Journal of Engineering Research and Reports

20(2): 142-148, 2021; Article no.JERR.65314
ISSN: 2582-2926

Understanding Package Delamination through Package Deformation Modeling at Different Thermal Conditions

Jefferson Talledo[1*]

[1]ST Microelectronics, Inc., Calamba City, 4027, Laguna, Philippines.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i217278
Editor(s):
(1) Dr. Guang Yih Sheu, Chang-Jung Christian University, Taiwan.
Reviewers:
(1) Vidya S, Sree Narayana Colege Kollam, India.
(2) A K M Ayatullah Hosne Asif, Mawlana Bhashani Science and Technology University (MBSTU), Bangladesh.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65314

Original Research Article

Received 01 December 2020
Accepted 03 February 2021
Published 19 February 2021

ABSTRACT

Package delamination is one of the problems in semiconductor packaging. Understanding the delamination mechanism in a specific situation is very important to identify the root cause and implement robust solution. In this study, package deformation modeling was done to analyze the deformation of the substrate or package at different thermal conditions. The modeling result was compared with the actual package deformation of the package with delamination problem. It was found out that the observed deformation through actual cross-section analysis matched with the modeling result at reflow temperature condition. Thus, it could be concluded that the delamination happens during package reflow and not after post mold cure or the preceding processes.

Keywords: Package delamination; deformation modeling; die attach film; reflow; thermal conditions.

1. INTRODUCTION

In semiconductor packaging, interfacial delamination is a common problem. It is the separation between interfaces of different materials in contact or bonded together. It could happen at the interface between the mold resin material and substrate, the die and the die attach material, or the die attach material and the substrate. As mentioned in one study [1],

**Corresponding author: Email: jefferson.talledo@st.com, jst2kjeff@yahoo.com;*

interfacial delamination of the die-attach layer is much more likely to occur from a delamination located at the edge of the pad/die-attach interface than anywhere else along the interface. This delamination has many contributing factors. The evaluation results by Lin et al [2] showed that die attach paste voids were major factors affecting the package integrity and could produce the delamination initiation at the edge of the die attach paste and propagate down to the lead-frame paddle/mold compound interface due to high stress concentration and weak adhesion strength. In the case of leadframes, the adhesion strength between the copper leadframe and mold compound was found to be dependent on the degree of leadframe oxidation [3]. Delamination between two dissimilar materials is also accelerated when the polymeric materials absorb moisture from humid environments [4]. Many other studies [5-7] are also discussing about the contribution of moisture to delamination. Moisture accumulation in the package can cause the popcorning phenomenon [8] with permanent package deformation [9]. Popcorning failure is usually preceded by delamination of either the pad/encapsulant interface or the die-attach-layer/pad interface [10].

In the specific problem encountered in the current study, delamination occurred at the die attach film (DAF) to substrate interface as shown in Fig. 1. The DAF material is separated from the substrate as manifested by the gap at the interface. Then, the delamination can be seen propagating down to the metal trace causing a crack in the substrate's solder mask material above the conductive metal trace. It appears that the delamination started at the central area of the DAF/substrate interface, which is quite different from the common observation of delamination that would start at the perimeter or edge of the DAF/substrate interface as also stated in [1]. This delamination is also associated with package deformation due to mechanical forces or temperature changes. Package deformation creates stress at the interface between two different materials and when the interface stress exceeds the adhesion strength, delamination happens.

To better understand the delamination mechanism in this specific problem and identify in what specific assembly process or thermal condition this occurs, package deformation modeling was performed. Knowing the package deformation behavior from modeling and comparing with actual package deformation could give an idea on how the delamination associated with package deformation happened. This would make the investigation of the root cause of the problem easier and more systematic.

2. MODELING THE PACKAGE DEFORMATION AT DIFFERENT THERMAL CONDITIONS

The semiconductor package in this study is a stacked-die land grid array (LGA) package. There are two dies stacked in this package and encapsulated with epoxy molding compound. In the package deformation modeling, different assembly processes and thermal conditions were considered. The study focused on 3 processes and thermal conditions shown in Table 1.

