ULTRA SHORT PULSE (USP) LASER GROOVING: A NEW SAWING TECHNIQUE TO ADDRESS DIE STRENGTH ISSUES IN THINNER PACKAGES

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ABSTRACT

Wafer sawing using laser grooving process has become necessary for low-k integrated circuit (IC) dies since mechanical sawing alone could cause interlayer dielectric film delamination. However, more die crack issues are encountered with thin dies processed using laser grooving and significant die strength reduction has been observed. In this study, a new wafer sawing technique using ultra short pulse (USP) laser grooving was explored. Dies singulated using USP were subjected to 3-point bent test to determine the die strength. Results revealed that dies processed using USP laser grooving has significantly higher die strength compared with standard laser grooving process. The use of ultra short pulse in laser grooving has been proven effective in reducing heat damage in die preventing reduction in die strength.

1. 0 INTRODUCTION

With the introduction of laser grooving process in wafer sawing with low-k thin dies, the occurrences of die crack issues have increased. Using actual 3-point bend testing, significant die strength reduction has been confirmed. The mechanical strength of dies singulated using standard laser grooving is much lower compared to that of the dies singulated using mechanical sawing alone. Mechanical sawing using dicing blade could have been better in terms of die strength. However, low-k interlayer dielectric is more prone to delamination or peel off as shown in Fig. 1 when mechanical sawing is used alone. This is the main reason laser grooving is needed.

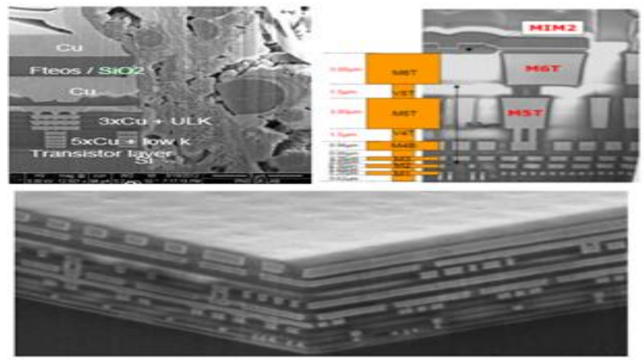

Fig. 1. Typical Low-K Die Construction.[1]

1.1 Mechanical Sawing

In wafer mechanical sawing process (Fig. 2), the dies are singulated using a rotating dicing blade. This is the most common and traditional method of wafer sawing. For dies without low-k technology, this wafer dicing process gives higher die strength.

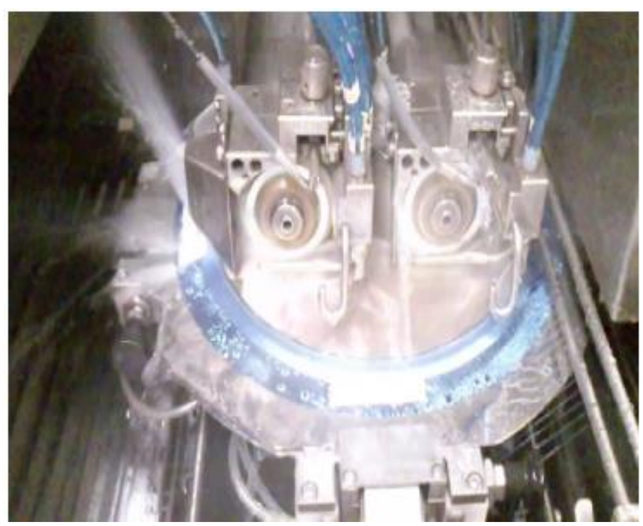

Fig. 2. Mechanical Sawing Process.

1.2 Conventional Laser Grooving

The conventional laser grooving process is required when singulating low-k and ultra thick Cu stack wafers to avoid dielectric film delamination. The whole process involves removing the interlayer dielectrics (low-k film) by laser grooving and then followed by blade dicing process to fully singulate the die [2].

