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Thermal characterization of lead-free epoxy solder on ultrasonically bonded flip chip package

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1. Introduction

Miniaturized, multi-functional and portable electronic devices have been realized by the development of flip chip bonding (FCB) technology using solders. Solder bump connections show superior electrical and mechanical properties, while the excessive growth of intermetallic compounds (IMCs) at the joint interface significantly degrades the performance and reliability of the solder joint during bonding and system operation[1,2)].

Recently, ultrasonic FCB technology has become an interesting that is one of the most suitable bonding methods, because of its high mechanical and electrical performance, high reliability, short processing time, low processing temperature and environment-friendly process[3,4)].

Packaging technology provide an excellent electrical performance, high interconnection speed, and good manufacturability with high reliability. Underfills are commonly used in advanced microelectronic packaging to reduce the thermal expansion mismatch between the silicon chip and organic substrate, thus improving the reliability of the solder joint. Underfills reduce the shear strain of the device and the printed circuit board (PCB), protect the flip chip from the external environment, and provide the whole package with mechanical strength, thereby greatly improving the solder joint reliability and package service life[5~7)].

In this study, therefore, we investigated the thermal reliability of ultrasonic bonding with various underfill states by high temperature storage test, thermal shock test and constant temperature/humidity test.

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2. Experimental

Three different types of solder imperfections were considered; (1) using epoxy solder (TCAP-5401-25, Sn-58Bi), (2) underfill process after ultrasonic bonding, (3) only ultrasonic bonding without underfill or epoxy. Underfill cured 80 ℃ in oven.

Surface treatment of flip chip electrodes was ENIG process. First bonding methods were reflows to epoxy solder paste on substrate. Second bonding methods used transverse ultrasonic vibration energy (ultrasonic flip chip bonder) at room temperature. **Table 1** shows ultrasonic FCB conditions. In order to finds the optimum condition range of bonding time and pressure. Bonding interface was analyzed by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). Optimum ultrasonic FCB strength was conducted electric resistance on 4-point probe station. Using underfill and epoxy solder, bonding strength was too strong to define shear test.

Reliability test were high temperature storage test, constant temperature/humidity test (85℃/85% test) and thermal shock test. **Table 2** shows condition of reliability tests.

3. Results

Fig. 1 shows, the cross sectioned images of the ultrasonic bonded joints. During ultrasonic bonding, the temperature produced along the epoxy solder interface was enough to cause curing of the bonding materials.

Fig. 2 shows, high temperature storage test analysis results for the thermal behavior of the underfill/epoxy. Ultrasonic FCB package and underfill process or epoxy solder sample were not changed electric resistance about thermal reliability test about 300 hours. However no underfill/epoxy flip chip was small increased resistance. This indicates that the resistance of the package increased with increasing aging time. Underfill/epoxy was more endure the temperature and epoxy solder has good properties similar to underfill process.

4. Discussions

In this paper, the thermal reliability of ultrasonic FCB followed by existence of underfill/epoxy. The thermal stress cracks of the flip chip occurred in the region between the IMC layer and solder region. Underfill/epoxy presence reduced the inelastic strain. The solder and substantially improved the thermal lifetimes of the solder joints to the underfill/epoxy and to the delay of crack growth in the thermal shock tests.

Underfill processed and using epoxy solder sample were better reliability than not using underfill. Epoxy solder has similar characteristic to use underfill. It was a composition between upper chip and lower substrate coefficient of thermal expansion (CTE) Therefore epoxy solder was low cost, small process number.

Therefore, it was determined that the properties of the epoxy solder affected the reliability of ultrasonic FCB package.

Acknowledgment

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Table. 1. Specifications of ultrasonic FCB used in this study.

Ultrasonic frequency	40 kHz
Bonding load	0.5, 1, 2 Kgf
Duration time	1, 2, 3 sec
Epoxy solder paste	Sn-58Bi
Solder mask opening	500 ㎛
Underfill	Bisphenol-A + Bispheno-F + Aliphatic type)

Table. 2. Reliability test conditions

High temperature storage test	125℃
Constant temperature/Humidity test	85℃ / 85%
Thermal shock test	-40 ~ 125℃ (30 min/30 min)

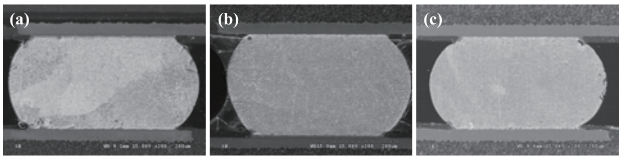

Fig. 1 Cross-sections of the bonded joints versus different underfill type; (a) epoxy solder; (b) underfill; (c) no underfill/epoxy.

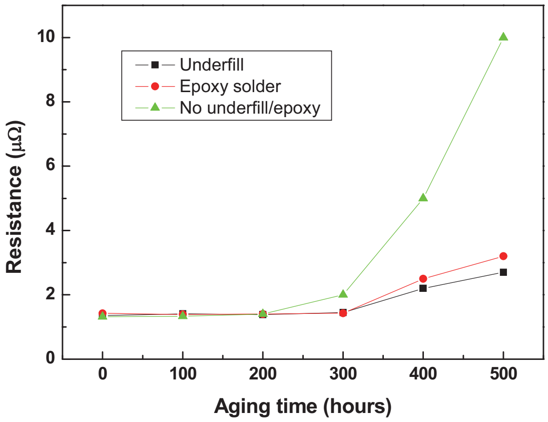

Fig. 2 High temperature storage test with 500 hours.