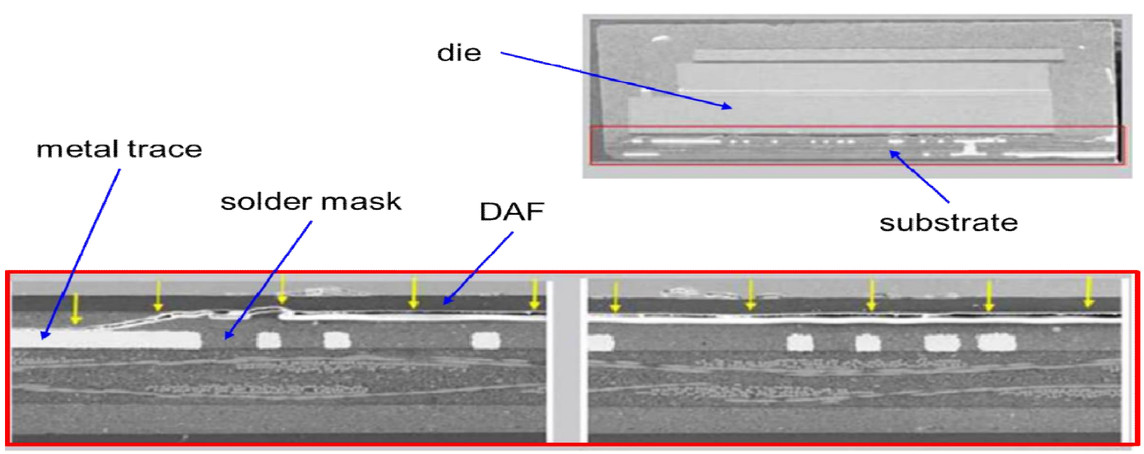

Fig. 1. Delamination between the die attach film (DAF) and substrate

Before the die attach process, the bare substrate is baked at 125°C in a standard semiconductor package assembly process. In this study, the bare substrate deformation after bake was modeled. The details of the metal trace layout and solder mask of the substrate were included as indicated in Fig. 2. For package deformation after the post mold cure (PMC), the whole package 3D solid computer-aided design (CAD) model was created (Fig. 2). As shown, the package is a land grid array (LGA) package with stacked dies. The die is bonded to the substrate using die attach film (DAF). The same 3D CAD model was also used for the package deformation at package reflow condition.

From the CAD model, a finite element analysis (FEA) model was created for the substrate and package deformation modeling by meshing the 3D CAD solid model in ANSYS Workbench. Fig. 3 shows the FEA model showing the mesh and finite elements of the whole package. After assigning the material properties to each package component, model constraints and thermal conditions were applied. The package deformation results from modeling were then compared with the actual cross-section of the package with delamination described earlier in this study.

3. RESULTS AND DISCUSSION

The results from the processes and thermal conditions considered and simulated are presented here. The deformation discussed in the following sections is mainly due to temperature changes that the package is subjected to during package assembly.

3.1 Deformation after Substrate Bake

The result of the modeling of the substrate deformation is shown in Fig. 4. The unit warpage after substrate bake is minimal, which is about 3 microns only and in a "frowning" mode. Thus, the thermal process (bake) prior to die bond is not expected to cause die bonding issue. When the substrate deformation or warpage is in "frowning" mode and very minimal as shown, it is not expected to cause die bonding issue like the formation DAF voids that could also be a contributor to delamination. However, the model here assumes perfect substrate flatness and could not capture the impact of actual substrate planarity issue. Thus, the model result only shows the impact of temperature on substrate deformation.

3.2 Deformation after Post Mold Cure (PMC)

After the post mold cure (PMC), the warpage or deformation result is also in a "frowning" mode (Fig. 5). This deformation would not tend to open the interface between the die attach film (DAF) and solder mask at the package center. As shown in the deformation result, the substrate tends to be pushed upward and in effect, it would compress the substrate interface against the DAF material. With this observation, the specific delamination problem encountered could not be happening after the post mold cure process.

