaluation method

The multi-interface advection and reconstruction solver (MARS) method developed by Kunugi[2], adapted to consideration of the interface between fluids was used to analyze the process. This method is a kind of finite volume method. Substitution of each valuables into basic equation enables expression of the mass conservation law, the volume of fluid (VOF) ratio conservation law, and the law of conservation of momentum, and analysis of the phenomenon.

A two-dimensional model was used to reduce the consumption of computer memory and analysis time. A schematic diagram of this model is shown in Fig. 4. This article focuses on the effects of volume fraction, *VF* [vol. %], resin viscosity, η [kg/m s], and resin inflow velocity, *f* [μm/s].

The result-evaluation formula is expressed as eq. (1).

$$F_{SI} = a^{w}{}_{\max} \Big/ \sum a \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

a is the area of a filler, a^w is a of the wetted one, and $a^{w}{}_{max}$ is the maximum value of a^w. At the initial conditions, no filler touches the substrate or terminals, and F_{SI} (t=0 [s]) always equal to 0. When all fillers form one huge filler and the filler is wetted to the terminal, F_{SI} becomes equal to 1.

4. Results and discussions

Rate-limiting factor at low resin viscosity

Evaluation of these results using eq. (1) is shown in Fig. 5. The filler volume fraction at 9.6-35 [%] increased final value of the self-interconnection fraction gradually. Fig. 5 made us presume the existence of a threshold (F_{SI} = 0.4-0.8, *VF*= 40 [%]) expressing the success or failure of the conductive-path formation between 35 [%] and 49 [%]. Moreover, the initial rise of self-interconnection fraction shows that the rate-limiting factor of this phenomenon at low resin viscosity is the filler volume fraction.

Transition of rate-limiting factor

Previous analysis used 0.38 [Pa s], the minimum value of the resin viscosity through the process, as a constant value. In this section, the resin viscosity is treated as a variable, and the effects of resin viscosity are focused upon. The effect of the resin viscosity is shown in Fig. 6. Increase of resin viscosity delayed self-interconnection and conductive-path formation. At 3.80 [Pa s], ten times as high as the minimum value, self-interconnection took fillers almost

0.6 [s] due to the high resin viscosity.

The effects of resin-flow at high resin viscosity are shown in Fig. 7. It shows that resin flow rate-limits this process at high viscosity. Increase in the horizontal velocity of the resin-flow hastens the self-interconnection and formation of conductive path at high resin viscosity. Increase of resin viscosity made rate-limiting factor transit from the filler volume fraction to the horizontal resin-flow.

5. Conclusions

These study clarified following knowledge.

1) The self-interconnection phenomenon was confirmed by way of the experiment using Cu array-patterned FR-4.

2) The adequate window, 50-60 [%] and the threshold, 40 [%] for the filler volume fraction exist, and the fraction rate-limit the process at low resin viscosity.

3) Increase of resin viscosity make the rate-limiting factor transit from the filler volume fraction to the horizontal resin-flow.

References

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[2] T. Kunugi, Y. Ose, and M. Bannat: Proc. 5th ASME/JSME Joint Thermal Eng. Conf. (1999) CD-ROM, AJTE99-6435.

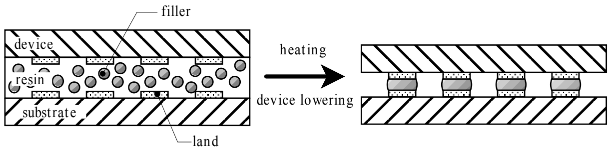
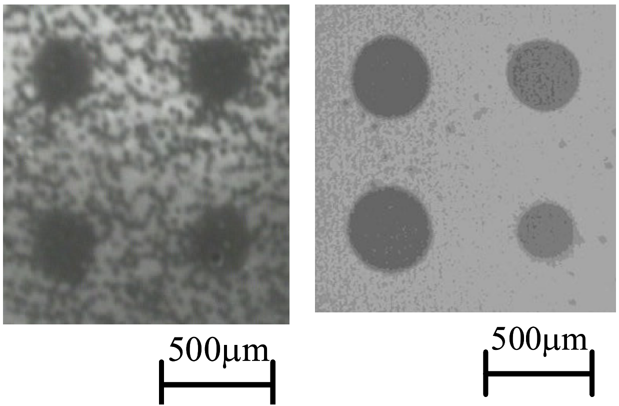


Fig. 1 Novel self-interconnection joining method.



