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Design of Ultrasonic Welding Horn for Microelectronic Components Bonding using Finite Element Analysis

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1. Introduction

High density packaging technology has been widely implemented for the miniature electronic devices. Micro-pitch terminals or flip chips without plastic package are essential for the high density packaging. The traditional soldering process can not be used for such highly integrated devices. In addition, lead-free bonding is required for the environmental protection. Ultrasonic bonding technique has been developed in order to address these problems [1].

Vibration modes and resonance are key elements of ultrasonic bonding in order to obtain bonding quality. FEA (Finite Element Analysis) is one of design tool in various scientific and engineering fields, and it can be also used for the analysis of ultrasonic welding horn [2].

In the present wok, the ultrasonic horn for flip chip bonding was designed by using FEA. Eigen modes were analyzed using COMSOL 3.3 [3].

2. Design Criteria

Schematic diagram for ultrasonic bonding of flip chip on FPCB (Flexible Printed Circuit Board) is shown in Fig.1. As shown in Fig.1, longitudinal vibration of the ultrasonic horn causes transverse motion of flip chip. In the present, longitudinal modes of welding horn were considered for a desired bonding. In addition, resonant frequency of a desired mode has been turned near 40 kHz.

Typical vibration modes of a 136×50×10mm^3 rectangular blocks are shown in Fig. 2. Fig. 2(b) is a desired mode and the others are nearest modes. This result shows that vibration patterns of neighbor modes are quite different, and frequencies of neighbor nearest mode should be separated from the desired one for proper generation of desired mode.

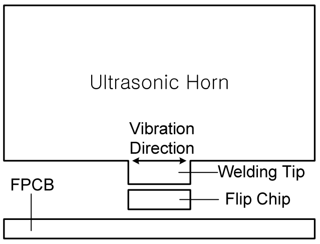


Fig. 1. Schematic diagram of flip chip bonding

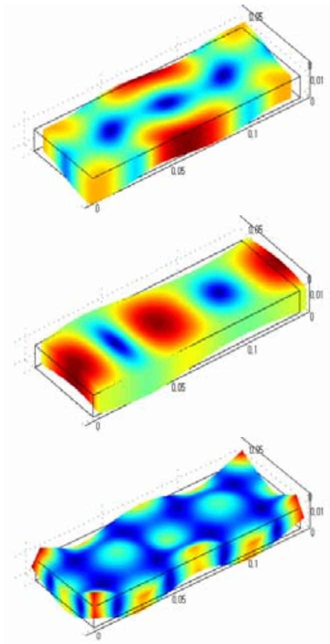


Fig.2. Vibration modes of rectangular horn near desired mode.

3. Properties of Horn Materials

The vibration modes and resonant frequencies are dominantly determined by the mechanical properties of horn materials as well as shape and dimensions of horn. The mechanical properties of horn materials were measured prior to FEA. Speeds of longitudinal and traverse waves were measured by ultrasonic pulse-echo methods and density was by Archimedes principle. Horn material was chosen as heat treated SKD-11 steel and elastic moduli and Poisson's ration were calculated from measured values and listed in Table.1.

Table 1. Mechanical properties of horn materials

Density	Elastic Moduli (GPa)		Poisson's
(g/cm^3)	Young's	Shear	Ratio
7.861	215	83.4	0.288

4. FEA of Full Size Horn

At first, effects of suction hole and fixture boundary condition on the resonant frequency were considered. The steps of modes are as follows:

(1) Simple rectangular block

(2) Add 4 fixtures

(3) Add suction hole

(4) Add welding tip

(5) Grip fixtures (boundary condition change)

The changes of obtained resonant frequency are listed in the table 2.

It was found that adding fixtures greatly changes the resonant frequency about 10% whereas other modifications change the resonant frequency less than 1%. In addition, frequencies of neighbor modes are closer by fixture, however gripping the fixture separates the resonance frequencies. Therefore, the shape of welding horn with fixtures is the main concern with the design of welding horn.

The vibration mode of the final model is shown in Fig.3. As expected, welding horn vibrates in longitudinal mode with 2 nodal positions at fixtures.

Table 2. Resonant frequency changes in each model

Structure	Resonant frequencies			Frequency change
	Before	Desired	Behind	
(1)	35.19	39.13	39,56	-
(2)	41.49	42.94	43.93	+9.74%
(3)	40.94	42.76	43.12	-0.41%
(4)	40.74	42.72	42.78	-0.01%
(5)	39.12	42.80	43.78	-0.21%

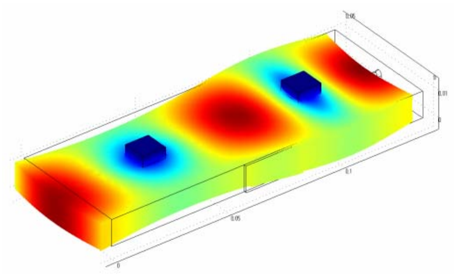
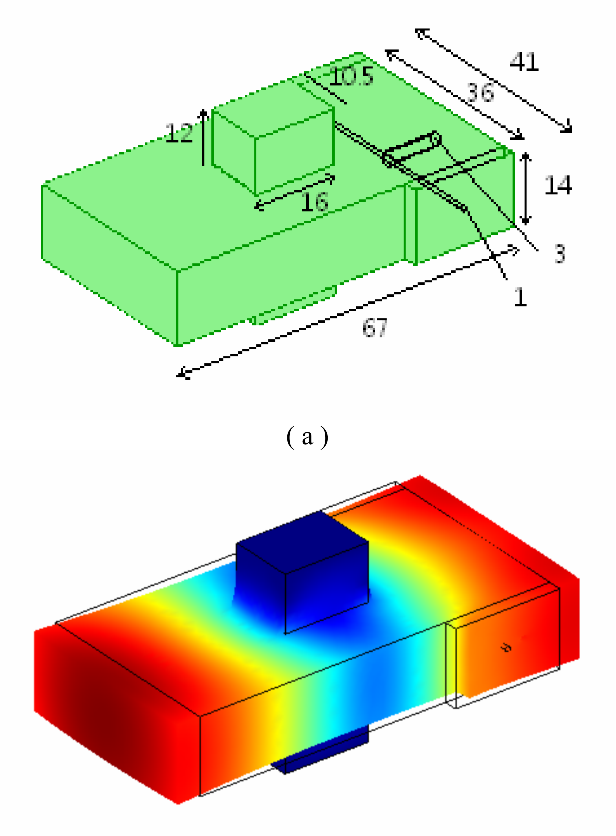


Fig. 3. Vibration mode of final design of full size horn.

5. Design of Half Size Horn

Bonding speed determines productivity, so it is important in the production line. The mass of welding horn affects the speed, and it should be reduced for the high productivity. The materials can be replaced by light materials such as aluminum, however, this kind of materials may have problems in structural integrity, durability, and thermal properties.

Therefore, welding horn with half size was considered. Because there are two nodal positions in the previous mode, which can be divided into two symmetric parts, we can get half sized welding horn with single nodal position at which fixtures are located. Final design of welding horn and its vibration mode are shown in Fig.4. The resonant frequency of final model was 38.43 kHz.



(a)

(b)

Fig.4. Final design of welding horn

6. Conclusion

Ultrasonic welding horn has been designed by using finite element analysis. The resonant frequency of horn is mainly affected by the horn geometries such as size of horn and fixtures. Effects of the suction hole and welding tip in the resonant frequency were negligible. Small size with single nodal points has been designed with the same resonant frequency. The designed welding horn is under fabrication and will be evaluated.

References

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