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Laser DAF Cut Augmentation for Thin Wafers

Bryan Christian Bacquian[1*] and Frederick Ray Gomez[1]

[1]New Product Development and Introduction, STMicroelectronics, Inc., Calamba City, Laguna, 4027, Philippines.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read, reviewed and approved the final manuscript.

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ABSTRACT

The semiconductor industry is becoming more inclined to thinner integrated circuit (IC) packages. Thinner packages with thin wafer or die prefer the die attach film (DAF) technology as the die adhesive material solution. As the wafer goes thinner, it becomes more of a challenge in process development, especially during its assembly preparatory stages. As the dies become smaller and thinner, wafer sawing process should have minimum effect on the mechanical integrity of the silicon so as not to alter its quality.

New technologies were developed and introduced in the industry and one of this is the laser die attach film (DAF) cutting. The method was developed together with dies before grinding (DBG) as a cutting medium to address potential processability problems that may occur on the conventional mechanical blade saw. This paper discusses the laser DAF cut development covering the design of experiments (DOE) to understand the different characteristics of laser DAF solution. Validations are made through actual simulation and wafer processing. The paper also covers the interaction of different DAF thicknesses and parameters in order to define the critical characteristics in achieving optimal DAF cutting process responses.

Keywords: Laser DAF cut; design of experiments; DAF; laser.

**Corresponding author: Email: bryan-christian.bacquian@st.com;*

1. INTRODUCTION

Nowadays, the demand for thinner packages become one of the major drivers for package miniaturization. Complex and thinner packages require dies of becoming thinner. As dies becomes thinner, devices bring more challenges during its preparatory stages. Thinning of die should not have any mechanical defect so as to achieve robust process and high quality package.

Thinner dies, specifically those on the range of 100 μm (microns) and below die thickness, shows significant drop in die strength. Die of thickness below 200 μm shows diminishing strength. Also, when it reaches critical thickness where die become so thin, it would not be able to withstand higher load.

To attain wafer thickness below 100 μm without compromising its die strength, a technology called dicing before grinding (DBG) was introduced. DBG focused on the removal of backside chipping that cause breakage on the silicon area of the die, thus improving its quality [1-2]. Nevertheless, DBG is not enough to cater the increasing demand for thinner packages. The inclusion of the die attach film (DAF) material attached underneath the pre-sawn grinded wafer pose another challenge for a breakthrough process development which is the light amplification by stimulated emission of radiation (LASER or laser) DAF cut. Laser DAF cut focuses on the successive singulation of the DAF material underneath the pre-sawn wafer using low power. With this, the introduction of DBG plus the laser DAF cut would improve the integration of the wafer thinning process without compromising the quality requirement of thinner dies.

1.1 Dicing Before Grinding

Dicing before grinding is a combination of processes shown in Fig. 1 that focuses on the processing of thinner wafers [1]. DBG process starts with the partial cut dicing similar to wafer grooving. Rule of thumb for cut depth is the target final wafer thickness + 40 μm. Next is the tape lamination process, wherein the backgrinding tape is applied on the top metal layer or the active side of the wafer for water and cushioning protection during wafer back grinding. Next is the wafer back grinding that involves the grinding of the wafer backside or the silicon part into the desired final wafer thickness. In addition, wafer back grinding is also the one that will separate the dies with each other. Then the singulated dies would be mounted on a frame with either a dicing tape or a DAF material.

With the DBG flow, cracks or chippings at the back of the dies brought by mechanical dicing process is removed during the grinding process. Backside stresses like chippings leads to lower die strength. Previous works shared that DBG has significantly higher die strength compared to conventional wafer thinning and dicing technology [3], thus, would help achieve ultra-thin strong dies, good process yield and better reliability performance.

