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Comparison of Silicon Die Strength Using Different Loading Anvil Shapes

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Author's contribution

The author JT performed the actual experimental testing in this study and also read and reviewed the final manuscript.

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Short Research Article

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ABSTRACT

Die fracture strength measurement is important to assess the robustness of a specific silicon die such that it is strong enough to resist die crack. There are several methods used to measure the strength of silicon die and 3-point bend test is the most common. However, the impact of the loading anvil shape on die strength results needs to be investigated. This paper discusses the comparison of die strength characterization using different loading anvil shapes in a 3-point bend test. The anvil shapes considered were wedge shape and needle shape. Die strength calculations were all done using the standard 3-point bend formula for flexural stress. Statistical analysis of the results revealed that die strength measured using wedge shape loading anvil is not significantly different from the strength measured using the needle shape loading anvil. Therefore, using the needle shape loading anvil in a 3-point bend test could still provide die strength results comparable with the results using the standard wedge shape loading anvil.

Keywords: Die strength; die fracture strength; die crack; 3-point bend test; loading anvil; wedge shape; needle shape.

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1. INTRODUCTION

Silicon die crack is one of the common problems in a semiconductor package for integrated circuits (ICs). When a die crack happens, the circuits will be damaged and make the electronic device non-functional. The strength of the silicon die must be high enough to have a robust semiconductor package with high yield and good reliability. With silicon die being a brittle material, die crack occurs when the die is subjected to a stress that is equal or higher than its fracture strength. Semiconductor package assembly process like die mounting (die attach) can cause die crack [1]. Silicon die wafer handling and sawing can also induce significant stress for die crack to occur. High thermomechanical stresses due to coefficient of thermal expansion (CTE) mismatch of the package component materials can also lead to die crack.

The characterization of die strength can be done to study the effects of surface damage due to processes like back grinding, polishing, and singulation processes [2-7]. One of the methods used to measure die strength is 3-point bend test [8-10]. A 4-point bend test could also be used [11] and there is even a new method called ball-on-ring microforce test [12]. Of all the methods used for die strength characterization, the 3-point bend test is the most popular method and commonly used in the semiconductor industry. In the 3-pint bend test, the upper loading anvil usually has a wedge shape. However, in actual package assembly manufacturing process, the loading could come from an ejector needle used during die bond process. Using a wedge shape loading anvil, issue on parallelism or alignment between the anvils could also affect the results.

In this study, the use of a loading anvil having a needle shape in a 3-point bend test setup was explored and the results were compared with those obtained by using the standard wedge shape loading anvil. From this, we would see if the needle shape loading anvil could be used as another alternative in the 3-point bend test for die strength characterization.

2. DIE FRACTURE STRENGTH CHARACTERIZATION

In this study, die fracture strength characterization was done using a 3-point bend fixture compliant to the international standard SEMI G86-0303 for measurement of die strength [10]. The Instron MicroTester 3-point bend test setup and testing procedure were based on that SEMI standard.

2.1 Testing Equipment and Setup

The Instron MicroTester equipment used in the experimental investigation has a load cell that measures the amount of force applied to the specimen in a 3-point bend setup as illustrated in Fig. 1. The silicon die is supported at the bottom by 2 stationary anvils and force is applied from the top with the movable upper anvil or the loading anvil.

The Instron MicroTester measures the maximum load before the die breaks and the die strength is then calculated using the following equation:

$$\sigma = \frac{3FL}{2bh^2} \quad (1)$$

where,

σ = die fracture strength
F = die breaking force (maximum load before breaking)
L = span or distance between supports
b = die width (parallel to the support axes)
h = die thickness

The silicon die used in this study was having a thickness of 70 microns with 6 mm width and 22 mm length. For the measurement of the silicon die strength, the same setup was used with both the wedge shape loading anvil and the needle shape loading anvil. The distance between anvil supports in the test setup was 3.0 mm. The loading anvil speed was set at 3 mm/min to ensure dynamic effects were eliminated. During the actual experimental testing, the maximum force was recorded, and the die fracture strength was calculated according to equation (1).

2.2 Different Loading Anvil Shapes

There were two loading anvil shapes used in the 3-point bend test in this study. The first loading anvil shape is shown in Fig. 2. It is the wedge shape commonly used for 3-point bend test setup. This wedge shape loading anvil has a 0.3 mm radius. Proper alignment of the loading and the support anvils is necessary to ensure correct die strength results. The second loading anvil used is shown in Fig. 3. It has a needle shape and is basically a die ejector pin used during the actual die bond process. The needle tip radius is 0.1 mm.

