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Low Temperature Interconnection of Cu Micro-bump on Polyimide and Ni/Au Film by Surface Activated Flip Chip Method

Zhonghua Xu, Tadatomo Suga

Department of Precision Engineering,
School of Engineering, The University of Tokyo,
7-3-1 Hongo, Bunkyo, Tokyo 113-8656, Japan
Tel: +81-3-5841-6495 Fax: +81-3-5841-6485 E-mail: Xu.Zhong@su.rcast.u-tokyo.ac.jp

1. Introduction

Recently, surface activated bonding (SAB), as a new method, has been well applied on the high density interconnection in the microelectronic and MEMS system. The pair of materials to be bonded were first surface activated by ion, fast atom bean or plasma source, and then aligned and bonded at room/low temperature. Different material groups, film to film, film to bulk material, bulk to bulk material, or metal to metal, metal to semiconductor, semiconductor to semiconductor have been well proved of good interconnection performance by SAB method, in vacuum, protective ambience, or even in air.

Based on SAB concept, several generations of SAB bonders have been developed in the University of Tokyo from the early 1990's. Plasma assisted low temperature flip chip bonder was one of the new attractive bonders. As bonding was carried out in air or protective ambience, the process cost was largely decreased. SAB interconnection between Au micro-bump and Au or Cu film has been demonstrated in the chip-on-hip (COC) system. This paper will illustrate the new application of low temperature SAB method on the Cu micro-bump bond with Ni/Au film in the chip-on-flex (COF) system.

2. Experiment

Polyimide sheets with a size of 20×20 mm^2 and thickness of 100µm were prepared as test substrate. 128 frustum-cone shape Cu bumps were manufactured in center area by electrolysis method. The top and bottom surface diameter of the bump were designed by 30µm and 50µm respectively. Bump height was 35µm and pitch was 120µm. Figure 1 illustrated the Cu bump. To avoid corrosive effect, a Ni2µm/Au0.5µm layer covered on the bump surface. Test chip was silicon chip with a size of 6×6mm^2. The pad was constructed by the Ni5µm /Au0.5µm film.

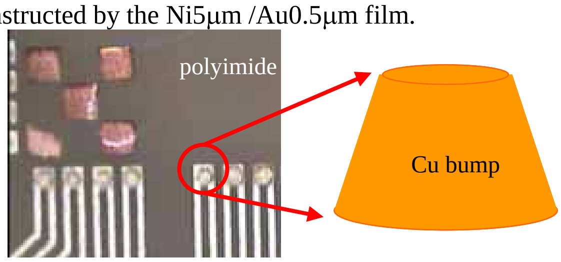


Fig.1 Illustration of Cu bump on the polyimide substrate

The bump/film interconnection was tried by the SAB flip chip method in air. Surface of substrate and chip were activated by plasma irradiation in Ar ambience at the pressure of 30pa. Irradiation was last for 10 seconds under the power of 100watt. Bonding feasibility under the load of 5-40kgf and temperature of 373-573K was investigated.

3. Results and Discussion

3.1 Bonding Feasibility

Low temperature SAB method has been well demonstrated for the interconnection between Au micro-bump and Au or Cu film. Both Au-Cu and Au-Au bond could be done in air or protective ambience such as N_2. To avoid a serious re-oxidization after Ar plasma irradiation, N_2 gas filled bond chamber, which was proved helpful for the better SAB bond at relative low pressure and temperature.

The bonding feasibility of Cu bump and Ni/Au film in air by the SAB flip chip method under the different pressure and temperature was investigated. The result was shown in the table 1. Without the protective ambience, it was found relative high pressure and temperature combination was necessary to help a good interconnection between bump and film, thus resistance of 7mΩ and bump shear strength about 5MPa could be achieved.

Table 1 Bonding feasibility of bump/film under the different pressure/temperature.
"N":un-bondeded. "P":poorly bonded. "W":well bonded.

	5_{kgf}	10_{kgf}	15_{kgf}	20_{kgf}	25_{kgf}	35_{kgf}	40_{kgf}
373_K	N	P	P	P	P	P	W
523_K	P	P	P	W	W	W	W
573_K	P	W	W	W	W	W	W

3.2 Alignment Effect

As of the room/low temperature process, surface activated bonding usually could achieve highly reliable interconnection for the micro-bond in the microelectronic system. Another obvious advantage was the good interconnection accuracy. SAB flip chip method is actually a liquid-less, wireless and RT/low temperature (<573K) process. Not only micro-bump and even the high density bump-less interconnection has been proved. Based on the good cognition of solid mark on the substrate and chip surface by IR camera, high parallel, alignment and bond accuracy were insured. Figure 2 shows the mark on the silicon chip. Basically, there is no special requirement on the mark configuration, however, to avoid the miss-cognition and shorten the alignment process, sometimes, some “sharp” mark was designed and prepared together during the manufacturing process of chip and substrate.

