WAFER SAW PROCESS IMPROVEMENT THROUGH LASER GROOVE KERF CHECK OPTIMIZATION

Vianriz Marini B. Bautista[1]
Francis Noel A. De Erit[1]
Jan Kurt A. Bulayungan[2]

[1]New Product Development and Introduction, [2]OPS1 – Assembly Engineering
STMicroelectronics, #9 Mountain Drive, LISP II, Brgy. La Mesa, Calamba City, Laguna 4027, Philippines
vianrizmarini.bautista@st.com, francis-noel.deerit@st.com, jan.kurt.bulayungan@st.com

ABSTRACT

Laser grooving process was introduced to process low-k wafers since mechanical sawing alone is not sufficient to support requirements of these wafers and could induce interlayer dielectric film delamination. However, to attain the most optimum performance of the process, inclusion of laser groove kerf check software capability in wafer sawing machines is necessary. In this study, laser groove kerf check data was optimized based on machine's camera capability, saw street dimension, device metal layer, and wafer dimension to support machine's capability to correctly detect and recognize groove and blade kerf. Results showed that after optimization, misrecognition of kerfs was reduced, process time was lessened, kerf was centered with respect to laser groove center, and visual inspection passed. The addition of laser groove kerf check capability and use of optimized kerf check data were proven to effectively increase over-all wafer sawing performance.

1. 0 INTRODUCTION

Continuous improvement and development are the direction of semiconductor companies to meet customer requirements and at the same time maintain high quality products and services. To sustain the growth of semiconductor industry, engineering innovations persist to create ideas that will maintain the high quality and reliability of different products and services.

In pre-assembly processes, specifically wafer sawing, it is essential to increase the number of units processed per hour without compromising quality. Reducing invalid machine errors will significantly lessen downtime and dependency of machine for continuous operation to line personnel assist.

Defining kerf check parameters is based on blade kerf width and laser groove width. Additional factors to be considered are lighting settings (combination of direct and oblique lightings), windows sensitivity, kerf check range, kerf check mask, algorithm, and machine's camera focus to enhance machine's recognition capability to detect difference in depth of blade and laser groove kerf.

1.1 Low-k / Ultra Low-k Wafers

A low-k is a type of material with a small relative dielectric constant (κ, kappa) relative to silicon dioxide. Introduction of Low-κ dielectric material is one of several advancements to produce chips with greater speed and lower power requirements. Development of new processes and materials emerged for assembling and packaging of inherently fragile devices, including the introduction of copper metallization, eventually integrated with low-k dielectric materials.[1]

In digital circuits, insulating dielectrics separate the conducting parts (wire interconnects and transistors) from one another. As components have scaled and transistors have gotten closer together, the insulating dielectrics have thinned to the point where charge builds up and crosstalk adversely affects the performance of the device. [1]

However, delamination or peeling is a common defect mode induced during conventional mechanical dicing of any wafer with Low-k technology as shown in Figure 1. As a result, a laser groove is introduced to create a shallow trench through the Low-k dielectric layer prior to a mechanical saw cutting through the remaining silicon material.[2]

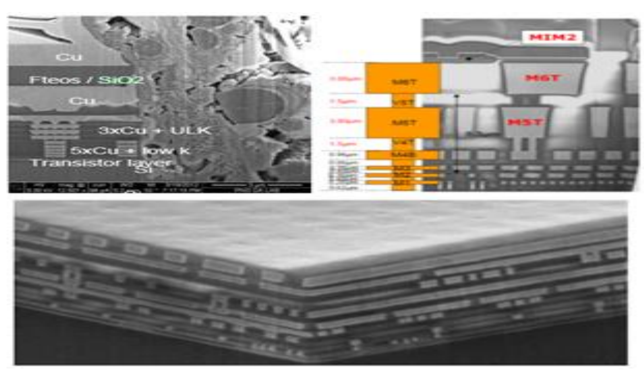


Figure 1. Typical Low-K Die Construction.[3]

