ENHANCING MECHANICAL SHOCK PERFORMANCE USING EDGEBOND TECHNOLOGY

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ABSTRACT

Edgebond adhesives have been widely used by the industry for improving the shock performance of area array packages [1]. Most of the studies focus on the impact of material properties, such as coefficient of thermal expansion (CTE) and glass transition temperature (Tg), on reliability at room temperature. However, the operating temperature of a component on the printed circuit board bonded with edgebond adhesive can be close to or exceed Tg of the adhesive, where the material properties may be very different than at room temperature. A test vehicle with a 1 mm pitch 52.5x52.5 mm^2 FCBGA is designed to study the impact of testing temperature on shock performance of edgebond material. Five edgebond adhesives with different Tg and filler content are tested at both room temperature and at 100°C. A non-edgebonded FCBGA is used as the benchmark. The results indicate that shock performance is degraded as the testing temperature increases from room temperature to 100°C. However, by either increasing Tg of the adhesive or by adding filler into the edgebond adhesive, the shock performance is improved. In summary, when using edgebond adhesive as an enhancement tool for shock performance, users may need to consider operating temperature during the material selection process. Material been selected, should have a Tg that is in the close vicinity of or higher than the operating temperature to provide needed or expected shock protection.

Key words: Edgebond, FCBGA, mechanical shock, elevated temperature shock test

INTRODUCTION

Large form factor FCBGA demand has increased to meet the boosting of high bandwidth network traffic. It is also well known that FCBGA is sensitive to external shock. The dynamic performance of electronics under mechanical loading, such as bending and shock conditions, has been an important factor on electronics quality and reliability of these large body size packages. Mechanical shock is due to a sudden transfer of energy through a waveform and usually imparts higher stress and strain in a fairly short time. It is more critical for Pb-free solders because of the differences in microstructure and mechanical properties between Pb-free and Sn–Pb solders. Second phase intermetallics precipitate out from the Sn matrix in SAC alloys compared to the uniform dual-phase eutectic microstructure in Sn–Pb solders. Many recent studies show that the microstructure, mechanical response, and failure behavior of lead-free solder joints constantly evolve when subjected to isothermal aging including room-temperature aging and thermal cycling [2]–[5]. Given the fact that the microstructure evolves during a higher temperature exposure, it is crucial to observe and assess the shock performance not only at room temperature but also at higher elevated temperature. Recently, edgebond adhesives have been adopted by the industry to improve FCBGA shock performance. Most of the published industry edgebond shock test results are performed at room temperature environment. However, as temperature rises and approaches the Tg of the adhesive, the properties of the material may change and, possibly, degrade shock performance. There are two folds of objectives in this work. First is to compare shock performance at room temperature and at elevated temperature. The other is to find the key factors, which can be used to enhance the shock performance.

EXPERIMENTAL PROCEDURE

For shock tests, 1.0-mm-pitch daisy-chained full-array flip chip ball grid array (FCBGA) packages with a size of 52.5 mm × 52.5 mm were used. Each package was assembled on an 0.093 inch eight-layer print circuit board (PCB) with adequate connection to form two separate daisy chain circuits as shown in Figure 1. One daisy chain is connected to the corner solder joints to monitor the solder joint connection during shock test and the other daisy chain was distributed under the silicon die area to provide as a heat source during the test. A calibrated current was passed through the inner daisy chain region to bring the temperature up to 100^{o}C at the corner joints, which was measured by a K-type thermocouple. Sn-3.0Ag-0.5Cu (wt%) (SAC305) solder alloy solder joints and solder paste were used for assembly. The PCB used was an organic solderability preservative (OSP) finish high-Tg FR4 test board. As seen in Figure 1, the mounting holes were located in a 5 inch × 5 inch configuration. The test board was fixed onto the drop table by four support standoff screws. To apply a shock wave, the drop table was raised and dropped from a calibrated height adjusted on the basis of the peak acceleration half-sine shock pulse. Accelerators were attached to both the table and board, the recorded data are those from shock table to keep the input shock level consistent. Each test board run started at 150G shock level six times with three times in the +Z direction and three times in the –Z direction. If no failure was noticed, shock level was increased in 50G steps to 200G, 250G, 300G, and 350G six times each (three times in +Z and three times in –Z) until failure occurred. All test boards were monitored in-situ for its electrical continuity during the shock test to detect failures. An increase in resistance of 20% of the initial resistance value during the test was considered a failure. Tested boards were analyzed by dye-and-pry analysis to observe the failure mode. Optical microscopy and polarized light microscope images were also taken to observe solder joint failures and IMC growth.