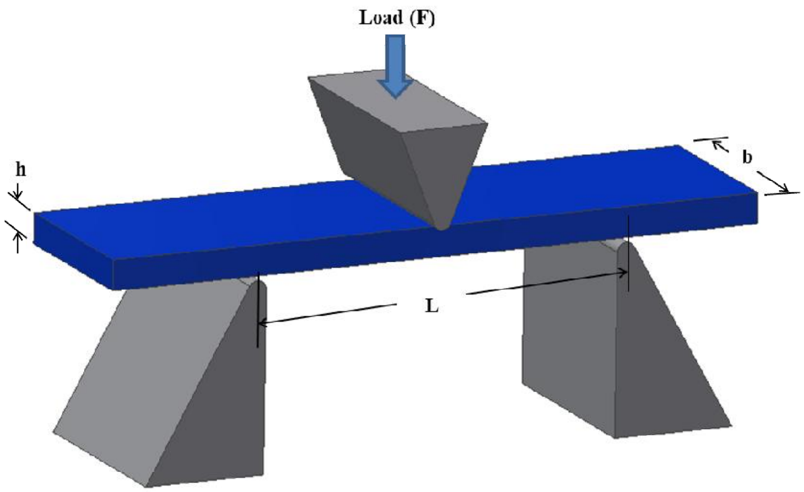

Fig. 1. Schematic of the 3-point bend setup

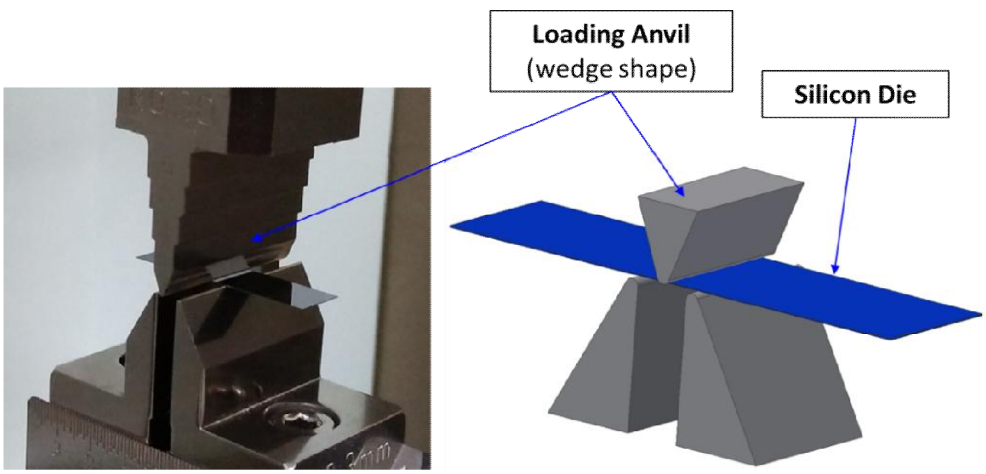

Fig. 2. Loading anvil with wedge shape

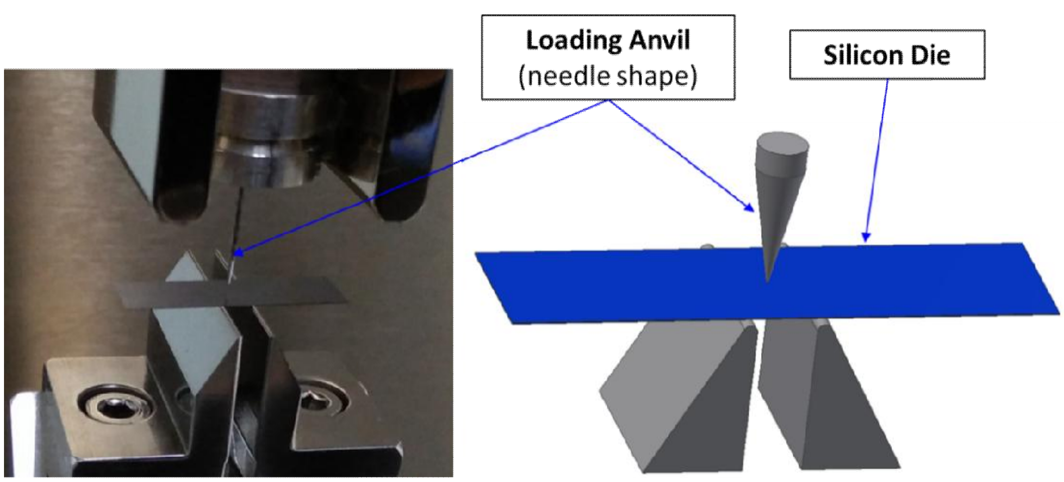

Fig. 3. Loading anvil with needle shape

3. RESULTS AND DISCUSSION

The load-deflection curves for the die breaking load results from the 3-point bend test using the wedge shape loading anvil is shown in Fig. 4. The load is linearly proportional to the silicon die deflection. The maximum load is force at which the die breaks and then a load drop could be observed. For the loading anvil with needle shape, similar load-displacement curve could be observed as indicated in Fig. 5.

