Investigations of Solder Ball Drop Reliability: BGA versus WLP

Amarinder SinghRanouta andXuejun Fan
Department of Mechanical Engineering, Lamar University, PO Box 10028, Beaumont, TX 77710, USA
xuejun.fan@lamar.edu

Abstract

In this paper, finite element modeling is performed to investigate the mechanisms ofreliability performance for wafer level packages (WLP) compared to chip scale ball grid array (BGA) packagesunder impact or drop loading conditions. Several scenarios are defined to reveal the different mechanisms of dynamic performance in WLP and BGA packages. Global/local finite element modeling is performed with the use of the direct acceleration input (DAI) method. In the first scenario of the simulation, a WLP (ball on I/O) package is compared to a BGA package with same ball geometries when package size is fixed. The vertical compliance at the package corner balls in BGA, due to the corner ball attachment to the compliant substrate/mold compound, makes BGA producing significantly less stresses than in WLP. However, when considering the second scenario, in which the same die is packaged with BGA and WLP (ball on I/O), respectively,the size of the package in BGA has increased, which presents the opposite effect in reducing the solder ball drop reliability. In the third scenario, a copper post WLP package is studied. It is found that the horizontal compliance by the epoxy layer, which is used to encapsulate the copper posts, has released the stresses in solder balls greatly under impact loading. Package size, vertical local compliance in BGA, and the horizontal compliance in WLP, constitute the major factors in determining the reliability performance of final products.
Theresm(e)7(c366(I1ts(ThTxy)-1)-1744.46 TD59(f[scen11(inin6.52 T6(he))-103(sames)6v)-57(f)5()9(plich)-14he)-168(pac)5(par)-3(3g

2011 International Conference on Electronic Packaging Technology & High Density Packaging

layer with two layers of elements is created at solder ball upper interface. 3-D solid elements are used for the entire structure including PCB board. Direct acceleration input (DAI) method is used to apply impulse loading (Dhiman, et al, 2008a, b, 2009). The damping coefficient for PCB is determined by correlating with experimental strain data.

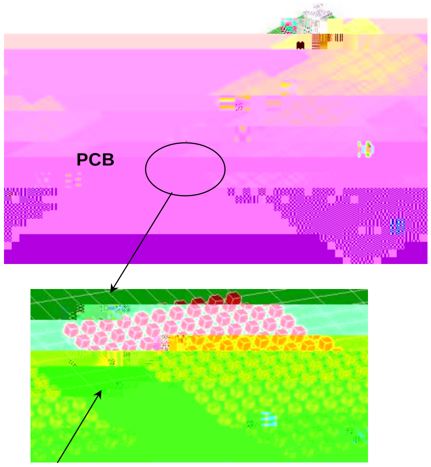
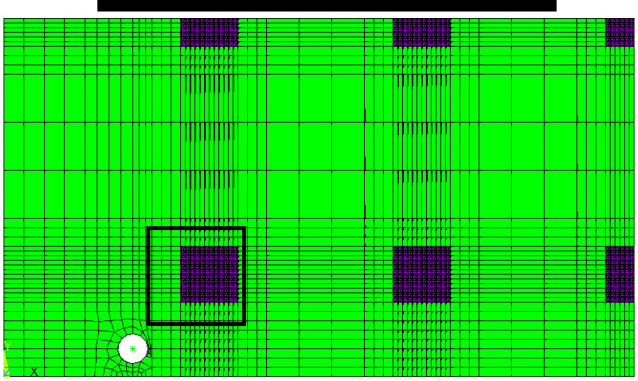


Figure 5 A quarter global finite element model

Table 1 defines the material properties used for both global and local finite element models. All the materials are considered as elastic ones.

Table 1Material Properties

[redacted]



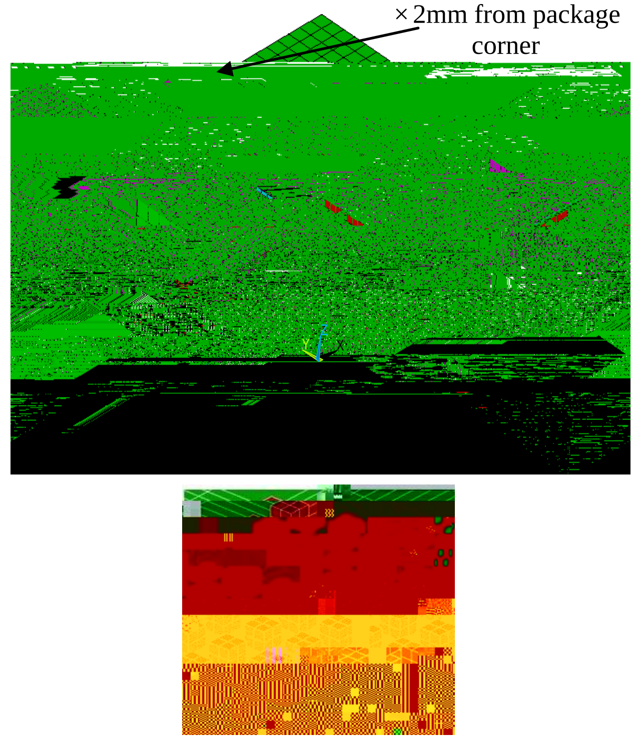


Figure 6local finite element models**(a)**. cut boundary from global model; **(b)**. 3-D view of a local model; **(c)**.solderball meshes in the local model

4. Results and Discussions

4.1 Scenario 1

Previous studies have shown that for any components located on the JEDEC test board, the maximum peeling stresses in each component always occur at package corners. (Ranouta, et al., 2009).Thus, in this study, only corner balls in two packages are investigated. The component U1 on the JEDEC test board is selected. Figure 7 shows the maximum peeling stress during drop for a WLP vs. BGA. From Figure 8, it can be seen that the corner balls in BGA are connected to interposer (substrate)/mold compound (8(b)), which provides a local flexibility in vertical movement for corner balls. However, in a ball on I/O WLP package, the solder balls are attached to the „rigid" silicon die directly (8(a)). This has led to the peeling stress in BGA corner balls significantly lower than that in WLP, as shown in Figure 7.Local compliant structure of substrate/mold compoundis connected to the solder balls in a vertical direction at package corners in BGA to provide a mechanism as spring structure to release the stresses in solder balls.

