



# Mechanical Modeling Study on the Impact of Pick-and-Place Design on Die Attach Voids

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## **Author's contribution**

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

## **Article Information**

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## **ABSTRACT**

Pick-and-place (PnP) rubber tip is used for the die attach process in semiconductor packaging. During the die attach process involving a very thin integrated circuit (IC) die, voids in the die attach film (DAF) adhesive were observed. This paper presents the modeling study conducted to understand the impact of PnP rubber tip design on the occurrence of DAF voids. Mechanical modeling was done to simulate the deformation of the very thin die when it is picked using the PnP rubber tip. Different PnP rubber tip designs were modeled. The results revealed that the die deforms during the die pick up process because of the vacuum force, and rubber tip design affects the amount of deformation. It was also found out that more DAF voids occur when the resulting die deformation is larger.

*Keywords: Die attach film (DAF); die attach voids; pick-and-place; rubber tip; mechanical modeling.*

## **1. INTRODUCTION**

With thinner IC (integrated circuit) packages, the use of very thin die has become necessary during package assembly. Die attach film (DAF) adhesive is commonly used to bond thin IC

silicon die onto the laminate substrate or lead frame instead of the conventional die attach glue. DAF has found popularity as a replacement for the liquid-based die attach glue because of adhesive overflow or insufficient glue coverage when used with thin dies. DAF has no such

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overflow or insufficient coverage problem. It can also provide more uniform bond line thickness and eliminate the issue of die tilting during die bonding.

However, DAF still has some problems and one of them is DAF voids. It was shown that the void issue is caused by insufficient gap filling and thermal history play an important role in gap filling capability. DAF with short thermal history has super gap filling capability [1]. In another study [2], it was found out that the DAF voids occur at substrate/film interface with fixed location and similar pattern. They can be reduced significantly by enhancement of transfer pressure during molding process, which can be explained that gap on substrate surface is filled furthest by film under high transfer pressure. Die attach parameters including bonding temperature, force and time also have an impact on die attach adhesion and reliability performance [3,4].

Die attach voids affect the package reliability and device performance. Voids in the bond line can cause failures in reliability testing for almost any adhesive [5]. For instance, it was shown that thermal resistance increases linearly with void

percentage for random voids but increases exponentially for contiguous voids [6]. Thermal resistance is also impacted by the adhesive thickness, attachment pressure as well as incomplete contact [7]. Another problem, delamination could be a consequence of die attach film void growth [8] but some causes are also common like contamination [9]. Though delamination could be addressed by the use of roughening processes in the case of lead frame surfaces for enhancing adhesion strength [10], eliminating the problem with die attach voids is very important to avoid reliability issues like delamination or increase in thermal resistance.

In the current study, the impact of the pick-and-place (PnP) rubber tip design on DAF voids was investigated. The PnP rubber tip with vacuum suction is used to pick and bond the die onto a substrate or lead frame. This was taken into consideration because of the initial observation that different PnP designs appeared to have different DAF void performance response. This is different from the previous studies discussed [1-4], which are focusing on the impact of process parameters and conditions. Fig. 1 shows some images of DAF voids encountered in this study.