The actual deformation of the silicon die when using the needle shape loading anvil is shown in Fig. 6. This is similar to the deformation using the wedge shape loading anvil. Generally, the die breaks along the die bending axis parallel to the axis of the two anvil supports. In this specific 3-point bend setup, the use of the needle shape loading anvil did not change the die breaking path or direction. This would be the kind of bending experienced in actual die bond process especially using the single die ejector design.

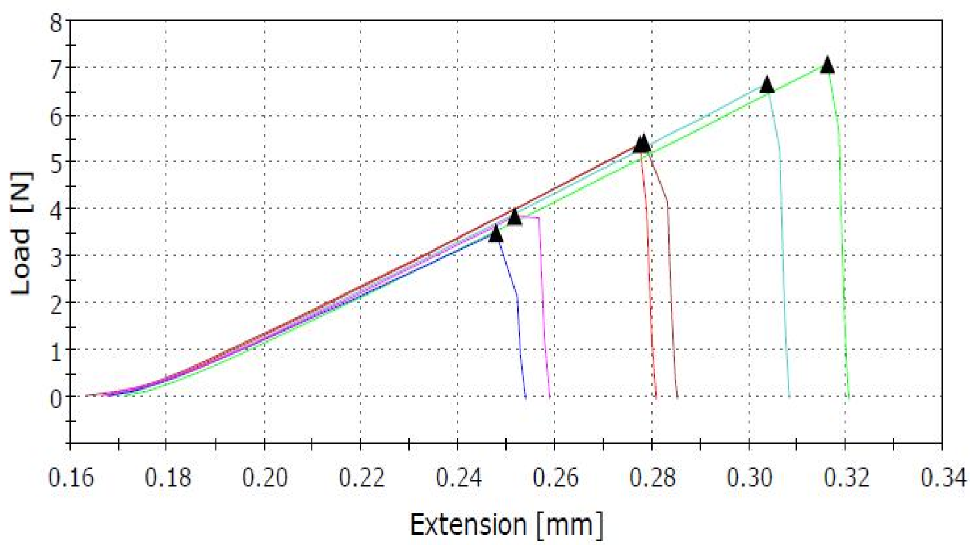

Fig. 4. Representative load-deflection curve with 3-point bend test using wedge shape loading anvil (applied force in N vs die deflection in mm)

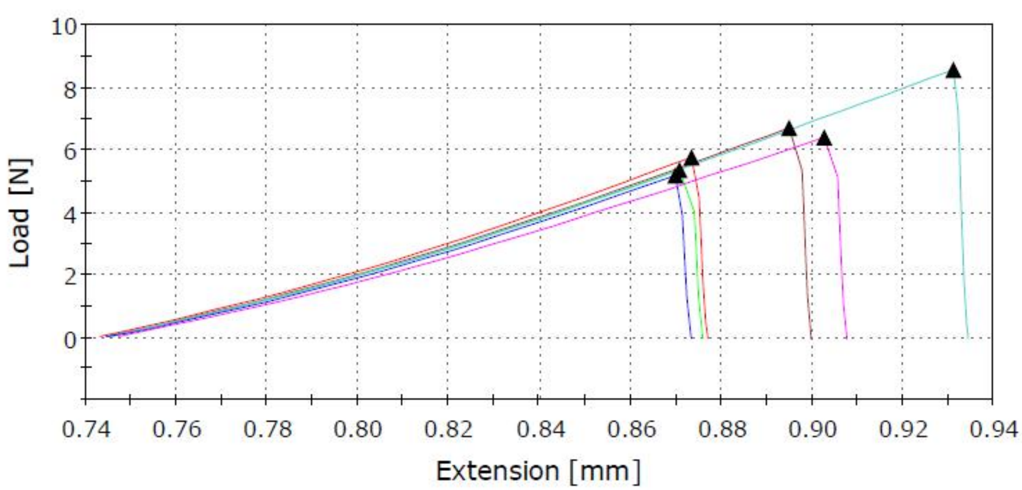

Fig. 5. Representative load-deflection curve with 3-point bend test using needle shape loading anvil (applied force in N vs die deflection in mm)