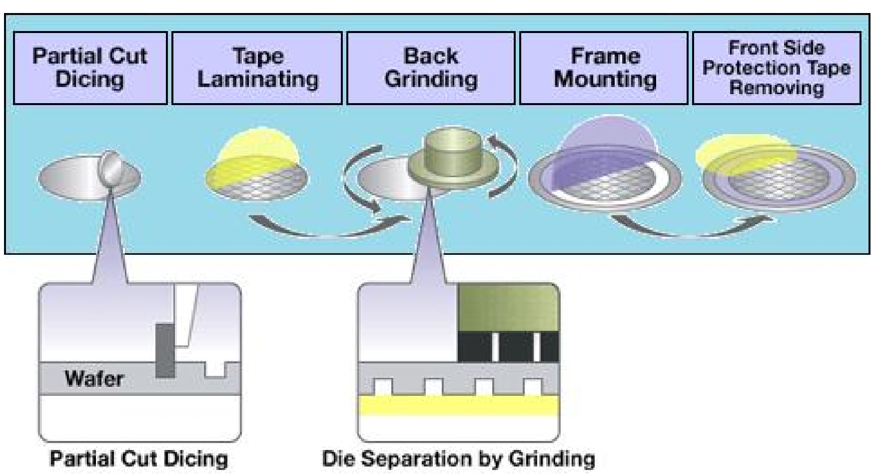

Fig. 1. DBG process flow [1]

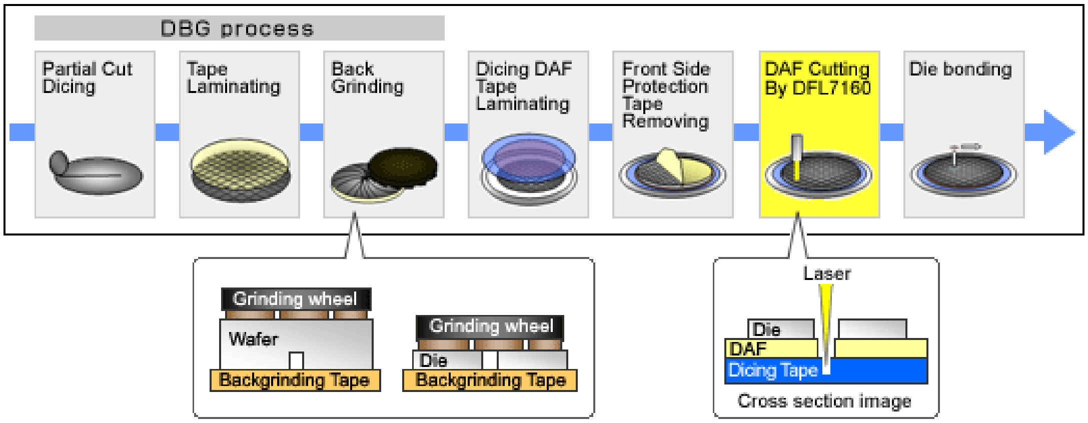

Fig. 2. DBG + laser DAF cut process

1.2 Laser DAF Cut

Laser DAF cut in Fig. 2 is a process developed for the cutting of DAF material mounted on the wafer backside after the DBG process using laser [4]. Laser is more efficient compared to conventional mechanical blade cutting wherein incurring different issues with regards to wafers being processed using DBG process. Three factors are noted, which are the die alignment, blade width and processing speed. After wafer back grinding, the singulated dies are more likely to move or shift in microns, this is termed as die shift. Large die shift after grinding results to die alignment issues, wherein there is a possibility not to ensure good blade passage. Another potential issue is that since dies are singulated, there is a need to have a more accurate and precise blade in order to fit into the saw street or the distance between adjacent dies. Die shifting can also lead to slow alignment resulting to slower processing and will impact for manufacturing cycle time.

In connection to the above issues for a conventional sawing, laser DAF cut offers a solution to manufacture DBG processed wafers with DAF. Laser can adopt to the large die shifting through special alignment feature and can curved its way into the center of the saw street, thus preventing the laser beam to hit the side of the die. With this special alignment feature, the machine can be able to increase the cutting speed thus reducing manufacturing cycle time. Lastly, one major advantage of laser DAF cut is the ability not to subject the silicon wafer and DAF to any mechanical stress thus removing the possibility of chippings or burrs.

2. LITERATURE REVIEW

Laser is a condensed monochromatic (one frequency) amplified light with the same phase and direction, and has high energy efficiency and density. In the semiconductor industry, one of the common lasers used is the Nd: YAG (neodymium-doped yttrium aluminum garnet; Nd: Y3Al5O12) [5].

Nd: YAG lasers are optically pumped using a flash tube or laser diodes. Moreover, this laser typically emits light with a wavelength of 1064 nm, in the infrared [6]. The process involved in laser machines is typically known as ablation. On a normal ablation, laser to be used for semiconductor manufacturing is focused on cutting either silicon or DAF materials. To illustrate, Fig. 3 shows a typical ablation process.