3.3 Deformation during Package Reflow

During the package reflow, package deformation is now in a different direction as shown in Fig. 6. As the substrate expands at high temperature reflow condition, the substrate tends to be pulled downward. Based on the comparison of the actual package deformation with the deformation result from modeling (Fig. 7), warpage or deformation result is in a "smiling" mode at reflow. With this, the DAF/solder mask interface at the package center would tend to open. If the DAF adhesion is already weak at the center, delamination propagates and breaks the mask at the thinner portion above the metal trace. The thinner portion of the solder mask is weaker.

Since the package deformation modeling result during reflow matches with the actual deformation of the package with delamination problem, this means that the observed delamination occurred during reflow. The package moisture soak before reflow could have aggravated the delamination. This is further supported by previous studies [5-6] stating that when the delamination takes places, the internal vapor pressure inside of the voids at the interfaces becomes an external pressure subjected to the delaminated surfaces. The interfacial adhesion also degrades continuously with moisture absorption. As explained by Tarr [11], absorbed moisture turns to steam when heat is applied, building up a pressure of several atmospheres in the interior of the component.

Knowing that the delamination occurred during reflow, it then pointed to weak DAF adhesion to substrate since other similar packages did not encounter such delamination. Further investigation revealed that there was problem with the die bonding. There were die attach film (DAF) voids observed right after die bond causing weak die attach adhesion at the center area. It was attributed to substrate planarity problem and not the thermal conditions the substrate is subjected to. This explains the observed delamination propagating from the center area of the DAF/substrate interface.

Table 1. Assembly process and thermal conditions

Assembly process	Thermal condition
Substrate Bake	125°C
Post Mold Cure (PMC)	175°C
Reflow	260°C

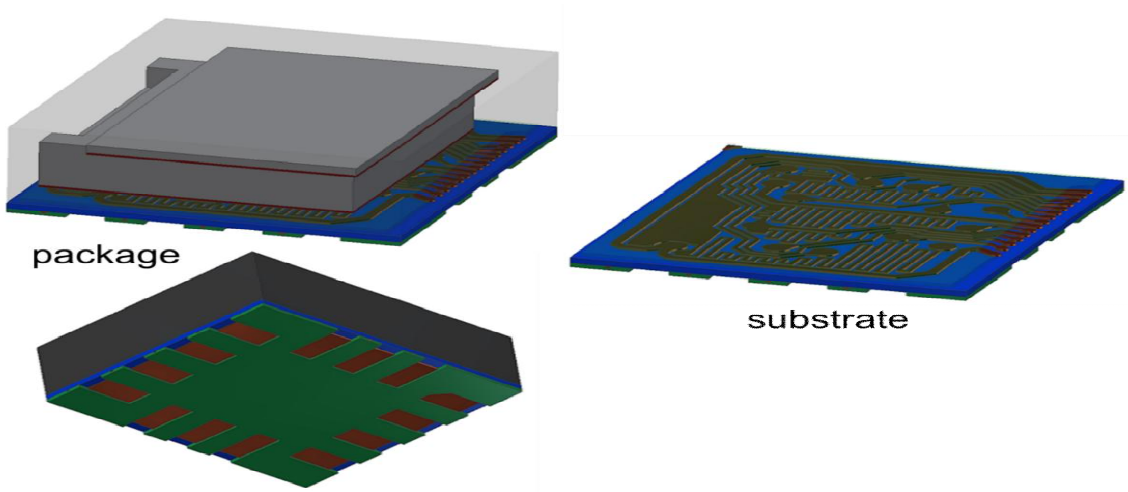

Fig. 2. 3D CAD model of the semiconductor package with details of the metal traces and solder mask included