Conventional laser grooving usually consists of three (3) passes as illustrated in Fig. 3. The first pass is dual narrow beam called the isolation pass. The second and third passes are wide beams, which remove the bulk metals. In addition, the conventional laser grooving is using long pulse laser as indicated in Fig. 4. It causes some damage to adjacent structures.

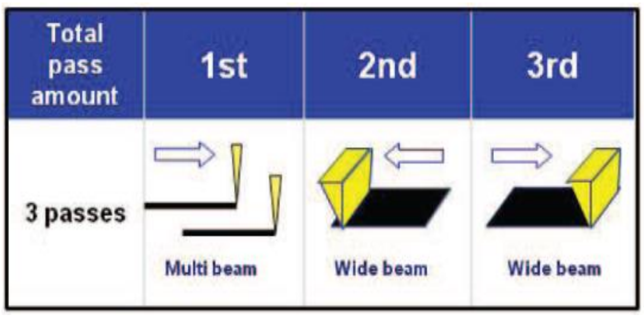

Fig.3. Schematic diagram of 3 laser beam pass.

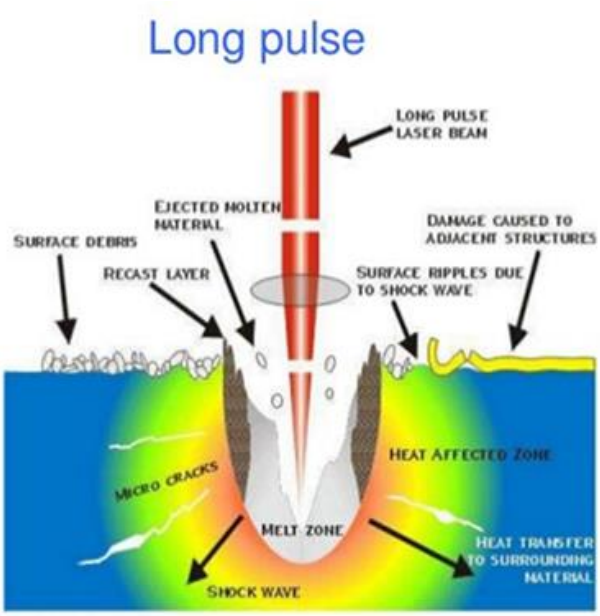

Fig. 4. Long pulse in laser grooving[2].

1.3 Ultra Short Pulse (USP) Laser Grooving

Laser grooving using ultra short pulse laser is intended to reduce heat damage to the die. With short pulse laser, the heat damage is controlled by irradiating the laser instantaneously[2]. As illustrated in Fig. 5, there is significantly less damage caused to the adjacent structures.

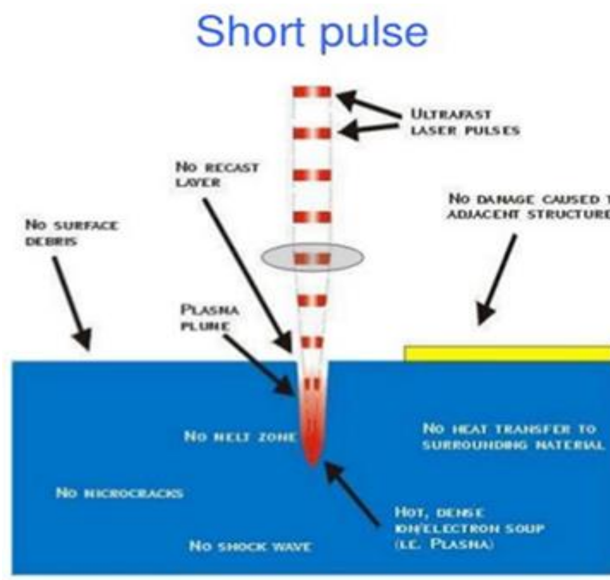

Fig. 5. Short pulse in laser grooving.

1.4 How laser works in wafer sawing

Light Amplification by Stimulated Emission of Radiation (laser) has three major characteristics such as straightness, coherence, and wavelength. Lasers can be generated artificially, and the output power can be easily controlled, so it is widely used in industrial applications.

