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Ultrasonic welding and evaluation for microelectric parts

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1. Introduction

Packaging density of electronic parts continuously increases for high-performance microelectronic devices. For example, micro-pitch terminals or flip chips without a plastic package are employed for the miniature electronic components. However, it is hard to bond those small and high density components with traditional soldering process. In addition, lead-free bonding technology is required for environment. To address those problems, ultrasonic bonding technique has been developed [1].

Ultrasonic welding horn should only vibrate longitudinal direction for high quality bonding. In order to make horn vibrating proper direction, FEA (Finite Element Analysis) can be used to analyze the resonant frequency of each vibrational mode and broaden the gap of frequency gap between longitudinal vibration mode and undesired vibrational modes. Other conditions are also important in order to obtain bonding quality. Pressure, temperature, bonding time, and the shape of bump are examples of important conditions for bonding.

In the present work, ultrasonic welding horn was designed by FEA, and chip bonding were carried out using designed horn for varied bonding time. Bonding quality was evaluated by SEM and shear test.

2. Ultrasonic welding horn

The ultrasonic horn was designed by FEA. The horn material was SKD-11 steel and the mechanical property of horn material was measured in the previous work, and listed in the Table 1 [2].

Design criteria were as follows: 1) The horn should vibrate in longitudinal direction at the given transducer's frequency (38.5 kHz). 2) Its frequency should be enough separated from those of undesired vibration modes. 3) It should be easily fabricated. In addition, the horn was designed circular shape to reduce the stress of edge and radius of welding area is small than exterior area for increasing vibration amplitude of welding tip. Fig.1 shows the vibration modes of designed horn. The desired mode is shown in the Fig.1.(b) and undesired modes are shown in the Fig.1.(a) and Fig.1.(c). Simulated resonant frequency of longitudinal vibration mode is 38.7 kHz and it has frequency gaps larger than 4 kHz with the other modes. Photograph of fabricated horn is shown in Fig.2.

Electrical impedance of ultrasonic horn with 38 kHz BLT measured by HP4194A is shown in Fig.3. It was found that measured resonant frequency is 38.3 kHz which is 1.0% difference from designed resonant frequency. It was also found that there is no other resonant modes in the frequency range of 34~42 kHz. Therefore designed horn seems to be satisfied the criteria.

Table 1 Mechanical property of horn material.

Material	Density (g/cm^3)	Elastic Moduli (GPa) Young's	Elastic Moduli (GPa) Shear	Poisson's Ratio
SKD-11	7.708	217	84.5	0.28

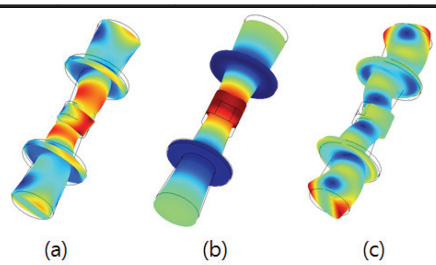

Fig. 1. Vibration modes of designed horn near desired mode

Fig. 2. Designed ultrasonic welding horn

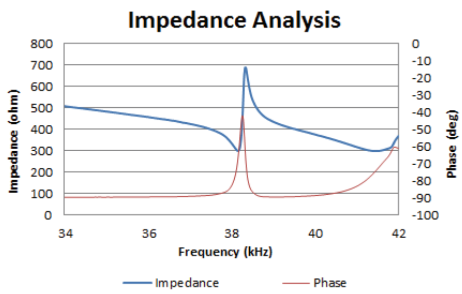

Fig. 3. Result of impedance analysis of designed horn

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3. Experiment setup

Fabricated horn was verified through real chip bonding. Gold coated aluminum nitride substrate and the silicon wafer with gold bump were provided for the verification. Each gold bump is 70×70 μm^2 area and 20 μm height and thickness of gold coated on the substrate is 20 μm.

Fig.4 and Fig.5 show the schematic diagram of experiment and the equipment of the experiment respectively. Welding time was varied 0.5, 1.0, 1.5 and 2.0 s with constant pressure (1.2 N/bump). Cross sections of bonding area were observed using SEM and bonding strength were measured by shear test. Fig.6 shows the schematic diagram of shear test.