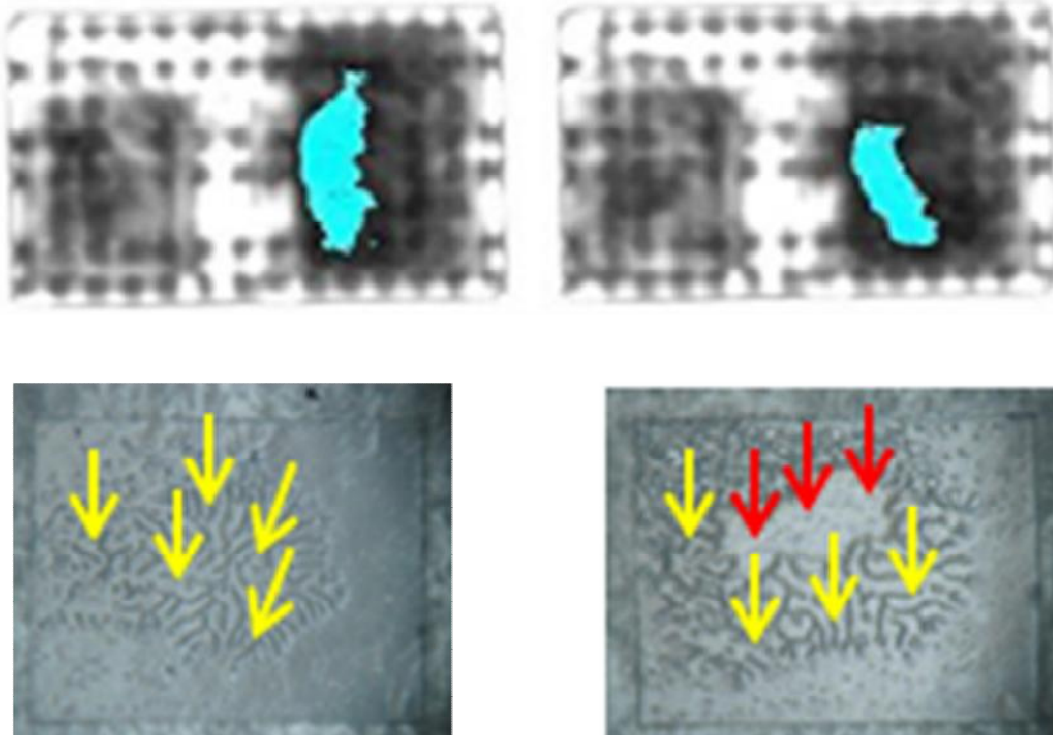


Fig. 1. Die attach film (DAF) void

## 2. MECHANICAL MODELING OF THE DIE DEFORMATION

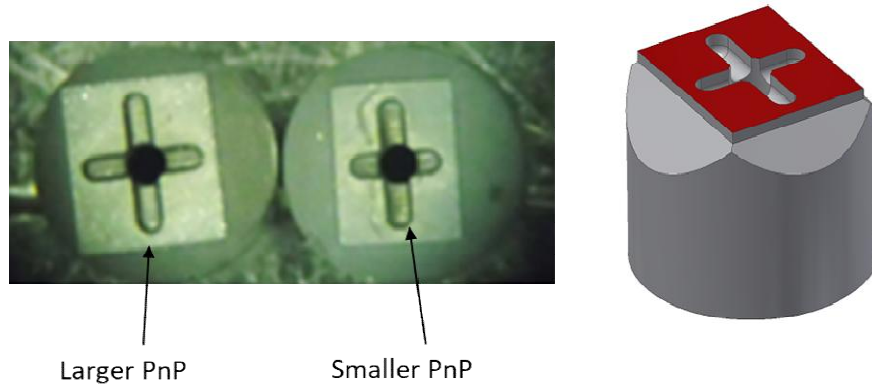
To understand the impact of PnP rubber tip design on die attach film (DAF) voids, mechanical modeling of the die deformation was done. Mechanical modeling has been used to analyze designs in terms of stress and deformation response under an applied force. Designs could be optimized before manufacturing the actual product. In the first set of mechanical modeling, the PnP designs shown in Fig. 2 were analyzed using finite element analysis (FEA) performed with ANSYS software. Table 1 shows the dimensions of the PnP rubber tip contact surface. Design A has a larger PnP rubber tip compared to Design B.

A finite element model for the die deformation mechanical modeling was created and

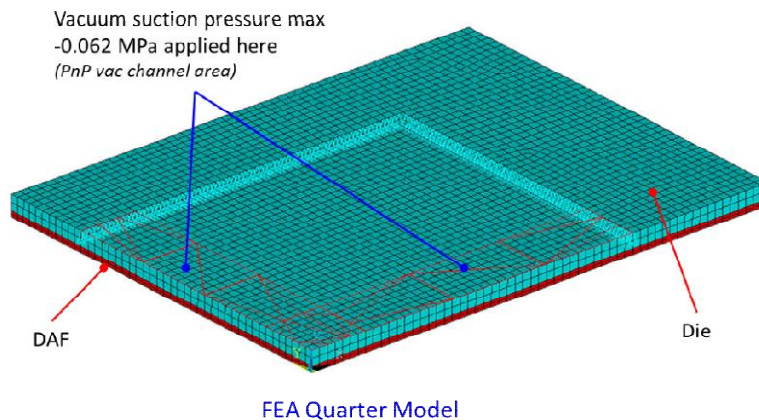
shown in Fig. 3. The model includes the DAF material and the silicon die. The size of the die is 3.412 mm x 2.604 mm with a thickness of 50 microns, which is already considered very thin. The DAF material has a thickness of 20 microns. A negative pressure was applied to the top region corresponding to the vacuum channel area to simulate the vacuum suction during die pick and bonding to the substrate or lead frame. A similar analysis was also done on a new PnP rubber tip design with distributed vacuum suction in the second set of mechanical modeling.