The energy from the laser beam is absorbed by the materials and converted to heat. Then materials vaporize due to the increase in temperature and scatter as debris into the air (Fig. 6a). At the same time, a plasma atmosphere called a plume is generated (Fig. 6b). Materials which did not vaporize during laser groove re-congealed, and their shape and other properties varies from the original state. This will generate burrs, voids, and cracks [3,4].

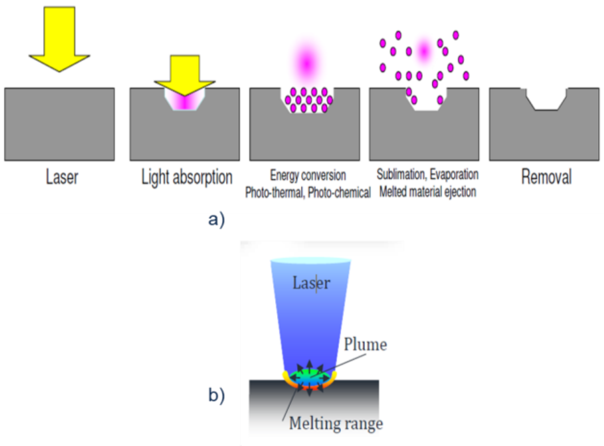

Figure 6. a) Laser Groove Cutting Sequence, b) Illustration of Plume.

In conventional laser grooving process, a limitation is observed in terms of die strength as well as narrow process window toward low-k wafers technology in thin packages as shown in Fig. 7.

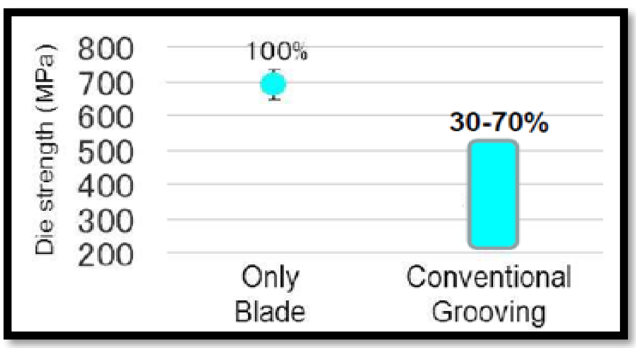

Fig.7. Die Strength Comparison between Mechanical Sawing and Conventional Laser Grooving.

In this study, ultra short pulse (USP) laser grooving was used to address the die strength issues encountered with dies processed using the conventional laser grooving.

2. 0 REVIEW OF RELATED WORK

Refer to 1.0 Introduction.

3.0 METHODOLOGY

To understand the difference between USP laser grooving and conventional laser grooving, a test vehicle was used with details indicated in Table 1. Die samples were prepared based on the required dimensions for die strength testing (3.9 mm x 2.5 mm with 70 µm thickness).

Table 1. Test Vehicle Information

Test Vehicle	Description
Wafer Size	300 mm
Silicon Technology	40 nm
Die Size	3.9 mm x 2.5 mm
Die Thickness	70 um
Sawing Street	80 um

There were dies singulated using USP laser grooving and others with conventional or standard laser grooving. Samples were taken from 9 different locations in the wafer as shown in Fig. 8. From each location, 5 die samples were picked with a total of 45 samples.

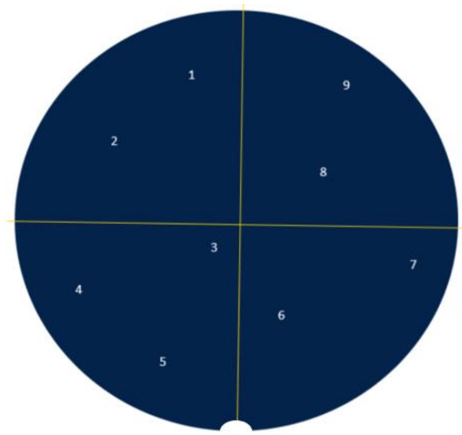

Fig. 8. Different locations in the wafer from which die samples were taken.