For edgebonding, five edgebond adhesives were selected based on Tg and filler content. The five material characteristics are shown in Table 1. To prevent voiding due to moisture releasing from PCB material in curing cycle, test boards are pre-baked for 4 hours at 125°C. The edgebond adhesives are dispensed at room temperature using a pneumatic, hand-held dispenser on each of the four corners. Each leg of adhesive is 13.5mm in length, which covers 25% of the BGA edge. The board is then cured at 150°C for 30 minutes. The curing schedule is longer than required. It is to ensure the edgebond adhesive under the large FCBGA has been fully cured.

Table 1. Edgebond adhesive properties

		Low Tg without filler	Low Tg with filler	Medium Tg without filler	Medium Tg with filler	High Tg with filler
Tg	°C	30	30	40	40	130
Filler	%	0	40	0	40	50
CTE	1/°C	60	40	62	45	30
Viscosity	mPa*s	63,000	75,000	71,000	64,000	41,000

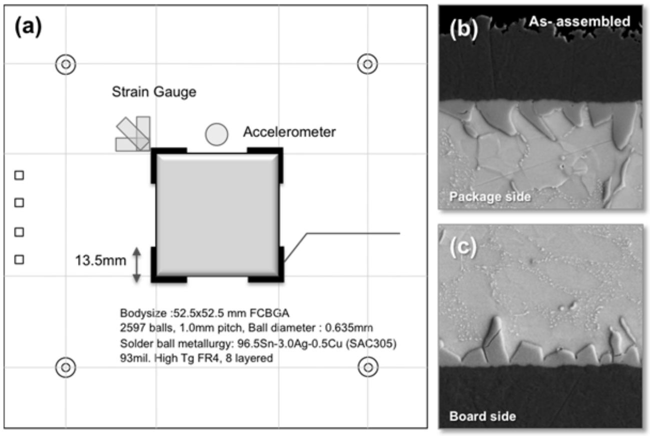

Figure 1. (a) Schematics of the test board and edgebond location. (b)(c) Initial SEM microstructure of package and board side interface.

RESULTS AND DISCUSSION

Figure 2 shows the overall results after shock test. Figure 2(a) is the results after shock testing the boards at room temperature environment. The non-edgebonded board passed the 200G shock level but failed in one cycle at 250G. This is the expected shock performance of this large form factor component. Compared to the non-edgebonded sample, the edgebonded samples all exceeded the 300G shock level. This means that edgebonding is an effective method to improve the shock performance of large form factor components.

Figure 2(b) is the results after shock testing the boards at 100^{o}C at the corner solder joint. The performance of the edgebond adhesives begins to show a dependency of their Tg and their filler content. First, when we look at the shock performance dependence on the adhesives' Tg's, we can see better performance from higher Tg material. The filled edgebond adhesive with a 30^{o}C Tg barely passed the 250G level but the filled adhesive with a 90^{o}C Tg yields a 350G level shock performance. When we look at the shock performance dependence on the presence of filler in the adhesives, we can see better performance from filled material. Both 30^{o}C Tg and 40^{o}C Tg materials yield better shock test performance when filled.

