



# Study of the Impact of Curing Condition on Flexural Strength of a Very Thin Semiconductor Package

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## Author's contribution

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

## Article Information

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## ABSTRACT

Thinner semiconductor package is becoming popular especially in consumer electronics applications. As package becomes thinner, it is more vulnerable to package crack when subjected to external load. It is important to ensure that the package is strong enough to resist package cracking. This paper presents the study of package flexural strength under different epoxy mold compound curing condition. A 3-point bend test was done to characterize the breaking strength of the package that was subjected to post-mold curing. It was then compared to the strength of the package not subjected to post-mold curing (PMC). Results of the bend testing showed that the package flexural strength is much lower when the package is not subjected to post-mold curing. This study demonstrates that the measurement of flexural strength can be used to determine if the package has undergone post-mold curing or not. Performing the right post-mold curing of the thin molded package is required to ensure higher flexural strength.

*Keywords:* Flexural strength; curing condition; thin package; package crack; 3-point bend test.

## 1. INTRODUCTION

There is a growing demand for smaller and thinner semiconductor packages. Thinner

packages are commonly required in electronics applications like smart card. Even with thicker packages like Quad Flat No Lead (QFN), there are already reliability challenges [1] and one of

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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]. When a package gets thinner, the risk of having crack increases during package manufacturing and assembly. Package crack happens when the stress in the package encapsulation or molding compound reaches its flexural strength. Compared with a thicker package, a very thin package (Fig. 1) is more prone to damage when an external force is applied during package assembly or in actual use. Higher stress is induced in a very thin package even with a small amount of bending force that would then result in package crack (Fig. 2).

Aside from the external force, package crack can also be a result of delamination in a package component interface such as between the leadframe and mold or resin encapsulation [3] and some problems can also be customer-attributable [4]. To help avoid problems during customer assembly processes, there are manuals or guides, such as the one developed by Epson [5], that provide precautions when designing systems, handling or storing devices to minimize the chance of package damage.

A package molding compound material with higher flexural strength is necessary for reducing the risk of package crack. Flexural strength is dependent on the type of material. For instance, different molding compound materials have different flexural strength. Some types of molding materials are stronger. There are factors that

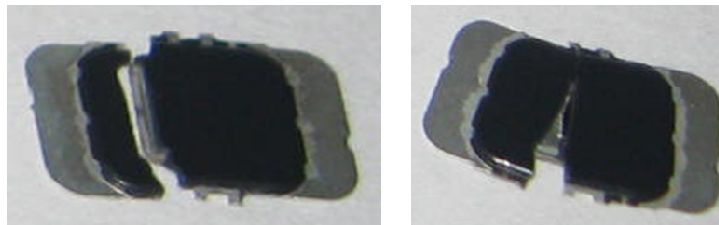
affect the properties of epoxy molding compounds. Post-mold curing contributes to the electrical and mechanical properties of molding materials and affects how those properties change with thermal and humidity environments [6]. Filler configuration and moisture can have effects on dissipation factor [7] and even the filler silica particle size also affects the properties of molding compound materials [8].

During molding, epoxy resin is liquefied by high temperature and high pressure and forced through a mold chase over the die and leadframe [9]. The epoxy resin has well-balanced physical and chemical properties (high adhesion strength, chemical strength, thermal resistance and moisture resistance, low viscosity and shrinkage ratio), low cost and good aesthetic properties [10]. The cross-link density of molding-compound molecular chains increases as time increases during molding and post-mold curing [11]. Longer thermal treatment after curing leads in general to further cross-linking of the polymer chains [12].

In this study, the impact of post-mold curing condition on the flexural strength of a very thin package was investigated. This was done to check if skipping the standard post-mold curing for this very thin package would not significantly affect its flexural strength since cross-linking already starts to occur during molding even before the post-mold curing. Thus, an increase in package assembly production output and cost reduction could be achieved when post-mold curing process is eliminated.



**Fig. 1. Very thin smart card semiconductor package**



**Fig. 2. Broken package after being subjected to bending**

## 2. METHODOLOGY

The very thin package considered in this study has a total thickness of 0.25 mm and the resin area is approximately 5.1 mm x 4.8 mm. This package has a silicon die attached to the thin leadframe using die attach adhesive and encapsulated with an epoxy molding compound. There were two sets of package samples tested. The first set of samples (with PMC) was subjected to the standard post-mold curing condition used in package assembly production. The standard PMC process was done at 175°C with 4-8 hours curing time recommended by the material supplier. The second set of package samples (no PMC) was not subjected to the standard post-mold curing process. However, it was molded using the same molding process and parameters as the first set of samples. The only difference was that the PMC process was skipped for the second set.

The package breaking load testing was done using a 3-point bend test setup as shown in Fig. 3. This setup was implemented in an Instron MicroTester equipment that has a load cell that measures the amount of bending force applied. The distance between the fixed anvil supports or the span was set at 3 mm. The package sample was oriented such that the molding compound encapsulation is facing downward as shown. Force was applied at the center of the package

and the maximum force was recorded. The breaking force was considered as the force where a first load drop could be seen in the load-displacement curve.