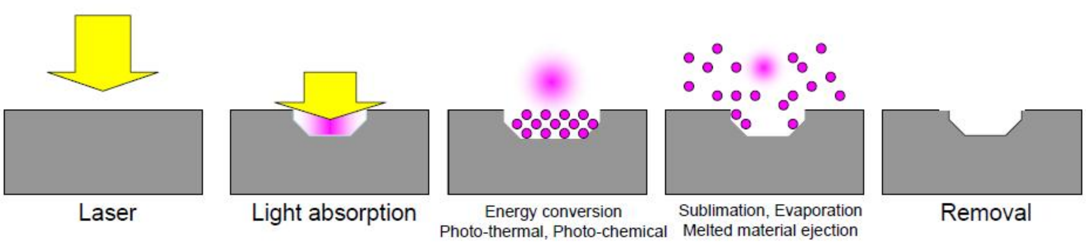

Fig. 3. Ablation process

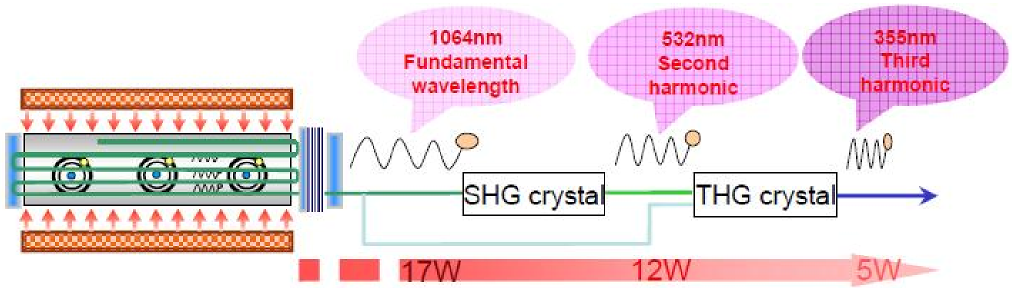

Fig. 4. Typical laser wavelength and power conversion

Conventionally, a YAG is used as a laser rod which is excited by a medium controlled by water cooling to eliminate breakage. The Electrons will then be oscillated by a Q switch that will deliver the fundamental wavelength of 1064 nm. To be suitable for processing, wavelength needs to be converted into a lower value, as depicted in Fig. 4.

Laser DAF cut using ND: YAG is used to ensure that lower wavelength and power is applied since the target medium to cut is only a DAF material that is typically soft. The cutting should not be as high as cutting metals that can lead to glue splattering and worst DAF melting.

3. EXPERIMENTATION

3.1 Materials

To understand the characteristics and responses of the laser DAF cut process parameters, such as frequency, laser power and feed rate into the DAF material, different DAF materials with varying thicknesses given Table 1 were evaluated.

Table 1. DAF material evaluation matrix

DAF material	DAF thickness
DAF #1	7 µm
DAF #2	20 µm
DAF #3	25 µm

3.2 Process Scope

Design of experiments (DOE) focused only on the laser DAF cutting process. All wafers were processed using the same parameters and conditions at DBG and mounted on different DAF thickness which is part of the laser DAF cut DOE.

3.3 Design of Experiments

Design of experiments was conducted to understand the effect of 3 critical laser parameters namely laser power, repetition rate or frequency, and feed rate. Laser power pertains to the amount of energy being directed by the laser towards a medium or the material to be cut. Repetition rate or frequency refers to the amount of laser pulses on a certain time. Feed rate is the speed of the working table during laser cutting.

A parameter defocus amount refers to the height on top of the just focus or the focused position shown in Fig. 5, wherein lasers are being penetrated. Typically, –Defocus is equal to the die thickness of the DBG material. Therefore, throughout the DOE, defocus amount is set to -50 that is equivalent the 50 µm die thickness.