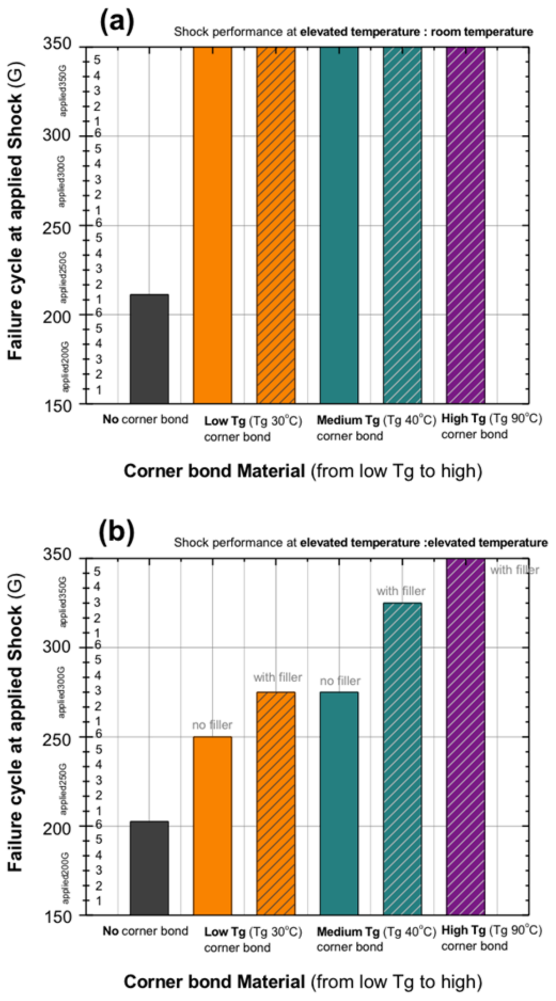

Figure 2. Results after shock tests per each condition. (a) Shock test results at room temperature. (b) Shock test at elevated temperature.

From these results we can see the factors that need to be considered. Once there is a higher temperature environment, we can see that the Tg is an important factor to consider. Thus, based on the component temperature and the temperature environment of the product, the edgebond adhesive selection needs more in-depth analysis to meet expected performance. At the same time, having the filler or not is another consideration, even with the same Tg material.

Figure 3 is the dye and pry results from the shock tested boards. Figure 3 (a-c) shows the failure location based on low, medium and high Tg materials tested at room temperature. As shown in Figure 2, the higher Tg shows better performance and also showed less impacted joints. As shown in Figure 3(c), no dye penetration was observed after 350G shock test with high Tg edgebond material. Compared to the room temperature tested samples, the elevated temperature test samples shown in Figure 3(d-f), show a few failure locations at each corner. Most of the failure mode was laminate crack propagation, which is expected, since the pad design of these boards was non solder mask defined (NSMD).