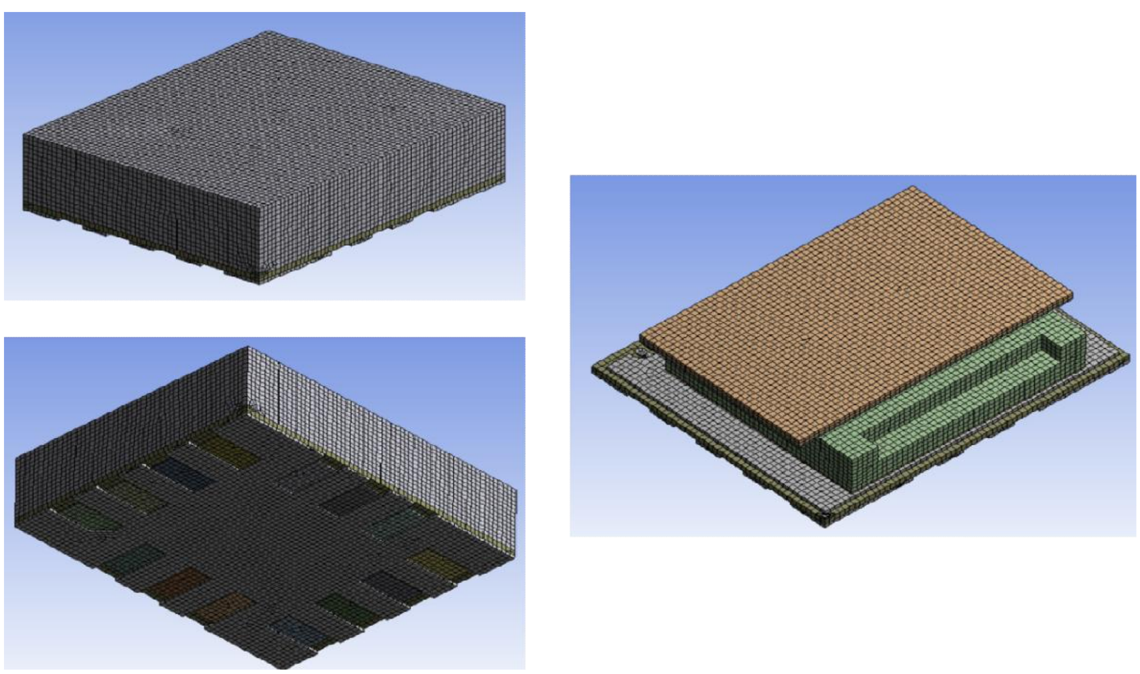

Fig. 3. Finite element analysis (FEA) model of the package

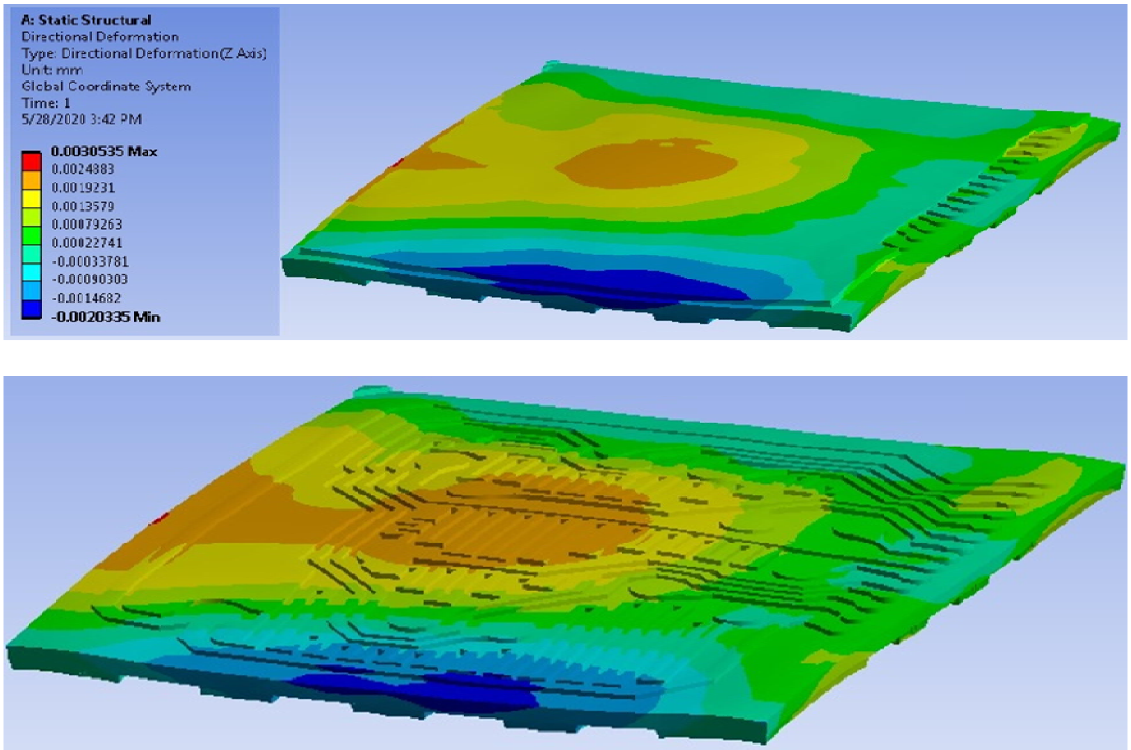

Fig. 4. Deformation of bare substrate after bake

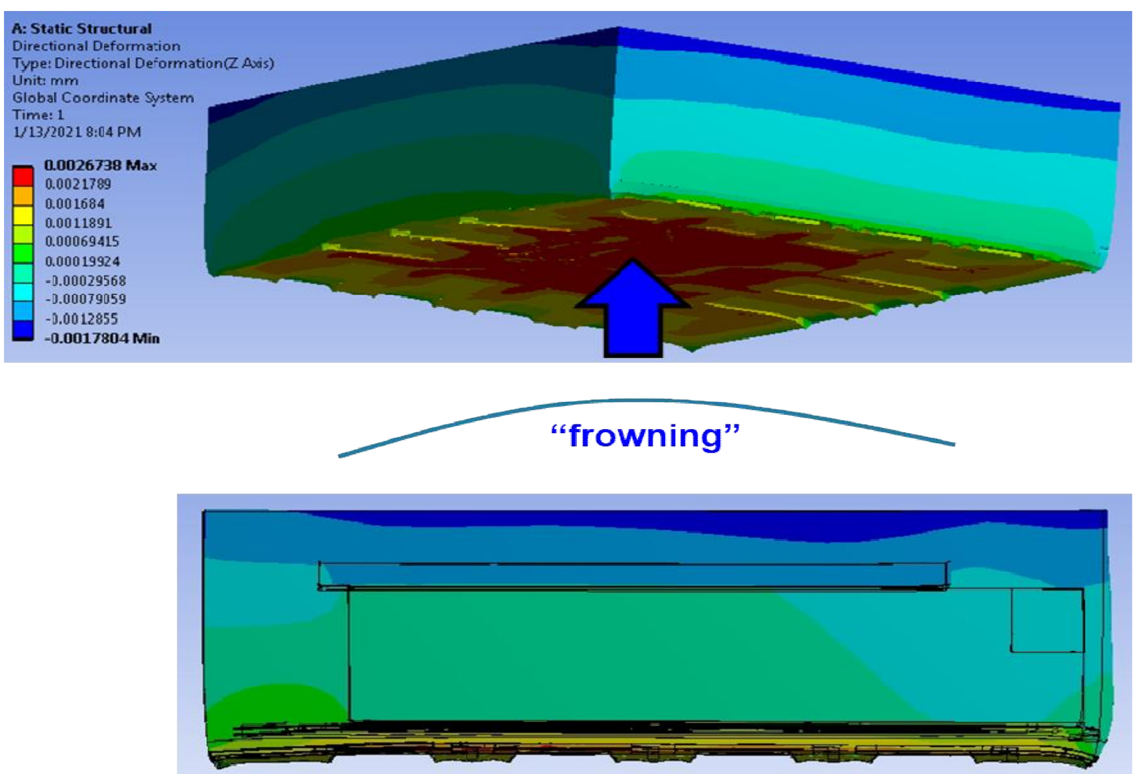

Fig. 5. Package deformation after post mold cure

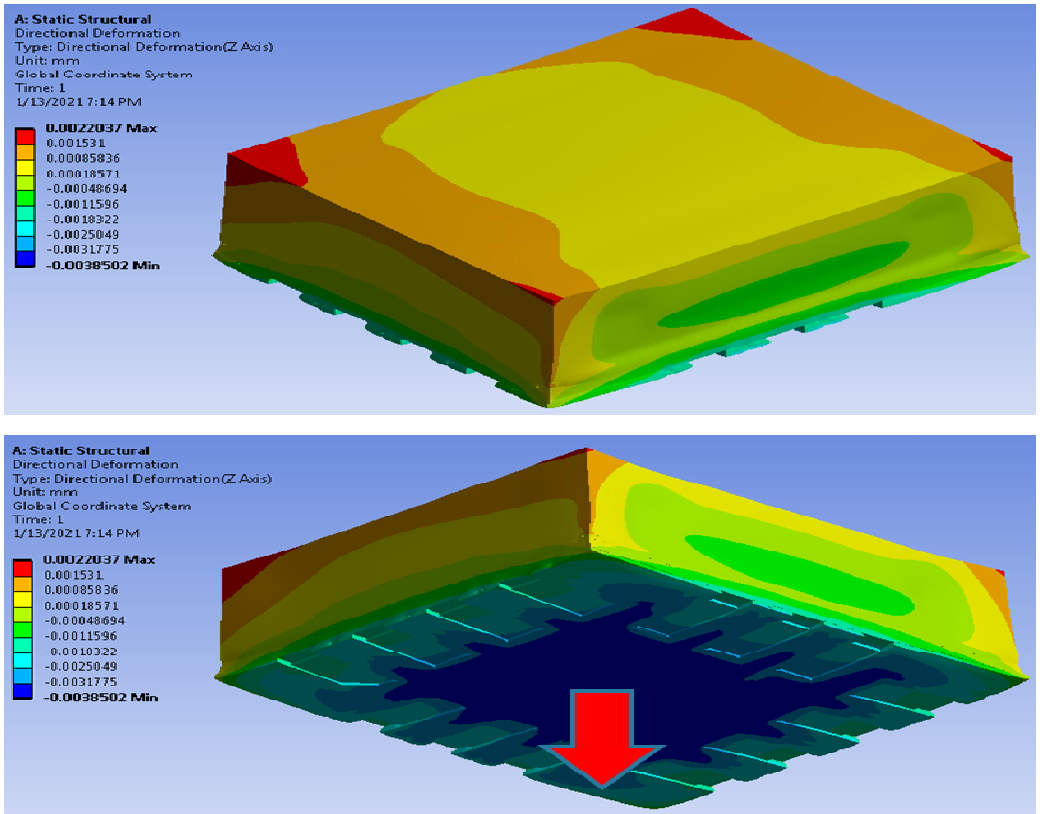

Fig. 6. Package deformation at reflow temperature condition

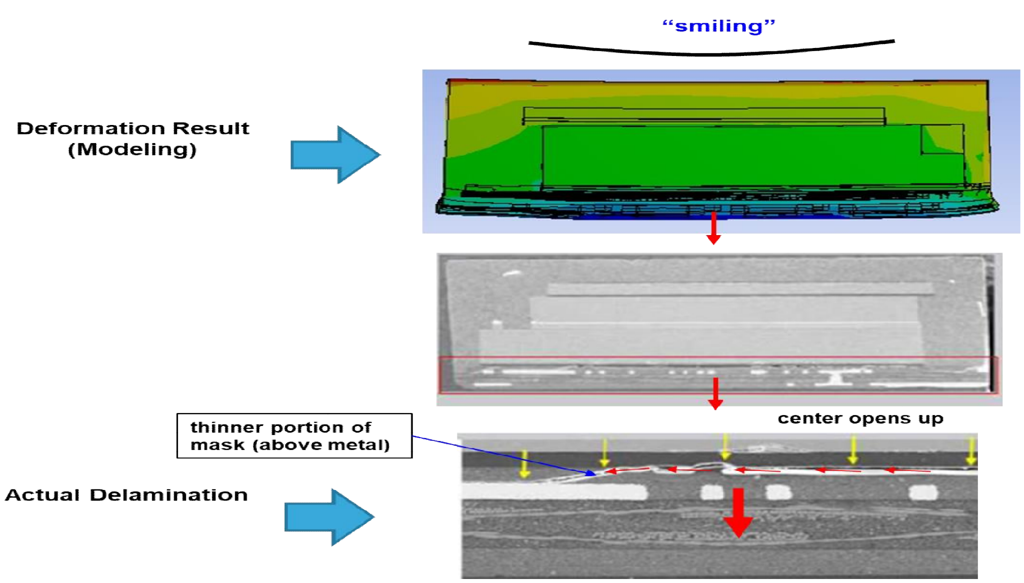

Fig. 7. Comparison of package deformation (modeling result vs actual)

4. CONCLUSION

The package deformation result from modeling was able to confirm that delamination in the specific package considered in the study occurred during reflow. Delamination happened because of weak die attach film (DAF) adhesion to the substrate. It was found out that DAF voids or gaps were present between the DAF and the substrate after die