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Stress Modeling Study on Package Crack Due to Debris

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Author's contribution

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

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ABSTRACT

Very thin semiconductor package is very prone to package crack. This paper discusses the stress modeling study conducted to understand the package crack problem in a specific smart card package. Finite element analysis (FEA) was used to analyze the maximum package stress level and corresponding location to find out if the presence of debris during the package assembly punching process could cause such problem and how it would happen. Based on the stress results, it was confirmed that even with a 60μm-thick piece of debris under the package, crack at the top is possible due to package bending and mold stress exceeding the flexural strength of the package mold material. The stress increases as the debris location is moved closer to the area where force is applied during the punching process. The study shows that the presence of debris should not be taken for granted though how small the debris may seem because significantly high bending stress could still be induced especially for very thin packages. Eliminating any source of debris in the package assembly process.is very important to prevent package crack.

Keywords: Package crack; debris; slug; package bending; stress modeling.

1. INTRODUCTION

Miniaturization is the current trend in the semiconductor packaging industry. A smaller and thinner IC (integrated circuit) package is required especially in applications like smart cards. However, there are reliability challenges even for thicker semiconductor packages as discussed in

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[1] and one of them is package crack that can be caused by handling, electrical test operations, shipping and surface mount technology (SMT) printed circuit board (PCB) assembly [2]. For thinner packages, crack starts to happen more easily during package manufacturing and assembly. A very thin package, as shown in Fig. 1, is more prone to damage than thicker packages.

Package crack can also be a result of delamination in a package component interface like between the leadframe and mold or resin encapsulation [3] and some problems can also be customer-attributable [4]. To help avoid problems to happen during customer assembly processes, there are manuals or guides, like the one developed by Epson [5], that provide precautions when designing systems, handling or storing devices to minimize the chance of package damage. In the current study, a package crack was encountered during the assembly of the very thin semiconductor package described. The crack was forming a straight line as shown in Fig. 2. This crack was observed in the package resin or mold material and propagated down to the encapsulated IC die.

It is very important to understand the causes of encapsulation crack for such package and confirm if the debris could possibly induce such problem. Though stress modeling using finite element analysis (FEA) has been used to study package reliability issues [6-8], their focus is on the solder joint crack and not package crack being considered in the current study. It is therefore the goal of this study to use stress modeling to understand the crack problem encountered.

2. STRESS MODELING USING FINITE ELEMENT ANALYSIS (FEA)

Stress modeling was conducted using finite element analysis to assess the possibility of package crack induced when a piece of debris or slug is under the package acting as a fulcrum at lead frame punching station. The package analyzed has a total thickness of 0.25 mm, which is already considered very thin. The resin area is approximately 5.1 mm x 4.8 mm. The finite element analysis (FEA) was implemented in ANSYS software. Before doing the stress modeling with debris, a baseline model was first created and validated with actual results from a 3-point bend test. The 3-point bend test setup and the baseline FEA model are shown in Fig 3. A 2D simplified model was created instead of a 3D model to analyze different “what-if” scenarios and obtain results faster.

After the 3-point bend test baseline modeling, package stress modeling considering a piece of debris was then conducted. The analysis would provide an idea on the stress level and location of the stress in a situation where such piece of debris is present under the thin package while force from the top side is applied as shown in Fig. 4. The element size set for the finite element mesh was the same as that in the baseline model to eliminate or minimize the impact of mesh size on the stress results. The modeling was using linear elastic material properties and a 2D plain strain element in ANSYS.

As shown in the FEA model, one end of the leadframe is fixed to simulate the clamping during the punching process and a displacement is applied to the other end for the punching. The 60μm-thick slug or debris is fixed for each location analyzed. There are 3 locations considered: (1) 1.0 mm from the package center; (2) 1.5 mm from the package center; and (3) 2.0 mm from the package center. The stress results were then compared with the flexural strength of the resin material.

3. RESULTS AND DISCUSSION

The result from the actual 3-point bend test (Fig. 5) shows that the package breaks at an average force equal to 9.1 N. The mold resin crack is close to a straight line as shown and occurs at the high stress region indicated in the FEA stress modeling result. Modeling result also reveals that the 160 MPa stress is induced when a force equal to 9.0 N is applied. This force is very close to the average breaking load obtained from the actual 3-point bend test validating the finite element model. The modeling is in good agreement with actual data and that the mold resin breaks when the stress reaches 160 MPa (mold flexural strength).