Die strength testing was performed using Instron MicroTester equipment with 3-point bend fixture compliant to the international standard SEMI G86-0303 for measurement of die strength[5]. The equipment has a load cell for force measurement. As shown in Fig. 9, two stationary anvils at the bottom support the die sample to be tested while the force is applied from the top as the upper anvil moves down.

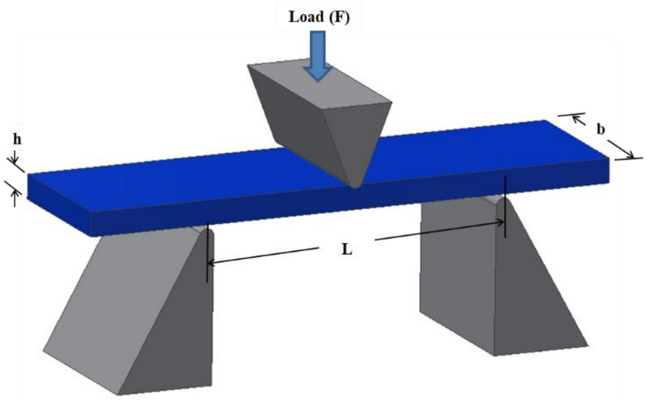

Fig.9. 3-point bend test setup.

The equation (1) below is the general formula used for the die strength calculation:

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

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

4.0 RESULTS AND DISCUSSION

The singulation profile of the die processed using the ultra short pulse (USP) laser grooving is shown in Fig. 10 and Fig. 12 shows the singulation profile with the conventional laser grooving (standard laser grooving).

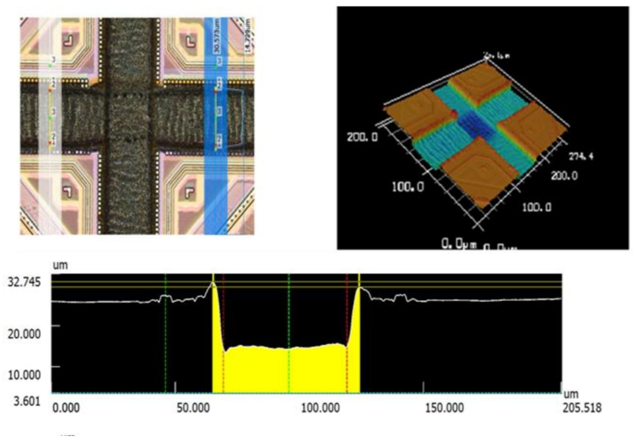

Fig. 10. Groove profile with ultra short pulse (USP) laser grooving.

Ultra short pulse SEM photo (Fig. 11) shows a limited recast layer with no ejected materials, limited surface debris, no melt zone and no microcracks.

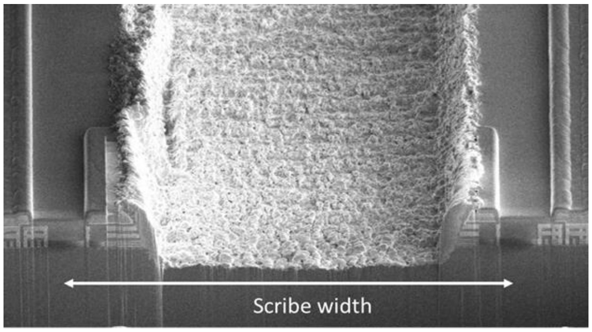

Fig. 11. SEM photo of the ultra short pulse (USP) laser groove.