The package breaking load results were then analyzed using Minitab statistical software to compare the breaking load of the samples subjected to post-mold curing (with PMC) and those samples that were not undergoing post-mold curing (no PMC).

## 3. RESULTS AND DISCUSSION

The load-displacement curve results from the first set of package samples (with PMC) are shown in Fig. 4. As the load or force applied increases, a load drop could be seen. This drop in the recorded load implies that the package breaking point is reached. Another load drop could also be observed after the first load drop. This could be the indication of the breaking of the silicon die within the package. This load-displacement curve is expected since the package has different component materials such as the integrated circuit (IC) silicon die, the die attach glue, the leadframe and the molding compound that encapsulates the whole package. The silicon die would not break at the same time as the molding compound. Thus, different load drops could be seen as each component breaks under bending load.

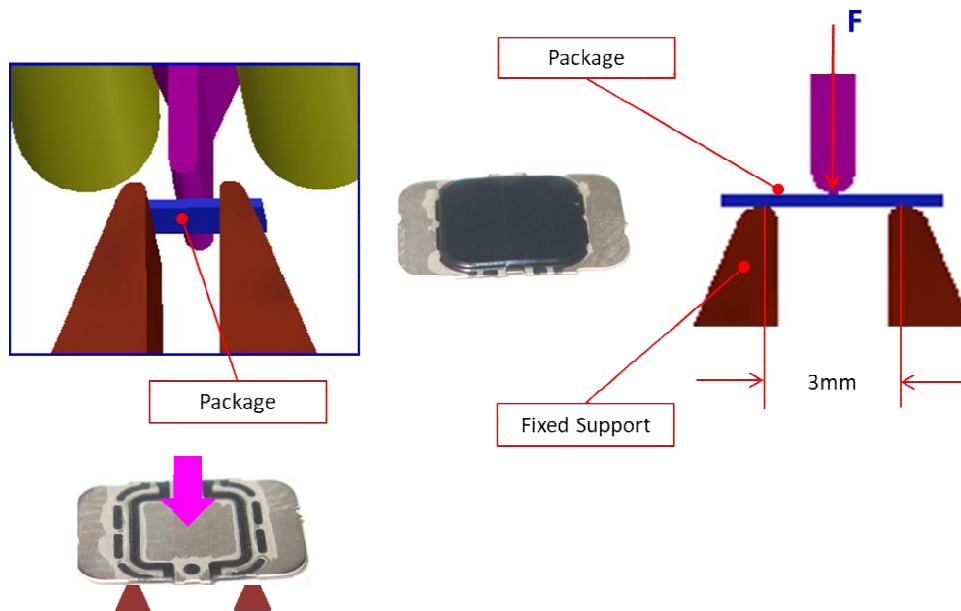
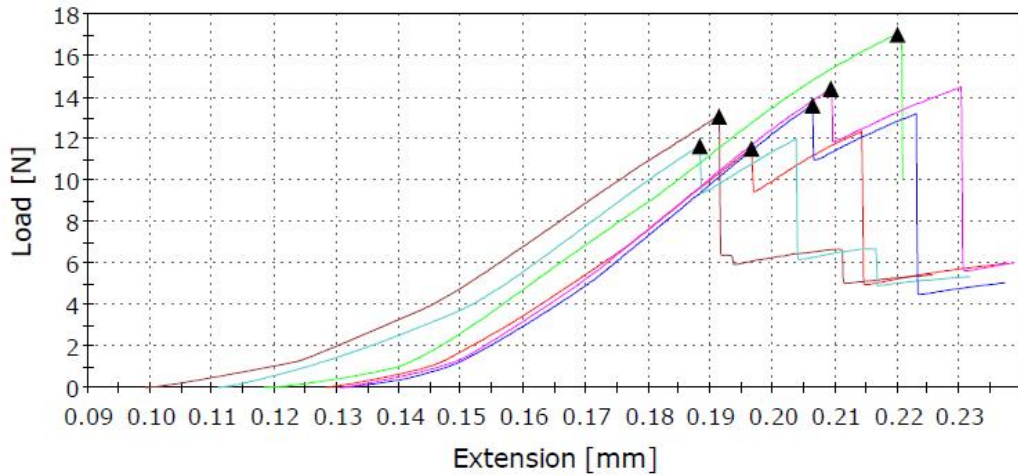