For the stress modeling with debris, the result (Fig. 6) shows that having a 60μm-thick debris or slug under the package causes package bending during the leadframe punching process. The maximum package resin mold stress is located at the package top side near the location of the piece of debris. At 1.0 mm slug distance from package center, the package stress already exceeds the flexural strength of the resin material. Package crack happens when mold stress exceeds its flexural strength. This flexural or bending stress due to debris could explain the straight-line package crack encountered in this study (Fig. 2).

As indicated in Fig. 7, stress further increases as the slug distance from the package center increases. It shows that even a small increase in the distance translates into a very significant increase in the bending stress. At 2.0 mm slug distance, the package mold stress is already more than 4 times the flexural strength of the mold material, which is 160 MPa. The stress modeling result shows how the package crack happens due to debris present during leadframe punching process. This observation would also be applicable to other package assembly processes where there is some debris or solid material that could cause package bending when force is applied.

Knowing from stress modeling that the package crack seen could be produced by the presence of debris or slug underneath the package, proper cleaning and elimination of possible sources of debris or slug would be needed during package assembly. It is shown from the results that even a small debris present could already create significant amount of stress enough to produce package crack. Anything that could create package bending resulting in high level of package bending stress should be avoided.

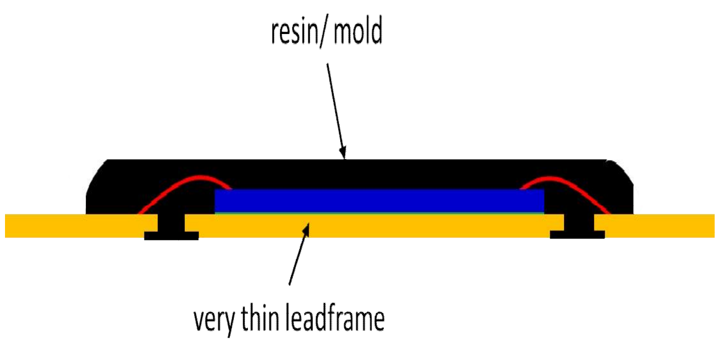

Fig. 1. Very thin smart card semiconductor package

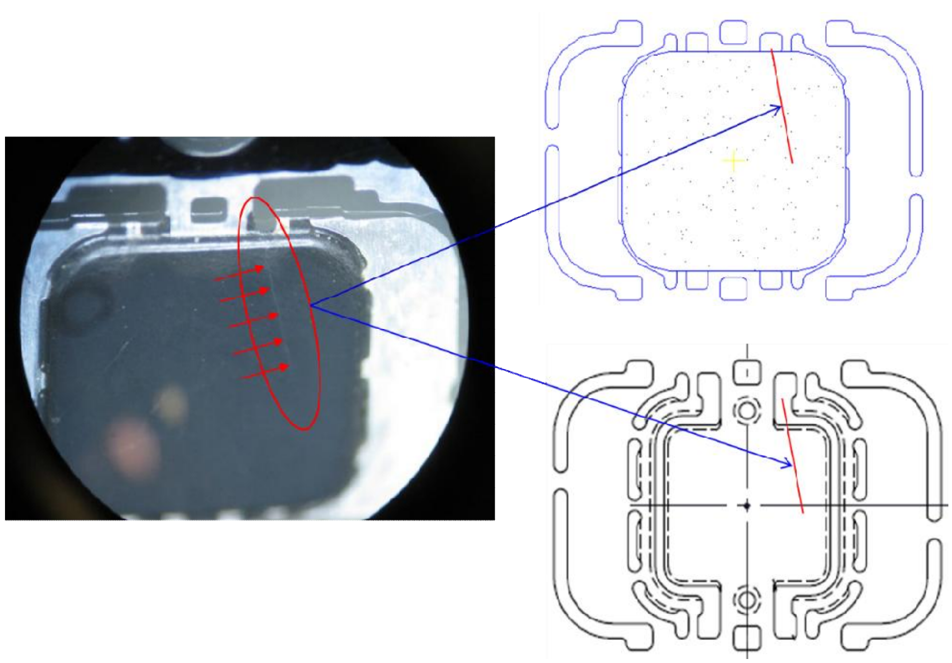

Fig. 2. Package crack forming a straight line

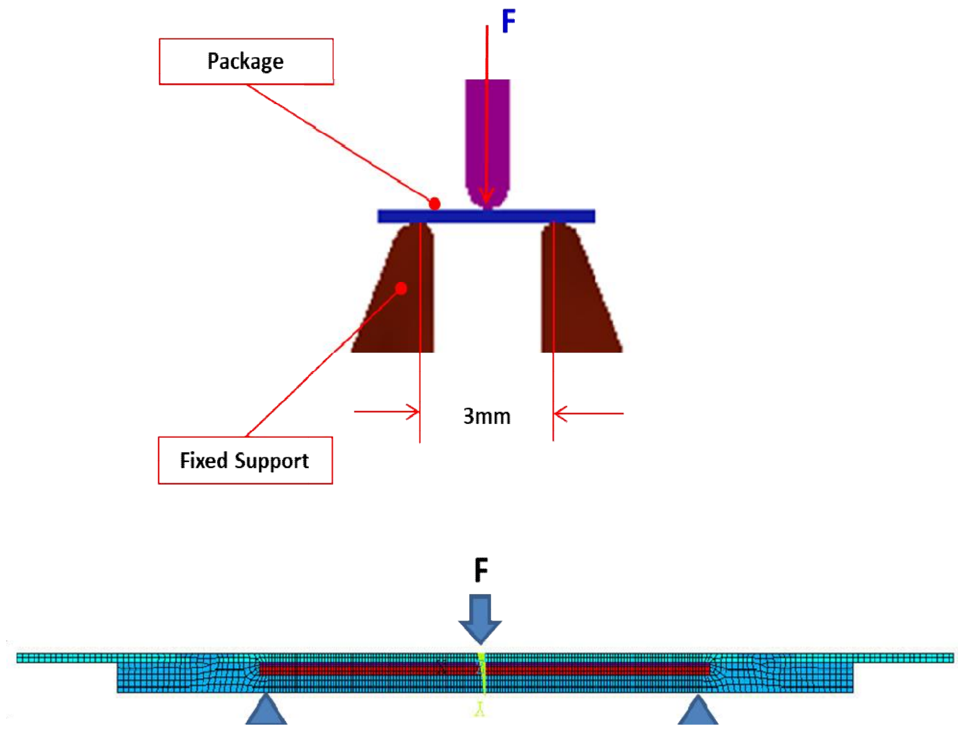

Fig. 3. 3-point bend test setup and FEA model

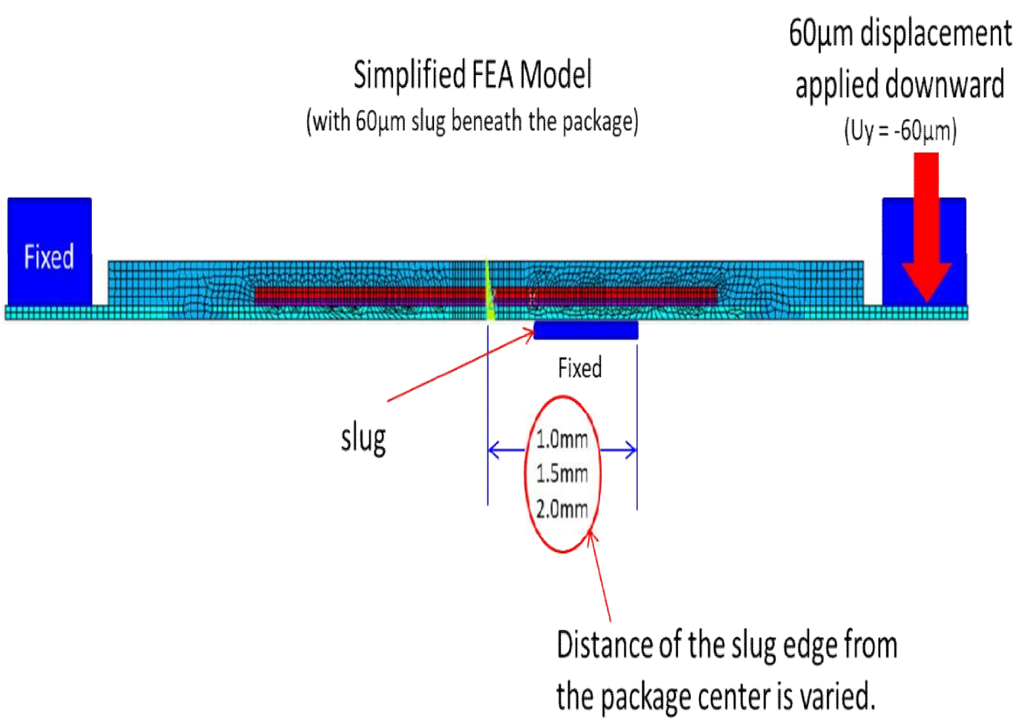

Fig. 4. FEA model of the thin package with a piece of debris or slug underneath

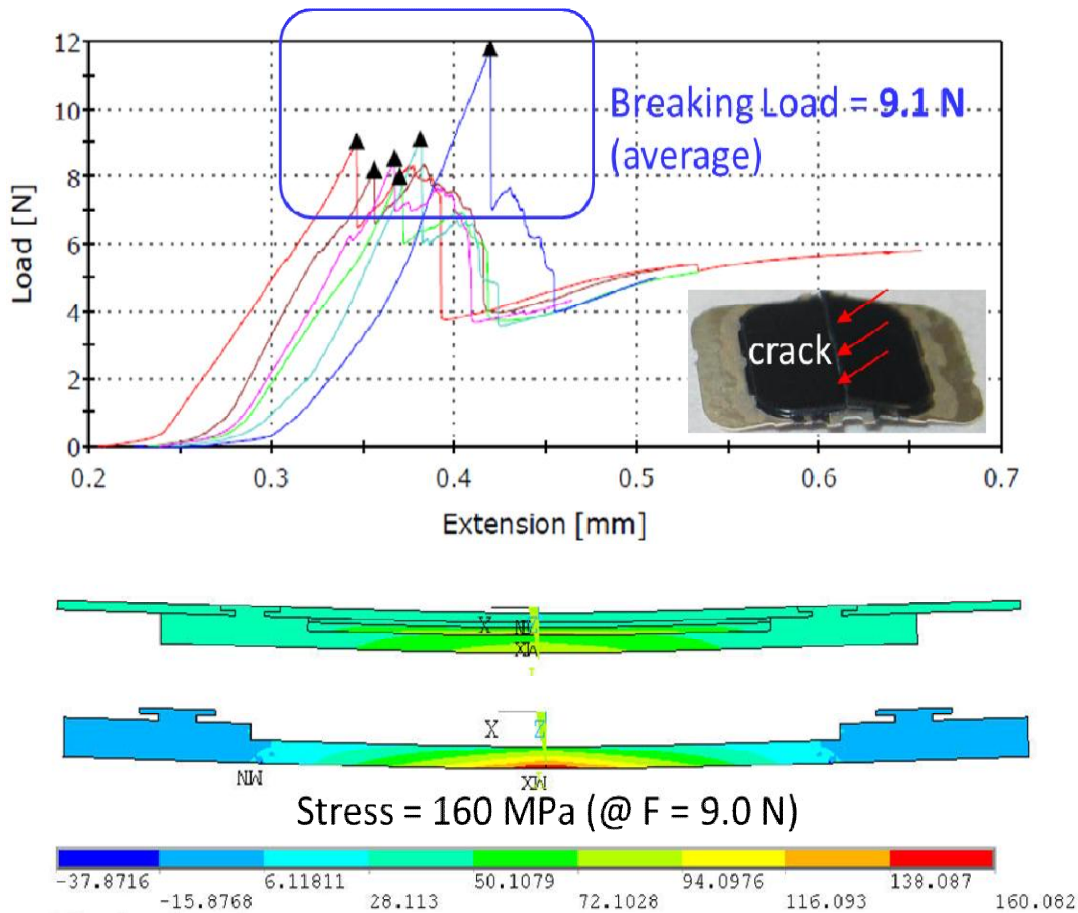

Fig. 5. Actual 3-point bend test result and the package stress modeling result

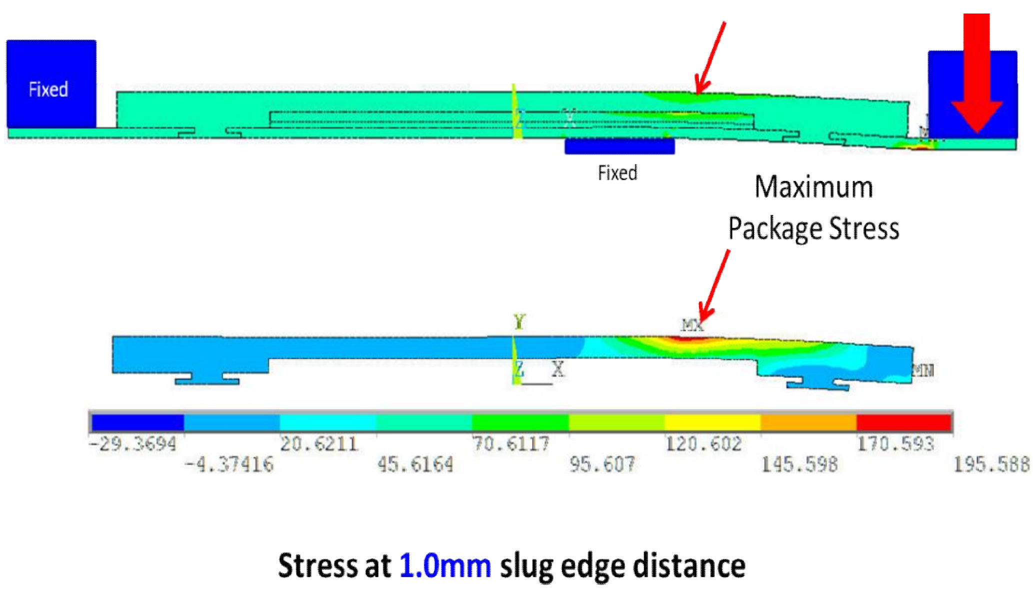

Fig. 6. Package stress result showing maximum stress location

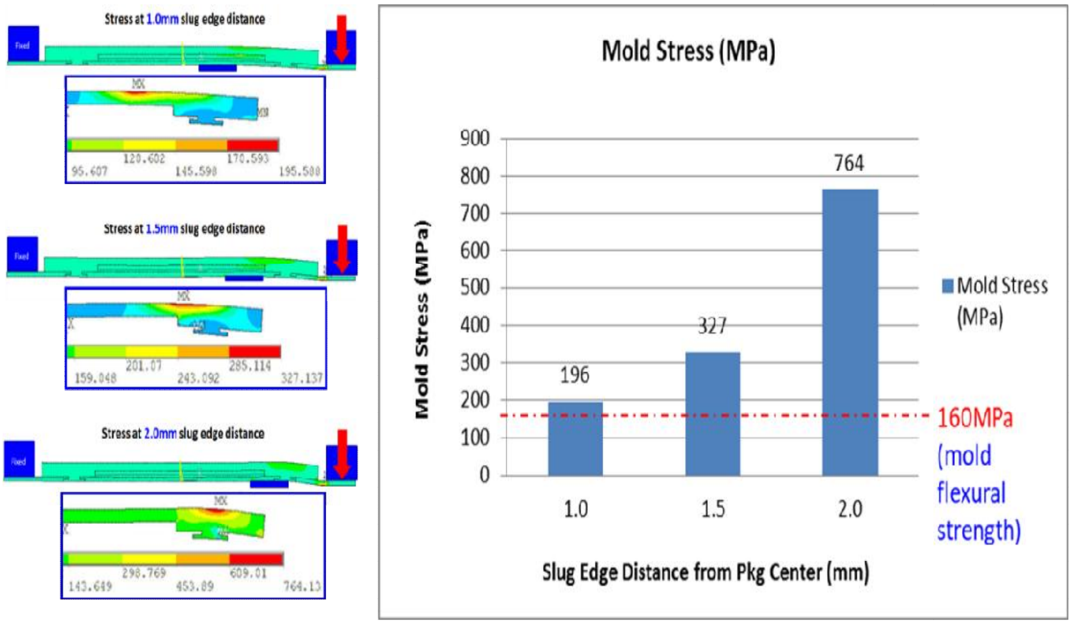

Fig. 7. Package or mold stress at different distances of the slug from the package center

4. CONCLUSION

Stress modeling results confirmed that the presence of debris under the semiconductor package during the punching assembly process could cause the package crack problem especially for very thin semiconductor package. There is also a higher chance of package crack as the debris location is moved closer to the punch location or the area where force is applied to the leadframe portion of the package. Cleaning and elimination of all possible sources of debris during the package assembly processes is very important to avoid package crack. The study demonstrates the usefulness of stress modeling in analyzing package failures. Further testing with actual debris intentionally placed under the package would be beneficial for future study.

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 authors.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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