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Pyramid Bumps for Fine-Pitch Chip-Stack Interconnection

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1. Introduction

A three dimensionally (3D) chip-stacking technology is attracting a great deal of attention for realizing advanced high-speed, compact, and highly functional electronic systems.[1−3] In order to realize the three dimensionally stacked-chip system, the bonding technology that can form a number of bump connections below 20 μm pitch is certainly required. The chip-stack bonding with resin has great potential for facilitating three-dimensional chip stacking because it possesses the following advantages: (1) low temperature process and (2) simple process. Figure 1 shows the process steps of chip-stack bonding with resin: (a) The resin is dropped on the chip. (b) The alignment is performed. (c) The another chip is pressed against the chip and two chips are heated to bond the bumps and cure the resin. Then the large bump deformation excludes the resin from the bonded region.

However, this method encounters two problems caused by "the bump height deviation" (see Fig. 2) when, in particular, the bump pitch becomes small. One is the bonding failure due to the fact that resin is not sufficiently squeezed out from the interface between short bumps. This takes place especially when the deformation of bump is small. The other is the generation of strain. The chip bends and strain is generated at the chip. This strain will cause the change in electrical characteristic of LSI devices on the chip.[4] Therefore, the bumps which easily deform and compensate the bump height deviation (named "compliant bumps") are required for high-density chip interconnection.

In this paper, we propose the pyramid bumps as one of the compliant bumps. The pyramid bumps made of Au are fabricated by bump transfer method. It is found that the resin exclusion effect of pyramid bumps is larger than that of conventional plated bump.

2. Fabrication of pyramid bumps

Figure 3 shows the process flow of pyramid bumps. The pyramid bumps were fabricated using bump transfer method[5,6]. First, the mold for transfer was prepared from a (100)-oriented Si wafer by using the anisotropic etching with KOH solution. After thermal oxidation, Cr and Au were deposited as the seed layer for electroplating (Fig. 3(a)). The adhesivity between the Cr film and the Au film was made to be small in order to release the mold easily. After photolithography (Fig. 3(b)), bump was formed by Au electroplating. The photoresist and the seed layer were subsequently removed (Fig. 3(c)). Then, the bump-to-chip bonding was carried out by flip-chip bonder (Fig. 3(d)). Bump transfer was investigated under bump-to-chip bonding condition as follows; pressing load: 5 kgf $\sim$ 25 kgf, temperature (mold side): 150°C $\sim$ 300°C, temperature (chip side): 200°C, bonding time: 20 sec, bump number: 10^4, chip size: 2.5 $\times$ 2.5 mm^2. Finally, the mold was released from the chip (Fig. 3(e)).

Figure 4 shows the optical micrograph and SEM image of transferred bumps on a chip. We can see that uniform pyramid bumps are formed over the chip area. The bump size is about 13 μm at the basement and the bump pitch is 20 μm.

Figures 5(a) and 5(b) show the dependence of transfer yield on the pressing load and on the temperature (mold side). We find that the transfer yield increased with the pressing load and the temperature (mold side). But the perfect transfer of 10^4 bumps was not achieved. We have found that uniform press and removal of particles are important issue for perfect transfer.

3. Effect of pyramid bumps

We investigated the resin exclusion effect of pyramid bumps. After the chip with bumps pressed against the resin on a glass substrate, the bump contact region was observed through the glass substrate. The applied pressing load was 5 kgf. Figures 6(a) and 6(b) show the optical micrographs of the bump contact region at conventional plated bump and pyramid bump, respectively. We find that resin is perfectly removed from bump contact region in the pyramid bumps while some resin remains in the plated bumps. This result and the fact the bonding of pyramid bumps can be achieved at smaller pressing load than plated bumps demonstrate that the pyramid bump offers high-density interconnection for chip stacking.

4. Conclusion

The pyramid bumps were proposed and fabricated by bump transfer method. It was found that the resin exclusion effect of pyramid bumps is larger than that of conventional plated bump. This compliant bump will offer high reliability in terms of suppressing bonding failure and minimizing pressing load in fine-pitch chip interconnections.

Acknowledgment

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References

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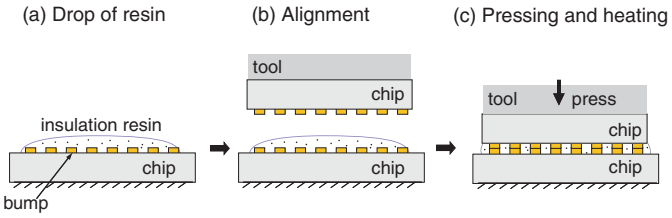

Fig. 1: The process steps of chip-stack bonding with resin: (a) The resin is dropped on the chip. (b) The alignment is performed. (c) Another chip is pressed against the chip and two chips are heated to bond the bumps and cure the resin.

