

Enhance Solder Ball shear Value in SiP Embedded Packages

Dyi-Chung Hu
ACE Technology, Inc.
65, Kung-Fu N. Road, Hinchu Industrial Park,
Hinchu, Taiwan 303
dc.hu@msa.hinet.net

Abstract

The trend of integrating more functions into portable devices has demanded IC packages to put more dies, more components into a small footprint. To meet this demand, SiP (System in Package) technology has been one of the alternative solutions to system integration. Compare to SoC (System on Chip), SiP has the advantages of integration of dies made from different technology, e.g. GaAs and Silicon; and also can integrate active and passive components together. Hence it gets lots attention lately. In ACET's SiP embedded process, the bare dies and other components are embedded in a filler material to form a wafer-like panel. Later, the dielectric and RDL are processed on top of this panel in a process similar to the RDL of WLP. After making the RDL, the UBM process is followed. Later, the solder balls are placed on top of the UBM and solder balls are reflowed. The packages are then been tested, inspected and ready for shipping. We have successfully used this process in mass production of SiP embedded packages using 8" panels. The technology has also been demonstrated by using both 12" circular and square panels. The filler material and dielectric material used have a low Young's modules. During ball shear test, the solder ball shear force for solder balls on top of the filler is less than that of on top of the die. For some customers, it is desirable to improve the shear force of the solder ball on top of the filler. For the package in this study, the shear force of solder ball on top of the die is averaged 235 gf, however, the same size solder ball on top of the filler materials is averaged only 136 gf. In order to enhance the solder shear force on top of the filler, two methods have been proposed. The first one is using dielectric materials with a higher Young's modules. The high Young's modules material is used only on the very top layer of package. The second method is using stiffer materials underneath the filler area. Both methods are successful to enhance solder ball shear values in the final packages.

Key words: SiP, Embedded, WLP, solder ball, shear test

ACET's SiP embedded process

In ACET's SiP embedded process, the bare dies are embedded in a filler material to form a panel. Later, the whole panel can be processed as if it is a piece of wafer.

Figure 1 briefly describes the process that we used to make the SiP embedded packages. First, the thinned dies with thickness 100 or 127 μm are bonded to a predetermined position on a temporary tooling by a die bonder. The tooling surface has a layer of adhesive to prevent the dies from moving during the processes that follows. Later, the gaps between the dies are been filled by filler materials. An additional back plate was placed on top of the filler materials. After the filler material is cured and fixed the dies to the predetermined position, the panel was then released from the temporary tooling. The released panel can be in 6 or 8 inch format. The released panel is again place on top of a carrier. The

panel and carrier structure then can be processed in standard wafer processing tools. The RDL pattern was defined by photo resist and lithography process. After making the RDL, the UBM can be processed. Typical Cu/Ni/Au is used for UBM. Later, solder balls are placed on top of the UBM. The packages are then tested, singulated, inspected and packed. ACET has successfully used this process in mass production of SiP embedded packages. This technology has been demonstrated both in 12" circular and square panel formats [1].

The Shear test of solder balls

Figure 2 shows the schematic of package structure made by ACET technology. As seen in this figure, die is embedded inside the filler material. Figure 3 shows a typical package used in this study. In this figure, the solder balls located on top of the die and on top of the filler area are indicated. We use 0.3 mm solder balls on 0.5

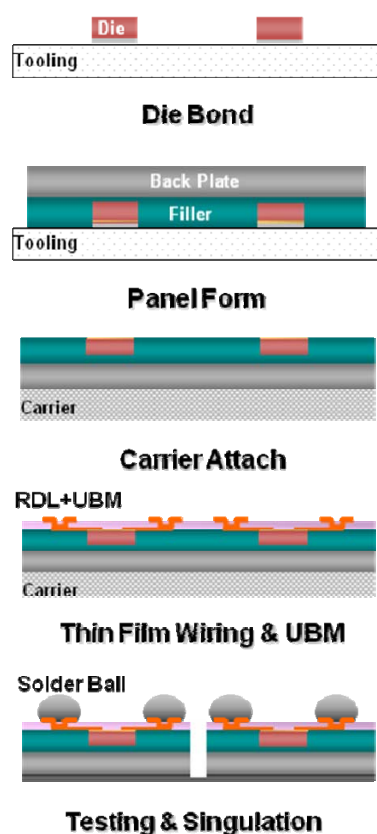


Figure 1. Shows the SiP embedded process used in this study.

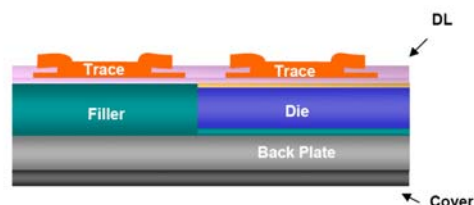


Figure 2. Schematic of ACET's package structure.

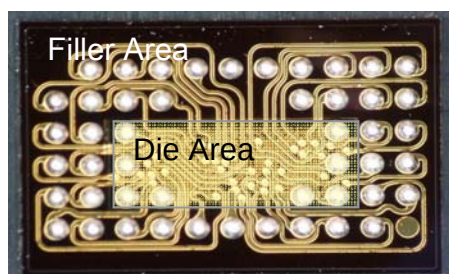


Figure 3. Shows solder balls located on the die area and filler area.