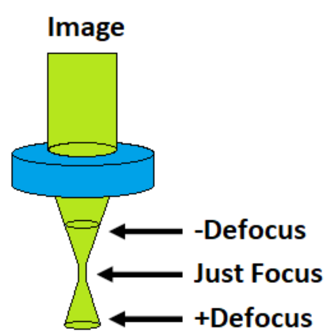

Fig. 5. Representation of just focus

In order to identify the characteristics and suitable parameters on each of the DAF material and thickness, fractional factorial DOE was conducted with the aid of a statistical analysis tool [7] and the guidance of the internal specification documents [8-9].

4. RESULTS AND ANALYSIS

The experiment results were assessed based on the following criteria: 1) depth value higher than the DAF thickness + 5 µm; 2) width typically equal to minimum kerf width to 3x DAF thickness. Different evaluation matrices have been analyzed through prediction profiler, identifying the parameters that would greatly affect the depth and width of the laser DAF cut.

4.1 DAF #1 – 7 µm Thickness

Laser DAF cut DOE was conducted starting with the use of 7 µm thick DAF using fractional factorial. Prediction profiler shown in Fig. 6 indicates that increasing feed speed results to decrease in both depth and width values, meaning the increase of feed speed will have a shallower and narrower laser DAF cut. In contrast, increase in laser power results to increase in value of both depth and width, indicating deeper and wider laser DAF cut.

As a result, feed speed should be decreased to ensure good DAF cut width. On the other hand, laser power must be increased to achieve enough depth and width through the 7 µm DAF cut.

4.2 DAF #2 – 20 µm Thickness

The second material experimented has a thicker DAF material at 20 µm thickness. The profiler in Fig. 7 shows that the effect of the laser parameters, specifically feed speed and laser power, versus the process responses (depth and width) have a tighter process window for 20 µm DAF thickness compared to the 7 µm thickness.

Further analyzing the parameters using prediction profiler, result shows that feed speed and laser power is inversely proportional in terms of width and depth. The incremental value of feed speed shows narrower and shallower cut while on the other hand, the incremental value of laser power is showing incremental effect for the depth and cut width.

4.3 DAF #3 – 25 µm Thickness

To further strengthen the data gathered for two thin DAF thickness, additional DOE was performed to cover the 25 µm DAF thickness. Prediction profiler in Fig. 8 shows that feed speed and frequency versus laser power is inversely proportional in terms of width and depth. The incremental value of feed speed and frequency shows narrower and shallower cut which supports the data from the latter DOE covering 7 µm and 20 µm DAF thicknesses, which is same with the laser power wherein the incremental value does support the increase on depth and width.