**Table 1. PnP designs**

PnP design	Contact surface dimension
Design A (larger)	2.45 x 2.9 mm
Design B (smaller)	2.0 x 2.72 mm



**Fig. 2. Pick-and-place rubber tip with cross designs**



**Fig. 3. Finite element model of the thin silicon die with DAF**

### 3. RESULTS AND DISCUSSION

The mechanical modeling result in Fig. 4 shows that the maximum die deflection or deformation occurs at the die center due to the suction force of the PnP rubber tip. The thin die deforms in such a way that it produces a concave surface of the DAF facing downward. So when the die is bonded to the substrate, the center of the DAF area would have some trapped air resulting in DAF voids as the perimeter of the DAF material is already in contact with the substrate restricting the escape of air from center area. This could explain the DAF voids observed as shown in Fig. 1.

For the smaller PnP (Design B), the silicon die deflection shape is the same with that of the larger PnP (Design A) but the magnitude is lower as indicated in Fig. 5. Comparison of the results

is shown in Fig. 6. Die deformation results correlate with actual DAF voids observed in this study as summarized in Table 2. The larger the die deformation, the more DAF voids were observed. The DAF voids were also larger with PnP design A.

For the new PnP rubber tip design with distributed vacuum suction, comparison of the results is shown in Fig. 7 for the different rubber tip design sizes (Design C, Design D, Design E). The die deformation is generally lower even with different rubber tip sizes compared to the results of the cross-design in Fig. 6. The new PnP rubber tip design minimizes the thin die deformation even at the same vacuum suction level applied. This also minimizes the formation of DAF voids during the die attach process. The new design is now used in the package assembly process and shows good performance.