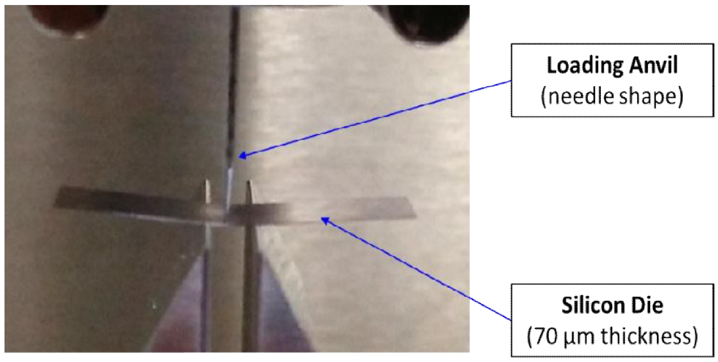

Fig. 6. Deformation of the silicon die during actual testing

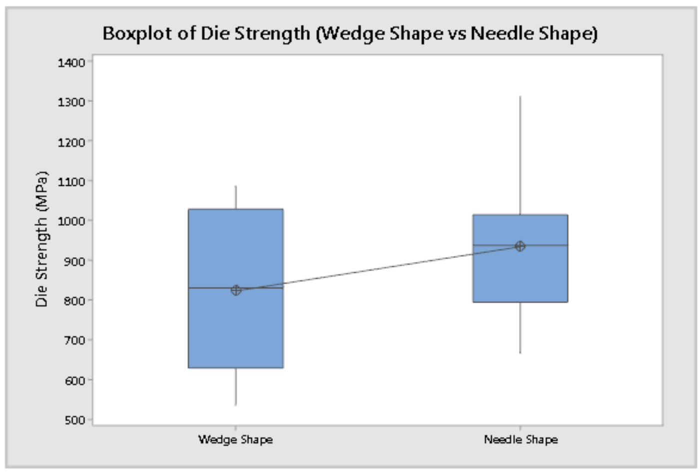

Fig. 7. Boxplot comparison of die strength (wedge shape vs needle shape)

One-way ANOVA: Wedge Shape, Needle Shape

Factor	N	Mean	Grouping
Needle Shape	15	933.8	A
Wedge Shape	15	822.7	A

Means that do not share a letter are significantly different.

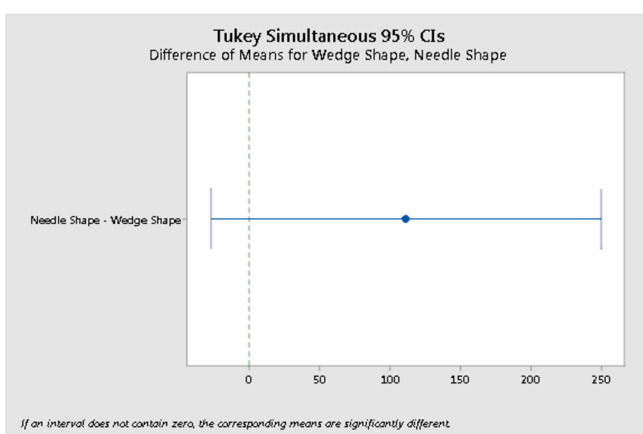

Fig. 8. One-way ANOVA comparison of die strength (wedge shape vs needle shape)

Based on the boxplot comparison of the results shown in Fig. 7, the average die strength using the needle shape loading anvil is a bit higher compared to the average strength using the wedge shape loading anvil (934 MPa vs 823 MPa).

Though technically the needle shape loading anvil gives a bit higher die strength results, statistical comparison using one-way analysis of variance (ANOVA) shown in Fig. 8 revealed that the die strength obtained using the needle shape loading anvil has no significant difference with the strength obtained using the standard wedge shape loading anvil in a 3-point bend test. The ANOVA result was obtained using Minitab statistical software. The range in Tukey simultaneous confidence interval does not include zero, which indicates that the difference between the means is not significant and this is also indicated in the grouping information. This implies that the needle shape loading anvil could still give comparable die strength results when used in a 3-point bend test.

4. CONCLUSION

The die strength characterization done in this study showed that using the needle shape loading anvil would produce results that are not significantly different from the results obtained using the usual wedge shape loading anvil in a 3-point bend test setup. The use of the needle shape loading would be closer to the actual scenario in the package assembly manufacturing such as in the die bond process where an ejector needle or pin is used to push the die during die pickup. Further testing using the needle shape loading anvil with different die thickness values and 3-point bend test support span could be explored to confirm if the results would still have no significant difference statistically with the results obtained using the wedge shape loading anvil.

DISCLAIMER

The products used for this research are common and predominantly used products in our area of research and country. There is absolutely 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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