# Reducing chipping defects during GaAs wafer dicing with a four-point diamond tool

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## Abstract

This paper reports the results of a DOE, analyzed with Mini-Tab software that studied GaAs dicing with a four-point diamond-scribing tool. An excellent scribe and break (S&B) yield was obtained by simultaneously controlling the cutting depth and applied force. An August automatic inspection system was used to determine the die yield after wafer dicing.

## Description

The dicing process for GaAs wafers with a diamond tool relies on generating scribe lines on the GaAs surface and then separating the chips by applying force from the wafer backside to crack the line propagating through GaAs. Figure 1 and Figure 2 show a typical good and bad crack profile of GaAs die after the scribe and break process. A die with a bad crack line profile will exhibit edge chipping issues and results in yield loss. In order to limit yield loss from the dicing process, it is very important to fully understand the mechanisms that affect the profile and then delicately control these to achieve consistent results and thus high yields [1].

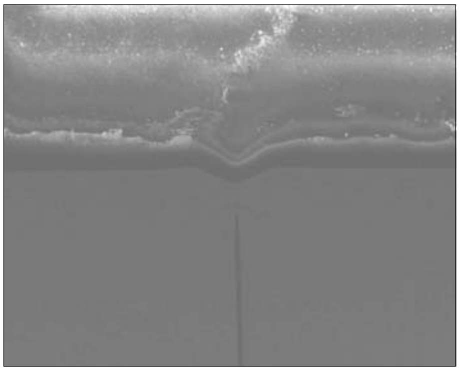

Fig.1. Good crack profile after scribe process.

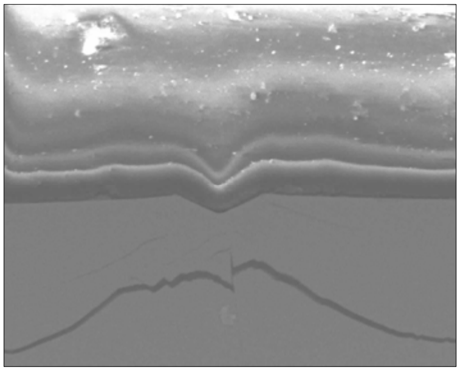

Fig.2. Bad crack profile after scribe process.

Selection of the correct type of diamond tool is critical to achieving high yields. In general, for GaAs scribe and break dicing, there are two kinds of diamond tools, a three-point diamond tool and a four-point diamond tool. Figure 3 and 5 show that a three-point diamond tool has the acute tip angles and the tool cutting edge is curved. A four-point diamond tool has the vertical tip angles and the cutting edge is a straight line as shown in Figure 4 and 6.

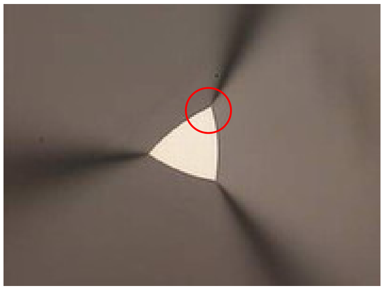

Fig.3. The tip profile of a 3-point tool.

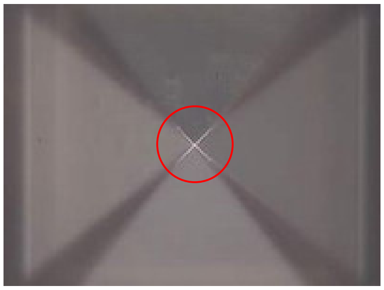

Fig.4. The tip profile of a 4-point tool.

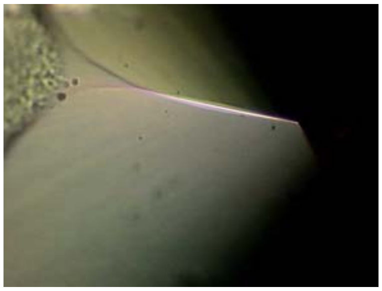

Fig.5. The cutting edge of a 4-point tool.

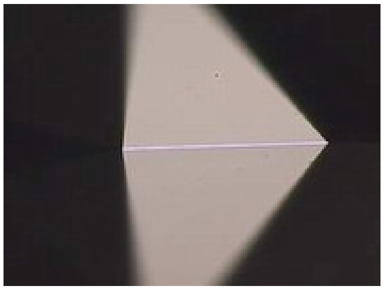

Fig.6. The cutting edge of a 3-point tool.