Fig. 3. Package 3-point bend test setup

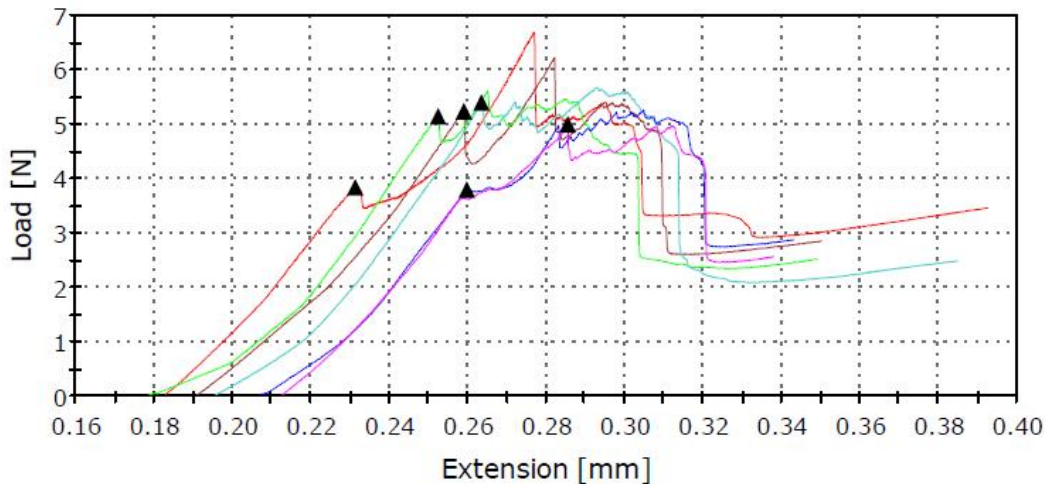


**Fig. 4. Load-displacement curve for package with post-mold curing (with PMC)**

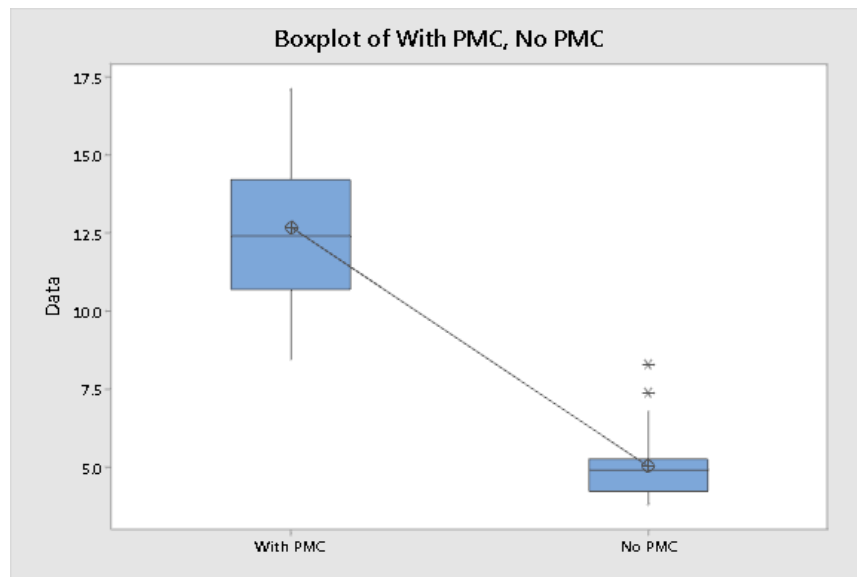
For the second set of package samples (no PMC), the load-displacement curve results are shown in Fig. 5. It is obvious that the package breaking load is lower compared to the breaking load of the first set of samples (with PMC). The first load drop signifying package crack could be seen at a much lower force. This shows that the package without post-mold curing is weaker and could not resist higher applied loads.

Further comparison using a box plot is shown in Fig. 6. A significant difference exists for the package breaking load of the two sets of samples tested. For the first set of samples (with PMC), the package breaking load has an average value of 12.7 N. On the other hand, the

average package breaking load for the second set of samples (no PMC) is only 5.0 N. This clearly reveals that the package subjected to post-mold curing (with PMC) is stronger. The post-mold curing has improved the flexural strength of the package. This observation enables agreement with the results in a previous study [13] that longer mold cure time results in an improved bending strength. Post-mold curing contributes to the realization of improved mechanical properties due to better crosslinking of the epoxy-resin network. The results showed that standard post-mold curing should not be skipped even for very thin packages. Without post-mold curing, there is significant reduction in the flexural strength of the package.



**Fig. 5. Load-displacement curve for package without post-mold curing (no PMC)**



**Fig. 6. Boxplot of the package breaking load comparison (with PMC vs no PMC)**

#### 4. CONCLUSION

Package bending test done on a very thin semiconductor package revealed that post-mold curing could not be skipped during package assembly manufacturing. Results showed that flexural strength is significantly lower when the package is not subjected to the standard post-mold curing. It can be concluded that post-mold curing is necessary to ensure higher package breaking load. With higher breaking load, the package would be stronger in resisting package crack due to different loads or package stresses. Flexural strength measurement can also be used as a method to determine if the package has undergone post-mold curing or not.

#### DISCLAIMER

The products used for this research are common and predominantly used in our area of research and country. There is no conflict of interest between the authors and producers of the products because there is no intent to use these products as an avenue for any litigation but just 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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