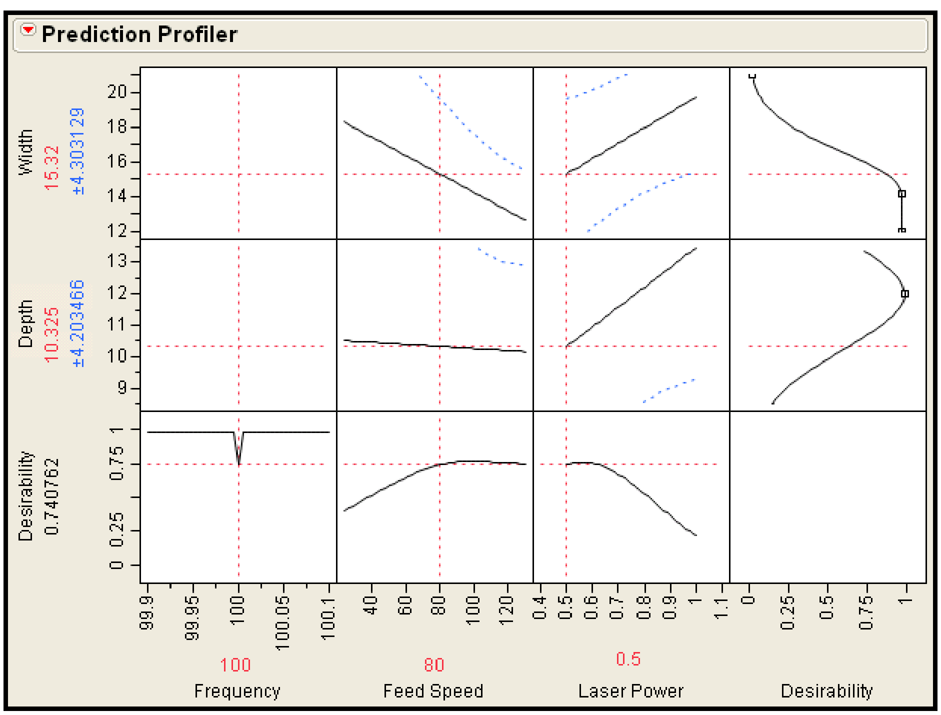

Fig. 6. DAF #1 thickness profiler

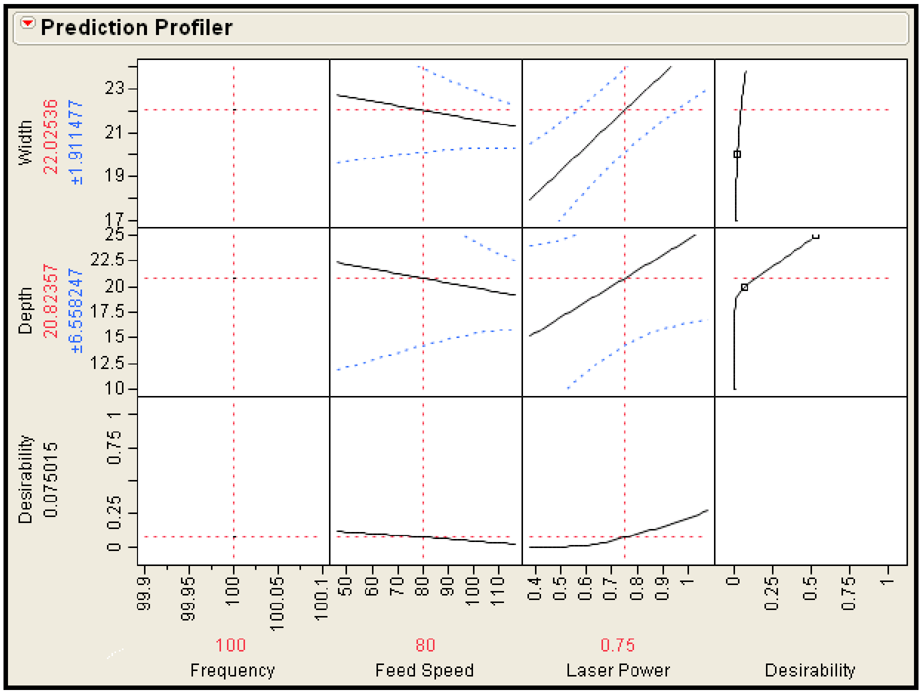

Fig. 7. DAF #2 thickness profiler

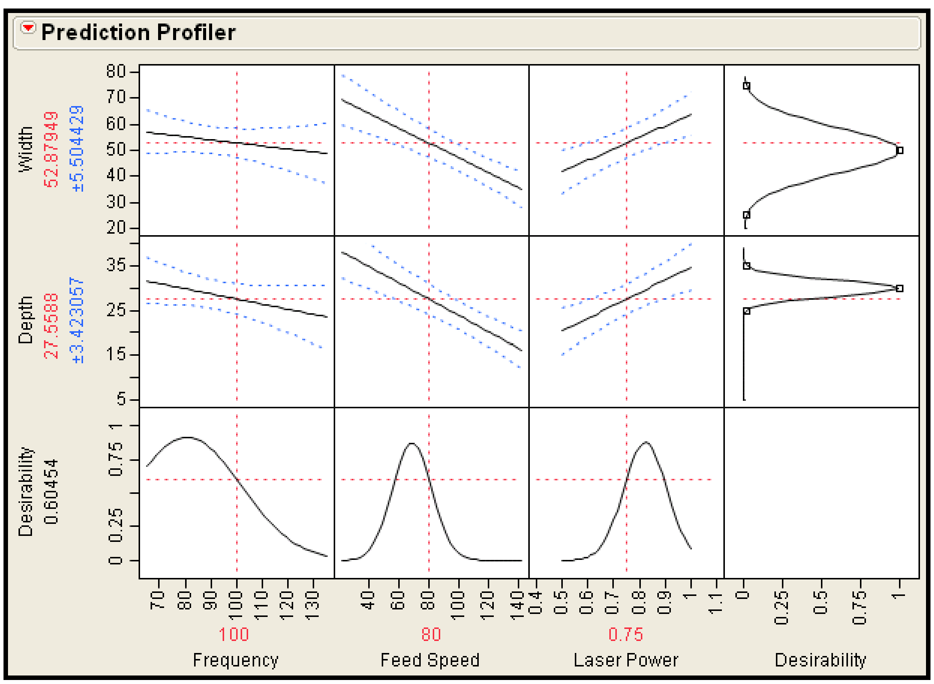

Fig. 8. DAF #3 thickness profiler

4.4 Revalidation of Process

To check the effectiveness of the cutting parameters defined for the different DAF thicknesses, revalidation run was performed on different die size but with the same configuration. Figs. 9 to 11 are the results.