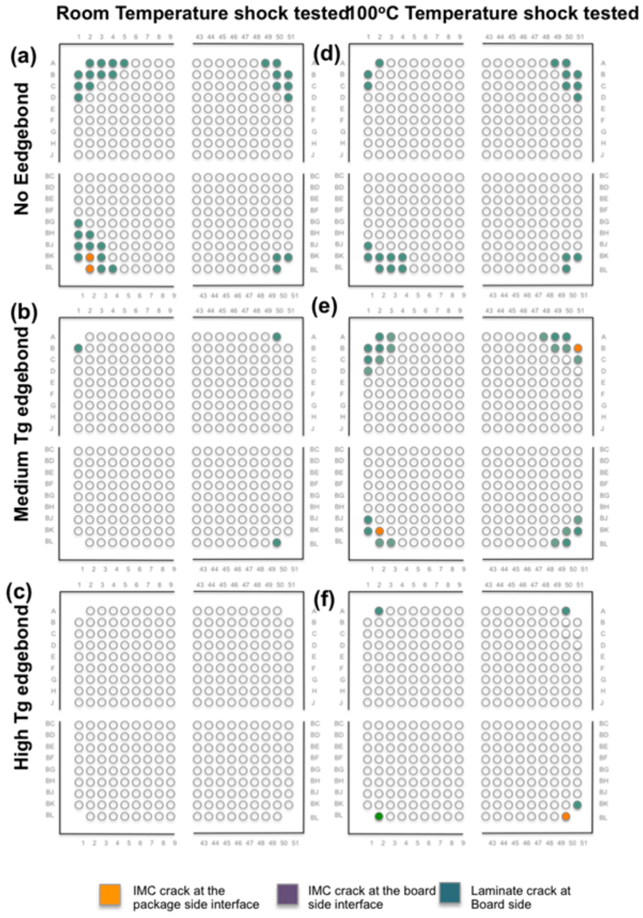

Figure 3. Dye and Pry result. Result after shock test per each condition. (a)-(c) Shock tested at room temperature (d)-(f) Shock tested at elevated temperature. (a)(d) no edgebond, (b)(e) medium Tg, (c)(f) high Tg edgebond.

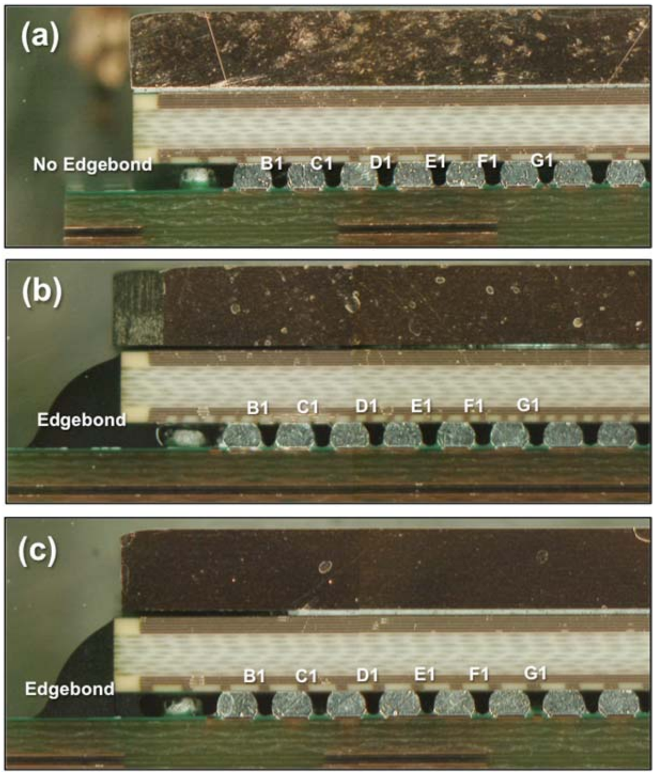

Figure 4. Optical microscopy cross-section of selected samples shock tested at elevated temperature. (a) No edgebond (b) medium Tg edgebond (c) high Tg edgebond.

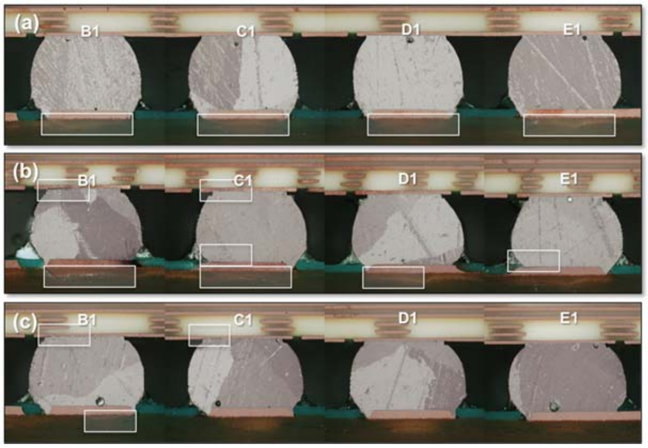

Figure 5. Higher magnification optical microscopy images from Figure 4. (a) No edgebond (b) medium Tg edgebond (c) high Tg edgebond.