Pads. For balls on top of the die, there is a sudden drop of shear force after around 200 ms of testing. Figure 4. However, for the balls located on top of the filler material, the drop of force is not obvious. Figure 5. The testing of solder ball extends to a longer time (~ 600 ms). This particular behavior indicates that the solder ball can “move” to a further distance before it finally fails. This implies that the solder balls with this structure can be more tolerate to a relative movement between the package and substrate compare with more rigid structure. The shear value is around 130 gf for solder balls located on top of the filler area. This value is significantly less than 280 gf for the solder balls located on top of the die.

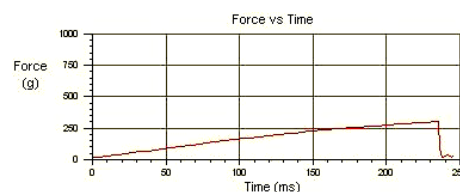


Figure 4 shows a typical force/time plot of the solder ball during the shear test for the solder balls on top of the die area. (Dage series 4000 ball shear tester)

Figure 6 shows the optical picture of solder ball after the shear test. The solder ball was over the die area. Figure 7 is the microsection of solder ball after shear test. The solder ball was over the filler area. The picture shows the fracture of filler after the ball shear test. But the integrity of the solder ball was preserved. This failure mode is different from the failure mode defined by the JEDEC standard [2]. Since JEDEC standard usually works with solder ball failure modes on a “rigid” substrate. The failure mode of ball shear test of solder balls on a stiffer dielectric, for example Polyimide or BCB, the typical failure mode is ductile solder fail.

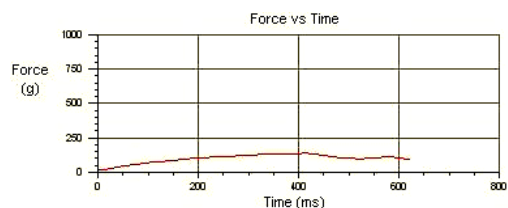


Figure 5. The shear force vs. shear time for solder balls on top of the filler area.



Figure 6 shows the solder ball after ball shear test for solder ball over the die area.

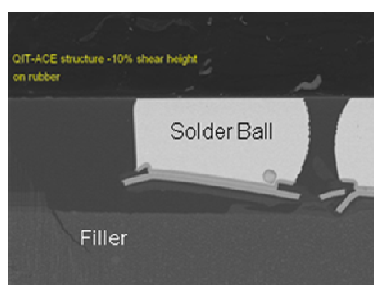


Figure 7 shows the microsection of solder ball over the filler area.

Methods to enhance the shear values of the solder ball shear test

Figure 8 and 9 show the two structures that we proposed to enhance the ball shears value of the solder ball on top of the filler area. Structure A is adding a stiffer dielectric on top of the soft dielectric as indicated in Figure 8. Structure B uses a stiffer material such as polyimide off the die area as indicated in Figure 9. Samples of structure A and B have been built. The RDL patterns, dielectric and metal thicknesses remain unchanged. The averaged ball shear forces over the "off die area" increase in both structures. For example, the averaged

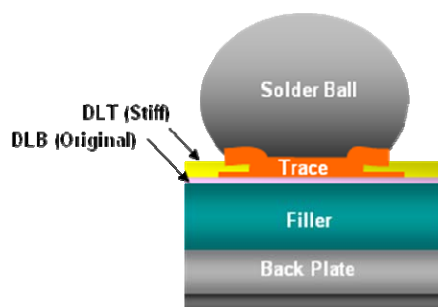


Fig 8. Structure A

ball shear force for structure B has increased significantly from 110 gf to 220 gf.

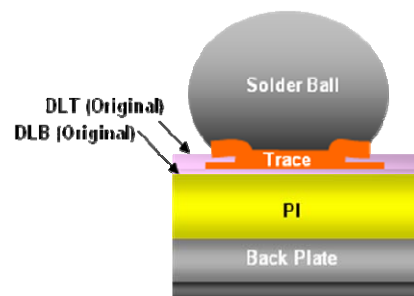


Figure 9. Structure B

Conclusions:

Due to the unique SiP embedded structure, there is a difference in ball shear values for solder balls on top of the die and solder balls on top of the filler area. There is a unique failure mode which is different from the standard JEDEC classifications. The solder balls can travel longer distances before decreasing in ball shear force value. This may indicate a longer solder balls reliability life compare with solder balls on a rigid structure. However due to this unique structure, the solder ball shear value over the filler area is significantly lower than that value over the die area.

Two structures have been proposed in this paper to enhance the solder ball shear value over the filler area. These two structures have successfully been built and the ball shear test values over the filler area are increased significantly. These values are close to the solder ball shear test values over the die area.

Reference:

[1] Dyi-Chung Hu, Tsung Jen Yang, Ferry Hu, "SiP Embedded Technology in 12 inch Format", 3rd IMPACT Conference, October 22-24, pp. 739-741, 2008.

[2] JEDEC: JESD22-B117, October, 2006.