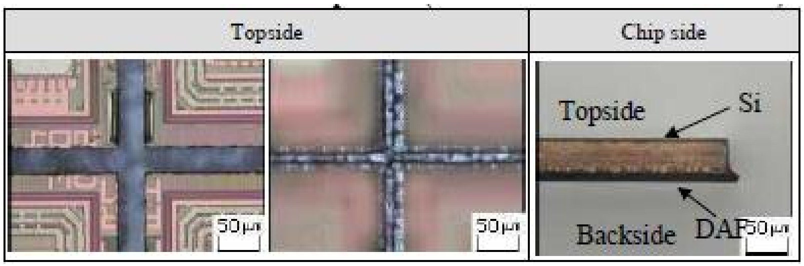

Fig. 9. DAF #1 – 7 µm thickness revalidation

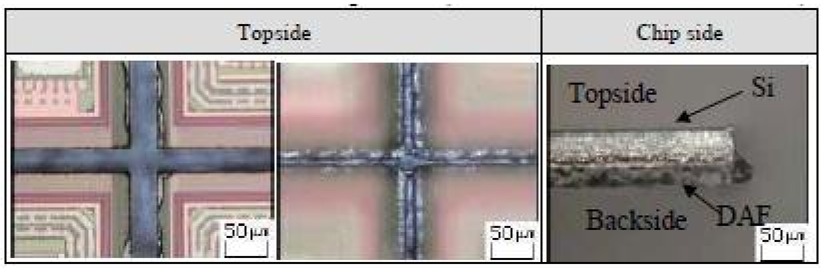

Fig. 10. DAF #2 – 20 µm thickness revalidation

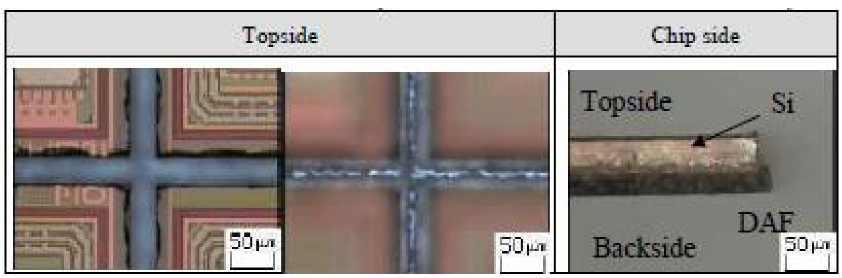

Fig. 11. DAF #3 – 25 µm thickness revalidation

The established Laser DAF cut parameters showed good DAF cut separation and achieved no silicon edge cutting. Hence, the parameters defined are ready for full qualification.

5. CONCLUSION AND RECOMMENDATIONS

Based on the evaluation and revalidation of results, it has been identified that the laser DAF process parameters interaction versus cut depth and width does shows that the increasing DAF thickness results to a narrower process window. Thus, showing the criticality of DAF thickness selection to be used for development. Feed speed and frequency show slower laser penetration time results to a wider and deeper DAF cutting effect. Laser power as a function of energy shows higher laser penetration energy results to a wider and deeper DAF cutting effect.

For thinner die plus DAF configuration, Laser DAF cutting is a good solution for achieving DAF separation through laser penetration. During the Laser DAF DOE, extensive DOE is critical to achieve good laser cut process response, especially if thicker DAF materials will be used. During the definition of laser DAF parameters, the following critical characteristics must be considered: 1) feed speed and frequency are inversely proportional to cut depth and width; 2) laser power is directly proportional to the cut depth and width.

For further improvement, discussions in [10-13] are helpful in reinforcing robustness and optimization of front-of-line assembly processes particularly the wafer preparation.

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 research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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