bonding. From this study, it can also be concluded that to avoid package interface delamination, good DAF adhesion to the substrate must be established. It was also shown that package deformation modeling is useful for understanding package delamination problem.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the author.

ACKNOWLEDGEMENTS

The author would like to thank STMicroelectronics management and the New Product Development & Introduction group for the support provided in this study as well as the Manufacturing Assembly group.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Tay AAO, Goh KY. A study of delamination growth in the die-attach layer of plastic IC packages under hygrothermal loading during solder reflow. IEEE Transactions on Device and Materials Reliability. 2003;3(4).
2. Lin TY, Xiong ZP, Yao YF, et al. Failure analysis of full delamination on the stacked die leaded packages. Transactions of ASME; 2003.
3. Chong CT, Leslie A, Beng LT. Investigation on the effect of copper leadframe oxidation on package delamination. IEEE Proceedings; 1995.
4. Shirangi MH, Otto C, Fischer A, et al. Advanced virtual testing of structural integrity in microelectronic assemblies. Electronic System-Integration Technology Conference (ESTC); 2010.
5. Fan XJ, Lim TB. Mechanism analysis for moisture-induced failure in IC packages. 11th Symposium on Mechanics of Surface Mount Assemblies; 1999.
6. Fan XJ, van Driel WD, Zhang GQ, Ernst LJ. Interfacial delamination mechanisms during soldering reflow with moisture preconditioning. IEEE Transactions on Components and Packaging Technologies; 2008.
7. Galloway JE, Miles BM. Moisture absorption and desorption predictions for plastic ball grid array packages. IEEE Transactions on Components and Packaging Technologies; 1997.
8. Toh CH, Mehta G, Tan HH, Ong WPL. Die attach adhesives for 3D same-sized dies stacked packages. Electronic components and technology conference; 2008.
9. Roy A. Instrumentation for studying real-time popcorn effect in surface mount packages during solder reflow. International Journal of Electronics Science and Engineering. 2013;7(8).
10. Tay AAO. Mechanics of interfacial delamination in IC packages undergoing solder reflow. Conference on High Density Microsystem Design and Packaging and Component Failure Analysis; 2005.
11. Tarr M. Reliability issues and failure mechanisms - Moisture absorption. Available:http://www.ami.ac.uk/courses/topics/;http://www.idconline.com/technical_references/

© 2021 Talledo; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/65314