(a) Before heated. (b) After heated.

Fig. 2 Self-interconnection using Sn-In fillers.

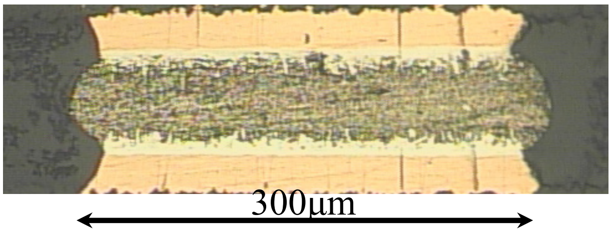


Fig. 3 Cross-section of the joint depicting conductive path.

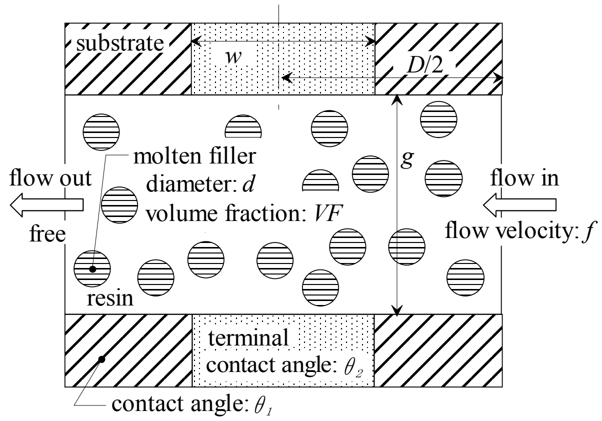


Fig. 4 Schematic diagram of simulation model showing distance between facing terminals, D, gap between substrate, g, and terminal width, w.

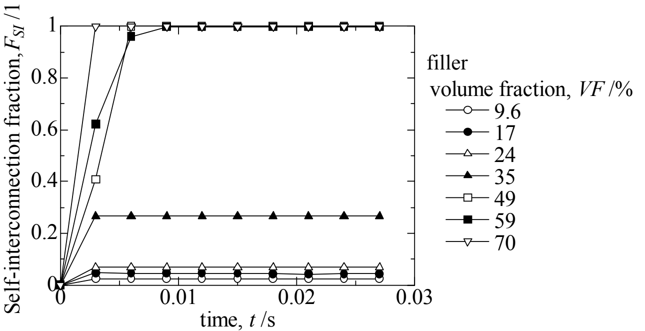


Fig. 5 Filler volume fraction as rate-limiting factor at low resin viscosity.

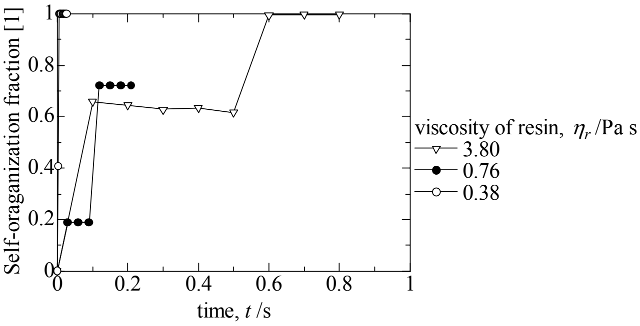


Fig. 6 Delayed self-interconnection phenomenon due to increase of resin viscosity.

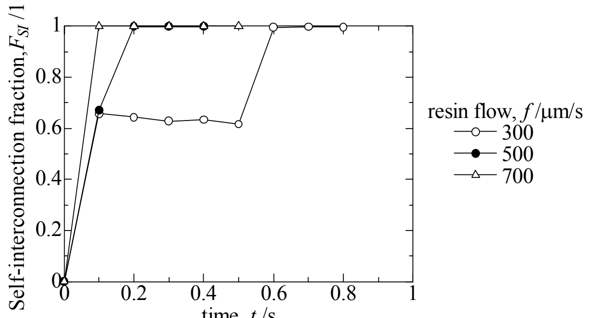


Fig. 7 Resin-flow as rate-limiting factor at high resin viscosity.