In our manufacturing line at WIN, we found that a four-point diamond tool is easier to implement than a three-point diamond tool. Also the die yield is higher with a four-point diamond tool. Therefore, in this study we focused solely on the chipping improvement of GaAs die by the scribe and break process with a four-point diamond tool [2].

## Experiments

We identified six important variables that could affect the dicing yield during the scribe and break process. There are: the cutting depth, the applied force, the cutting speed, the breaking pressure, the breaking height and the chip size.

Using a first experimental lot with thirty wafers, we identified that the cutting depth and the applied force are the two most important variables for dicing 4 mil wafers with a four-point diamond tool. The Mini-Tab analysis of this lot is shown in Figure 7 and 8. Figure 7 shows that factor A (applied force), B (cutting depth), and F (chip size) are three important variables among all factors. Since chip size will be differ from mask to mask, the important variables in this study that need to be considered are applied force and cutting depth. Figure 8 shows that with Mini-Tab software analysis a reasonable range was chosen for each variable such that it was within the typical range employed for GaAs scribe and break. By taking the cutting depth and applied force as the two key variables and generating a response surface in Mini-Tab, we designed a second experimental lot with fourteen wafers. The results are shown in Table 1. This data can be re-plotted as shown in Figure 9 and Figure 10. There are two optimum windows in Figure 10: the deep cutting depth with a low applied force in the upper left corner and the shallow cutting depth with a high applied force in the right lower corner. In practice, due to wafer thickness variation it would be very difficult to apply “shallow cutting depth with high applied force” to achieve good results. Therefore the “deep cutting depth and a low applied force” became the most practical approach.

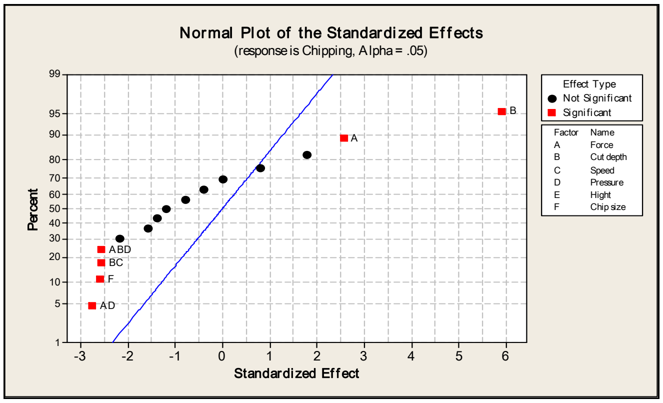

Fig.7. The variable's effect level for chipping defect.

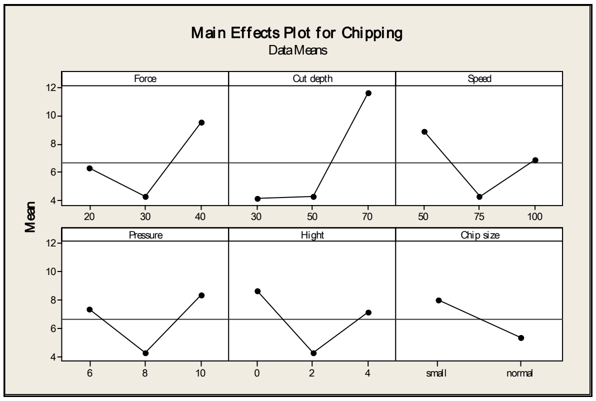

Fig.8. Optimization data for every variables of chipping.

| Run Order | Force (g) | Cutting Depth (μm) | Yield (%) | Run Order | Force (g) | Cutting Depth (μm) | Yield (%) | Run Order | Force (g) | Cutting Depth (μm) | Yield (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 36 | 30 | **85.3** | **6** | 28 | 44 | **82.6** | **11** | 28 | 24 | **77.8** |
| **2** | 20 | 30 | **20.0** | **7** | 20 | 58 | **72.3** | **12** | 28 | 44 | **86.5** |
| **3** | 28 | 44 | **47.7** | **8** | 39 | 44 | **52.2** | **13** | 28 | 44 | **81.6** |
| **4** | 36 | 58 | **73.0** | **9** | 28 | 64 | **72.9** | **14** | 17 | 44 | **41.2** |
| **5** | 28 | 44 | **84.8** | **10** | 28 | 44 | **50.0** | | | | |

Table 1: The data for different force and cutting depth by a response surface.