Figure 4 is the optical microscopy cross section of selected samples shock tested at elevated temperature. Figure 4(a) is a sample without edgebond adhesive applied. The joints at a higher magnification are shown in Figure 5. For the non-edgebonded samples, the main failure mode is laminate crack at the board side and as seen in Figure 5(a), all four joints from the corner show a full laminate crack under the Cu pad. The samples bonded with a medium Tg edgebond adhesive show a mixed failure mode with mainly laminate but also package side partial crack propagation. Please note that board experienced a higher level of shock. The non-edgebond applied boards were cross sectioned after 250G, both medium and high Tg edgebonded boards were cross sectioned after 350G shock test. But with even 350G shock level, the boards bonded with the high Tg adhesive show only partial crack at the board side corner and the package side corner region as shown in Figure 5(c).

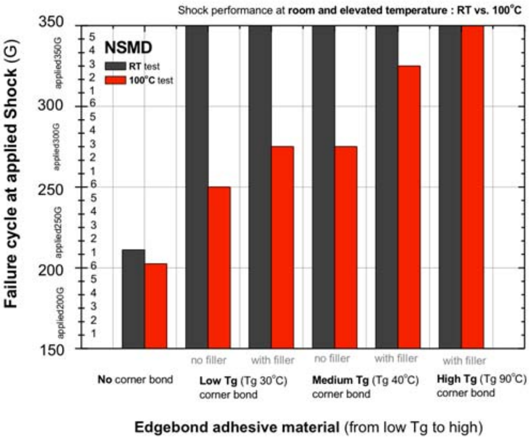

Figure 6. Overall shock test results based on test condition (room temperature vs elevated temperature)

Figure 6 is the summary plot of the tested edgebond adhesives and test condition. It is important to mention that these results based on Tg and filler material is on shock performance. Since the thermal cycling performance has other consideration factors like CTE, impact from filler and Tg values, it is difficult to conclude which material is better that the other. But based on the test and observation in these series of test, it is identified that the Tg and the filler plays an important role to assure the reliable shock performance.

CONCLUSION

A test vehicle with a 1-mm pitch 52.5x52.5 mm FCBGA is designed to study the impact of testing temperature on shock performance of edgebond adhesives. Five edgebond adhesives with different Tg's, with and without filler are tested at both room temperature and 100°C at the corner joints. An FCBGA with no edgebond is used as the benchmark. The results indicates the shock performance are degraded as the testing temperature increased from room temperature to 100°C. However, by either increasing Tg or adding filler into edgebond material, the shock performance was improved. In summary, when using edgebond material as an enhancement tool for shock performance, the user may need to include operating temperature into consideration during material selection process. The material selected should have a Tg that is in the close vicinity of the operating temperature, or higher, to provide needed or expected shock protection.

REFERENCES

1. H. L. Henry Wu, Fubin Song, Jeffery C. C. Lo, Tong Jiang, Keith Newman, S. W. Ricky Lee, "Material Characterization of Corner and Edgebond Epoxy Adhesives for the Improvement of Board-Level Solder Joint

Reliability", Proc. Electronic Components and Technology Conference, 2009, pp. 125-133

2. T.-C. Chiu, K. Zeng, R. Stierman, D. Edwards, and K. Ano, "Effect of thermal aging on board level drop reliability for Pb-free BGA packages," in Proc. 54th Electron. Compon. Technol. Conf., vol. 2. Jun. 2004, pp. 1256–1262.

3. H. Ma, J. C. Suhling, P. Lall, and M. J. Bozack, "Reliability of the aging lead free solder joint," in Proc. 56th Electron. Compon. Technol. Conf., San Diego, CA, May–Jun. 2006, pp. 849–864.

4. H. Ma, J. C. Suhling, P. Lall, and M. J. Bozack, "The influence of elevated temperature aging on reliability of lead free solder joints," in Proc. IEEE 57th Electron. Compon. Technol. Conf., Reno, NV, May 2007, pp. 653–668.

5. T.-K. Lee, H. Ma, K.-C. Liu, and J. Xue, "Impact of isothermal aging on long-term reliability of fine-pitch ball grid array packages with Sn- Ag-Cu solder interconnects: Surface finish effects," J. Electron. Mater., vol. 39, no. 12, pp. 2564–2573, 2010.