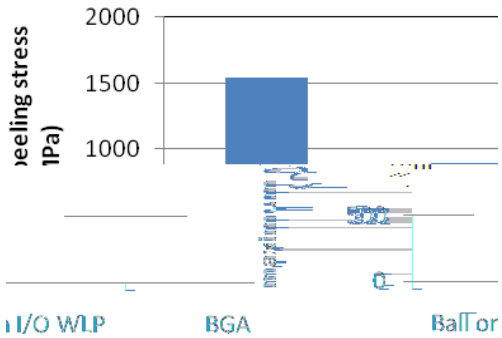
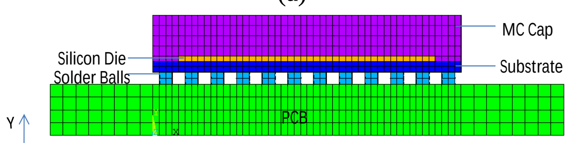


Figure 7 maximum peeling stresses for corner balls in U1 for scenario 1

(a)



(b)

Figure 8 Corner solder ball attachment in (a) ball on I/O WLP, and (b) chip scale BGA package

4.2Scenario 2

Many simulation and experimental data have been reported that the package size plays a significant role in affecting solder ball drop reliability. The greater the package size is, the less the reliability of solder balls is subjected to impact (Ranouta, et al., 2009). For a same die, if the WLP packaging is selected, the package size is the same of the die size. If the BGA packaging is selected, the package size will be greater. Assuming that the package size is 1.2 times of die size, it can be seen that two opposite mechanisms exist in BGA packages: larger package size will decrease the solder ball reliability, while corner solder balls in a BGA benefit from the local compliance as illustrated in the scenario 1. Figure 9 shows the simulation results of the maximum peeling stresses for scenario 2. Compared to the scenario 1, ball stresses in BGA has increased considerably due to the increase of package size.

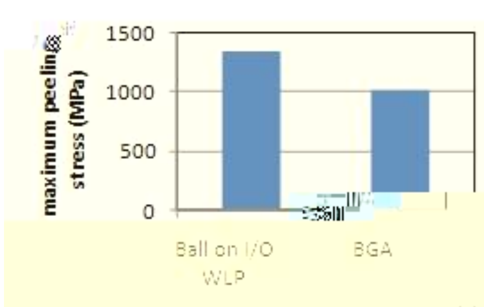


Figure 9maximum peeling stresses for corner balls in U1 for scenario 2

4.3Scenario 3

Ball on I/O WLP package is used in scenarios 1 and 2. However, such a WLP structure has been rarely used now (Fan, et al. 2010). Among a variety of WLP packages, copper post WLP package has shown the superior reliability performance in thermal-mechanical reliability (Rahim, et al., 2009; Zhou, et al., 2009). In a copper post WLP, thick copper pillars (~70 µm) are electroplated, followed by an epoxy encapsulation at wafer level. The copper post WLP can also incorporate with redistribution layer (RDL). The epoxy used in copper post WLP is very compliant with a typical modulus of 5 to 20 GPa, which is only a fraction of the modulus of silicon die (130GPa). Table 2 shows the results of a parametric study of the maximum peeling stress as a function of epoxy modulus, compared to a ball on I/O WLP. As expected, when the epoxy modulus approaches the modulus of silicon, the peeling stress is very close to the stress in balls on I/O WLP. With the decreasing of the epoxy modulus, the solder ball stresses can be reduced greatly. For the epoxy modulus of 4.7MPa, the stress in a copper post WLP is much less than the stresses in BGA for a same package size as shown in scenarios 1, and fo( ) 37(ba)4(lls) level.Irios 1,11(epovel.)o( )

horizontal spring structure to release the stresses in solder balls. Figure 10 plots the results of the maximum peeling stress for these two packages. For the given material properties for both packages, the stress level in both packages is comparable. This means that a copper post WLP package will have the drop reliability as good as a BGA package, or even better.

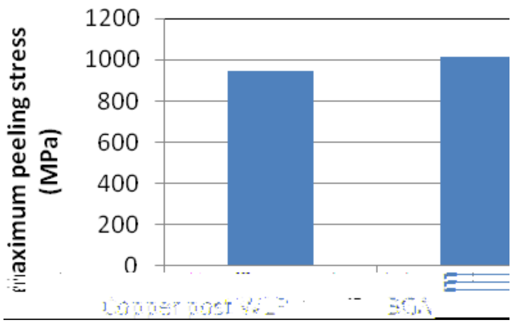


Figure 10 maximum peeling stresses in a BGA and a copper post WLP package (same die size)

Althoguh there are no direct experimental data available to validate the above results and findings, the individual resuts from several sources may support the conclusions made in

Electronics, Proceedings of the 57th ECTC, Reno, Nevada, pp. 924-939.
14.