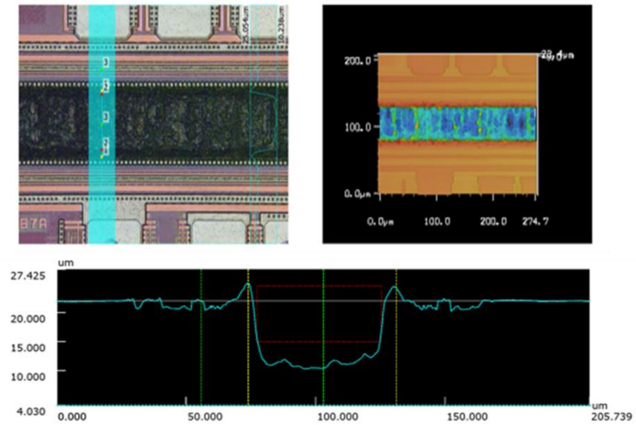

Fig. 12. Groove profile with conventional laser grooving.

In contrast, conventional laser groove SEM image is shown in Fig. 13. It shows a recast layer, ejected molten material, surface debris and heat affected zone/micro-cracks.

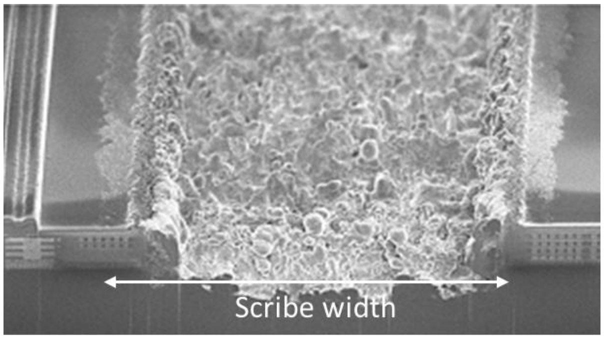

Fig. 13. SEM photo of the conventional or long pulse laser groove.

As summarized in Table 2, both laser grooving methods have comparable results in terms of top groove width, bottom groove width and groove depth. However, USP laser grooving has produced good U-shape and low roughness at the bottom (Fig. 10).

Table 2. Comparison of Singulation Profile Measurements

Profile	Ultra Short Pulse (USP) Laser Grooving	Conventional (STD) Laser Grooving
Top Groove Width (µm)	58.7	57.9
Bottom Groove Width (µm)	50.3	48.0
Groove Depth (µm)	12.3	12.0

From the 3-point bend test results, die strength comparison is shown in Fig. 14. The die strength of the dies processed using USP laser grooving is significantly higher than that of the conventional or standard (STD) laser grooving.

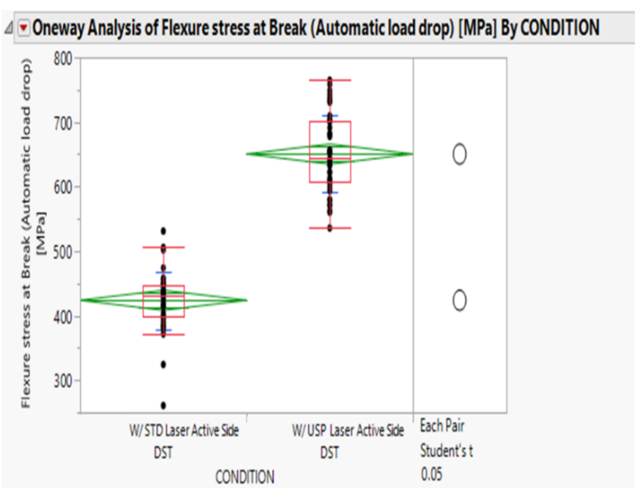

Fig. 14. Die strength comparison: conventional (STD) laser grooving vs USP laser grooving.

5.0 CONCLUSION

The study has proven that ultra short pulse (USP) laser grooving gives significant improvement in die strength for low-k dies. The higher die strength is attributed to the reduction in heat damage as compared to the convention laser grooving. The use of ultra short pulse laser can address the decline in die strength encountered in the conventional laser grooving process. The increase in die strength with USP laser grooving could help reduce or eliminate die crack in the succeeding package assembly process and improve package reliability.

6.0 RECOMMENDATIONS

It is highly recommended to use ultra short pulse (USP) laser grooving in singulating low-k wafer technology in thin packages to avoid significant decline in mechanical strength of the die.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

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9.0 ABOUT THE AUTHORS

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