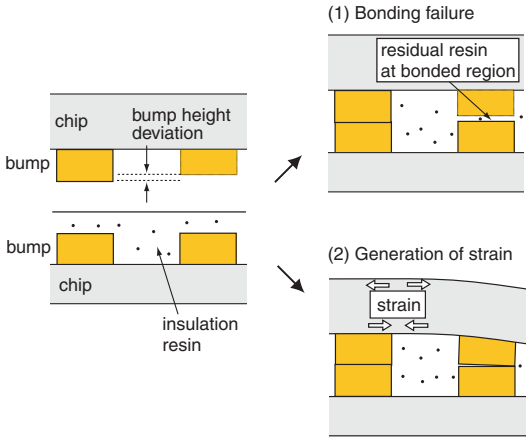

Fig. 2: Two problems caused by "the bump height deviation".

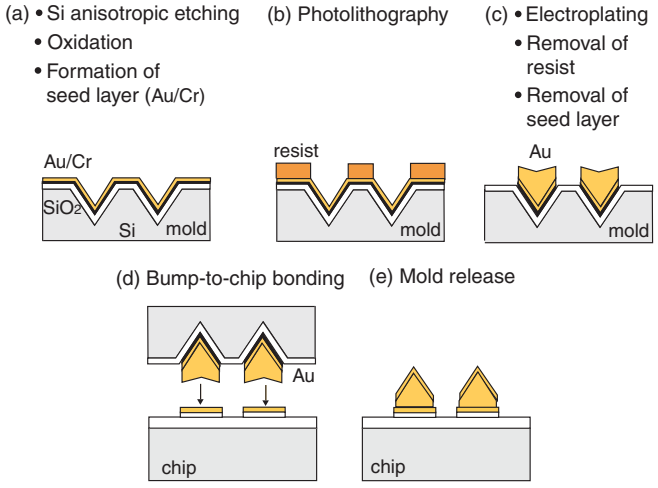

Fig. 3: The process flow of pyramid bumps using bump transfer method. Bump material is Au.

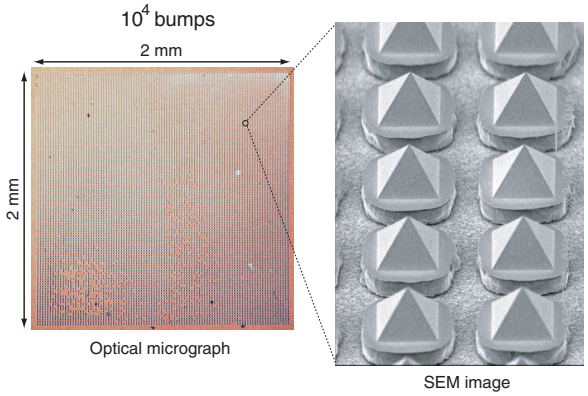

Fig. 4: The optical micrograph and SEM image of transferred bumps on a chip.

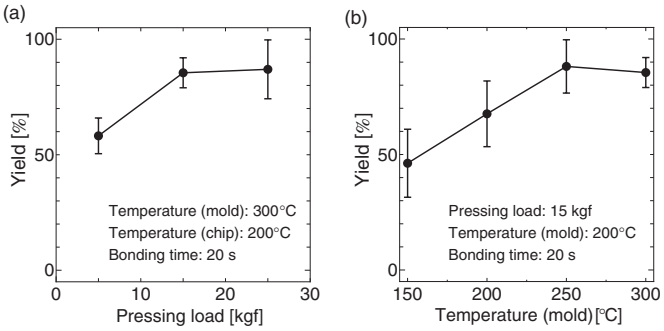

Fig. 5: The dependence of bump transfer yield on the pressing load and on temperature (mold side).

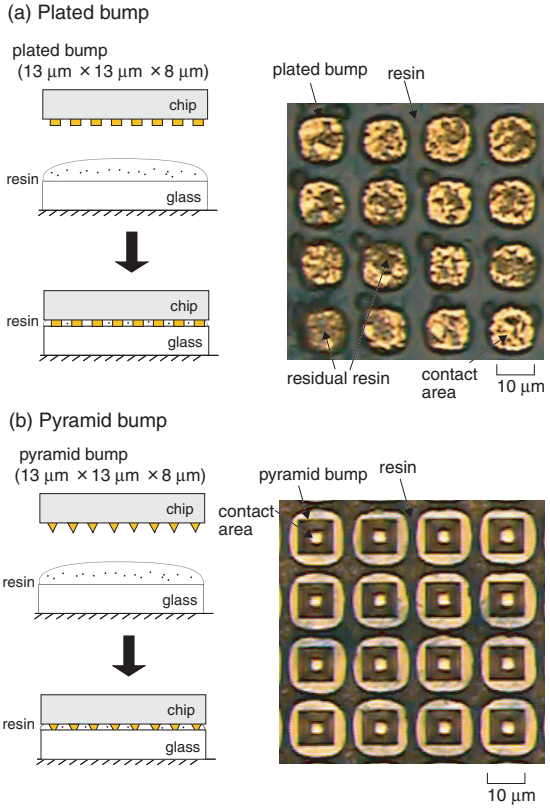

Fig. 6: The optical micrograph of the bump contact region: (a) plated bump. (b) pyramid bump.