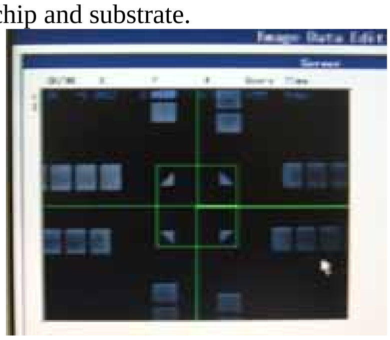
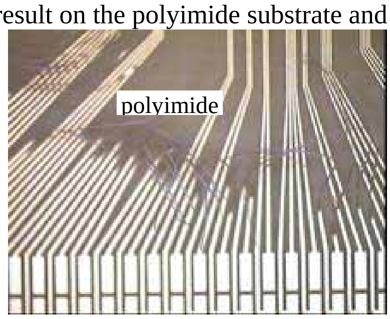


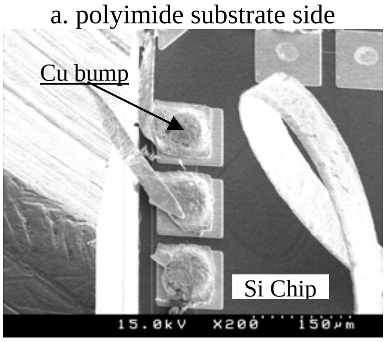
Fig.2 Mark configuration on the silicon chip.

3.3 Bond Reliability

Reliability of the bonded sample was investigated based on the electrical and mechanical measurement result. After the die shear test, Au wire was peeled off from the polyimide sheet, and Cu bump separated from substrate and bonded with Ni/Au film still. Figure 3 showed the failure separation result on the polyimide substrate and Si chip.



a. polyimide substrate side



b. Si chip side

Fig.3 Shear failure on the polyimide substrate and Si chip

3.3 Effect of the Bump Height Deviation on the Interconnection Reliability of Bump/Film.

During bonding, the polyimide sheet was fixed on the heating stage, and silicon chip was held by the bonding head. After alignment, chip and polyimide move close, contact and load was finally applied. In the case of flexible and uneven polyimide substrate, or a serious inhomogeneous bump height as be seen in the figure 4, unless higher load or temperature were applied, part of bump and film will be poorly bonded or even uncontacted. Thus, after die shear, some pairs of bump/film have strong bond strength, and other pairs of bump/film could be easily broken. The figure 5 illustrated the failure phenomenon arose from the deviation of relative bump height. Here “relative bump height” was introduced for the individual bump within one substrate, that the height of every bump was measured from the same point in the bottom face of one specific bump.

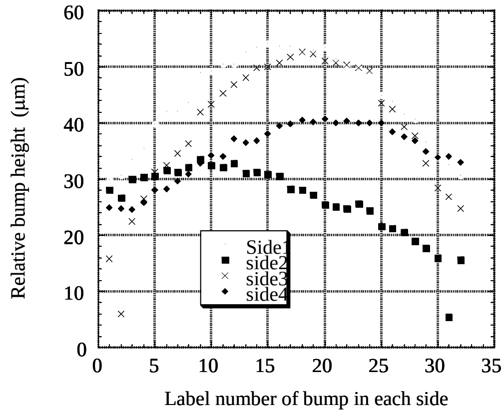


Fig.4 The relative height of the individual bump within one polyimide substrate.

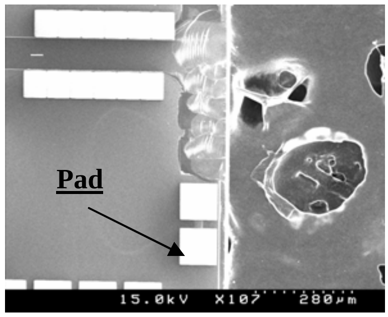


Fig.5 Shear failure on the silicon chip in the case of polyimide substrate with inhomogeneous relative bump height.

4. Conclusions

The possible reliable interconnection between Cu bump on the polyimide substrate and Ni/Au film on the Silicon chip was succeeded in air ambience by the surface activated flip chip method. For the bond of chip-on-flex, the homogeneity of relative bump height plays an important effect on the good bond rate of bump/film pairs. The deviation of relative bump height of more than 20μm may result in an invalid rate of about 50%for the interconnection of bump/ film pairs.

Acknowledgements

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