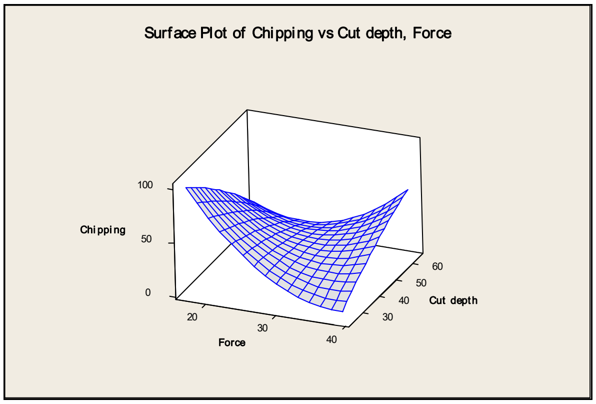

Fig.9. The 3D figure of chipping yield.

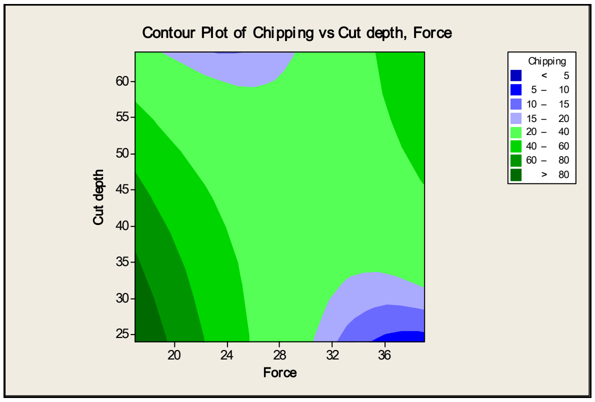

Fig.10. The 2D figure of chipping yield.

With Mini-Tab software a chipping yield formula can be derived as follows:

Chipping loss =

$$\{1-[391+ (-3.38 \text{ cutting depth}) + (-18.87 \text{ force}) + (0.20 \text{ cutting depth}^2) + (-0.01 \text{ force}^2) + (0.15 \text{ cutting depth} \times \text{force})]\}\times 100\%$$

According to the above formula, the die yield may be able to reach up to 90% for 68um cutting depth and 24-gram applied force.

| **Item** | **Cutting Depth (um)** | **Force (g)** | **Chipping Loss (%)** |
|---|---|---|---|
| **1** | **64** | **25** | **14.72** |
| **2** | **60** | **28** | **20.37** |
| **3** | **55** | **30** | **24.66** |
| **4** | **68** | **24** | **9.16** |
| **5** | **70** | **22** | **5.46** |

Table 2: The chipping loss for different combination with cutting and force by the above formula.

A third experimental lot was run to evaluate these conditions. It was found that 68 um cutting depth with 25 gram applied force did not produce the projected yield. In order to maintain yield during dicing it was determined that the cutting depth needed to be less than 66 um. Further testing has shown that 64 um cutting depth and 25 gram applied force are more optimum conditions. Table 3 and Table 4 show that the die yield can easily achieve more than 90% yield in the bare and product GaAs wafers using 64 um cutting depth and 25 gram applied force by a four-point diamond scribing tool.

| **Run Order** | **Force (G)** | **Cutting Depth (μm)** | **Yield (%)** | **Run Order** | **Force (G)** | **Cutting Depth (μm)** | **Yield (%)** |
|---|---|---|---|---|---|---|---|
| **1** | 22 | 66 | 87.2 | **4** | 26 | 66 | 81.7 |
| **2** | 25 | 64 | 89.8 | **5** | 23 | 60 | 86.5 |
| **3** | 25 | 64 | 91.3 | **6** | 27 | 61 | 77.6 |

Table 3: The yield of different recipes on dicing bare wafers.

| **Run Order** | **Force (G)** | **Cutting Depth (μm)** | **Yield (%)** | **Run Order** | **Force (G)** | **Cutting Depth (μm)** | **Yield (%)** |
|---|---|---|---|---|---|---|---|
| **1** | 22 | 66 | 92.2 | **4** | 26 | 68 | 86.1 |
| **2** | **25** | **64** | 97.2 | **5** | 23 | 60 | 92.5 |
| **3** | **25** | **64** | 93.6 | **6** | 27 | 61 | 93.8 |

Table 4: The yield of different recipes on dicing product wafers.

## Conclusion

The dicing yield of GaAs wafers has been studied using a DOE and mini-Tab analysis approach. Consistent Die yields of more than 90% are obtained using “64 um cutting depth and 25 gram applied force” condition with a four-point diamond tool.

References:

[1] DYNATEX INTERNATIONAL™, “Meeting the Challenge of Dicing and Fracturing Brittle III-V Materials”.

[2] How to select the Right Scribing-Tool for Your Application. APR.1973.