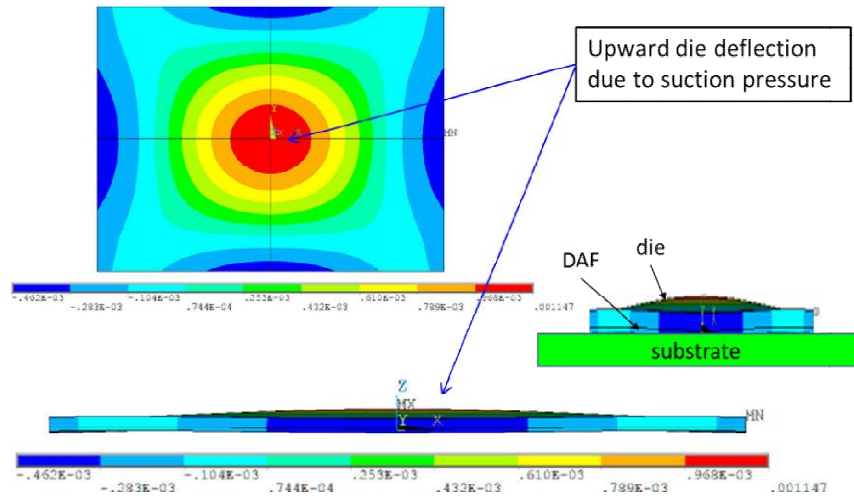


Fig. 4. Deflection result with the larger pick-and-place (PnP), design A

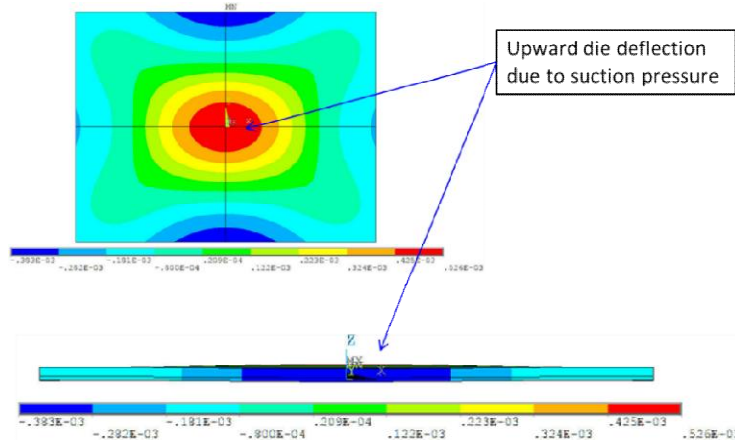


Fig. 5. Deflection result with the smaller pick-and-place (PnP), design B

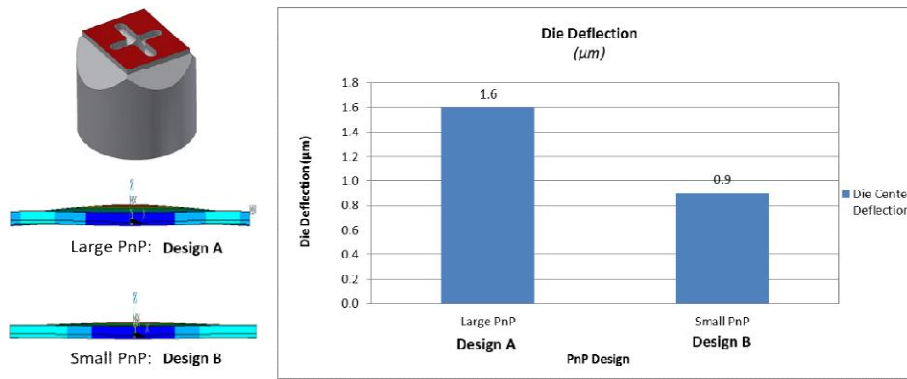


Fig. 6. Die deflection comparison (large PnP vs small PnP)

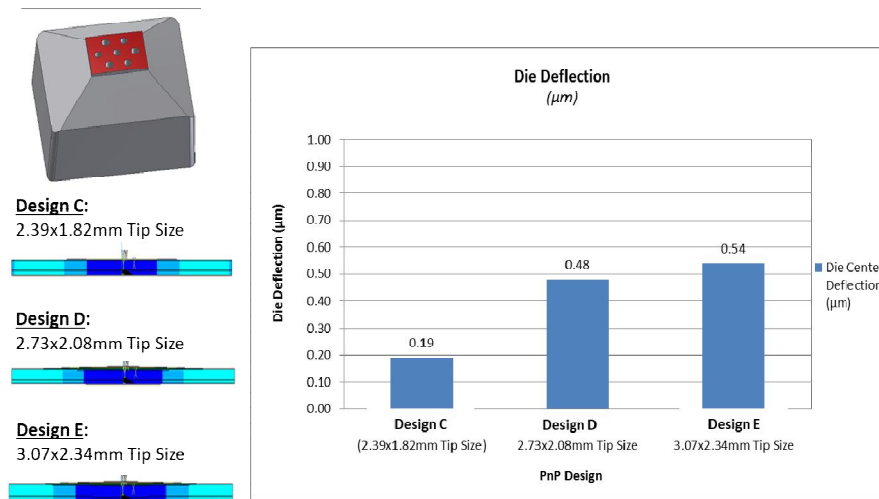


Fig. 7. Die deflection using distributed-vacuum designs

Table 2. Actual DAF voids observation

PnP design	Die deformation due to vacuum suction	Actual DAF voids
Design A (larger)	Larger	More, larger
Design B (smaller)	Smaller	Less, smaller

#### 4. CONCLUSION

Thin silicon die deforms during the die pick-up process because of the vacuum or suction force. The design of the pick-and-place (PnP) rubber tip has shown significant impact on the occurrence of die attach film (DAF) voids during semiconductor package assembly process. More voids are expected when there is larger die deformation especially when working with thin dies. The design of the PnP rubber must ensure minimal die deformation to reduce or eliminate occurrence of DAF voids. Thus, the distributed-vacuum PnP design considered in this study is a

good solution to eliminate die attach voids as it enables minimal die deformation even in the presence of vacuum force.

#### 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



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## COMPETING INTERESTS

Author has declared that no competing interests exist.

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