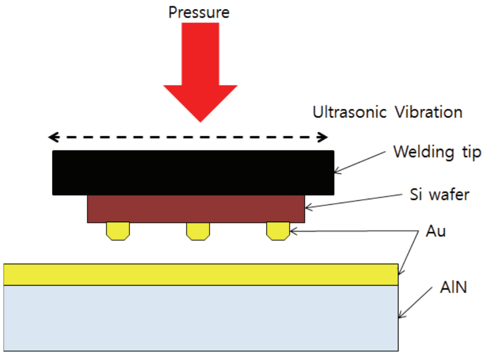

Fig. 4. Schematic diagram of ultrasonic welding

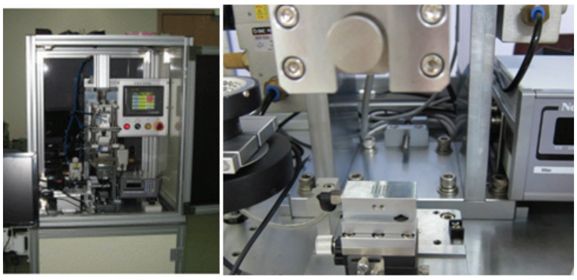

Fig. 5. Photograph of ultrasonic bonding machine

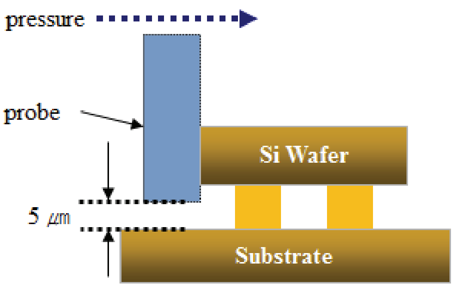

Fig. 6. Schematic diagram of shear test

4. Results

Fig.7 shows the cross section of bonding area. In this figure, the boundary between coated gold and gold bump seems to be well bonded. Any damage in neither silicon wafer nor substrate was observed.

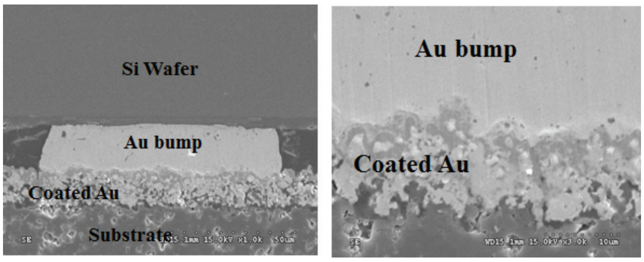

Fig. 7. Cross section of welded area

Fig.8 shows the shear strength versus bonding time. As shown in the figure, bonding strength was maximum for the bonding time of 1.5 s. Bonding strength for the bonding time of 2.0 s was weaker than that of 1.5 s. It seems that longer bonding time raise the temperatures of bonding area, and excess temperature may make large portion of bump be melt, so that bonding area may be weakened.

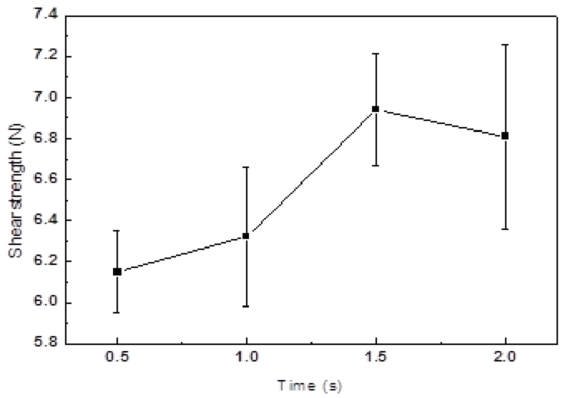

Fig. 8. Shear strength versus bonding time

5. Conclusion

In the present work, ultrasonic welding horn was designed, fabricated and verified through the real chip bonding. Bonding quality was evaluated by SEM and shear test. As results, the designed horn has desirable electrical impedance form. It was found that there is no damage in silicon wafer and substrate through SEM, and it seems to be well-bonded. It was also found that welding time may have critical range of bonding. Larger bonding time may affect undesirable influence to bonding quality.

Moreover, Ultrasonic evaluation of bonding quality is under development, however it is not finished at this moment.

References

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