The conventional dicing or sawing is still applicable for Low-k wafers, however, significant process optimization will be needed to attain good process responses.[4] In addition, Liu, H. et.al. (2015) shared that current advanced mechanical dicing is not sufficient to handle the requirement of Low-K, thus laser grooving has been introduced.[5]

1.2 Laser Groove Process

Laser groove process shown in Figure 2 is a thermal energy-based process which uses a focused high-energy laser to transfer thermal energy to the wafer, which is absorbed by the topmost low thermal energy inter-layer dielectric (ILD) metal layers. These metal layers then heat up and melt into molten and vaporized solids, which can be removed by directional flow of air pressure. There is now a substantial groove in the wafer, which is thinner and much less resistant to the blade dicing process, resulting in cleaner removal of the die.

This process is commonly used in low-k wafer technologies, hard workpieces that are normally difficult to process at wafer saw, and wafer with presence of metal test pads in sawing street to eliminate chippings and other saw-related defects. Sample of topside view of dice with laser groove is shown in Figure 3.

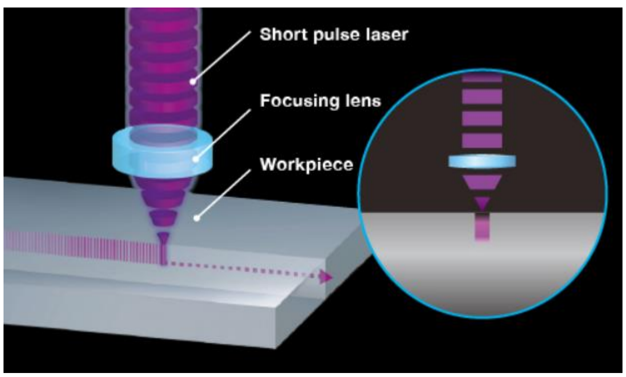


Figure 2. Laser Groove Process

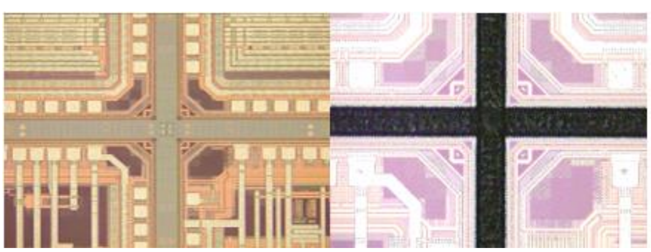


Figure 3. Dice prior and after laser groove

1.3 Wafer Sawing Process

Wafer sawing process as shown in Figure 4 separates wafer into individual dice based on die size requirement. Blade dicing performs saw- through after wafer was processed in laser groove. Laser groove process is incorporated prior wafer saw process to achieve better throughput.

Conventional kerf check parameters were set to recognize individual Z1 and Z2 kerfs, however, for grooved wafers, separate kerf check parameters settings are needed to recognize individual blade kerfs including laser groove kerf since they are all located in one area with difference in depth only. Thus, proper machine lighting and kerf settings are necessary to prevent misrecognition of kerfs resulting to numerous kerf check errors and machine downtime.

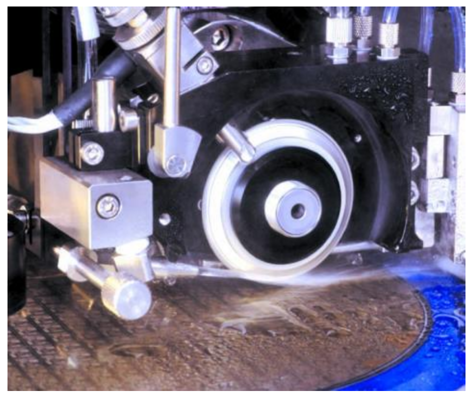


Figure 4. Wafer Saw Process

1.4 Laser Groove Kerf Check Parameters Settings

During wafer sawing process, when there is presence of low-k material or metal test pads in the saw street, which are difficult to cut, usually blade sawing is performed after laser grooving to achieve full cut. Adding the kerf check function can optimize this process.

The kerf check can be performed relative to the width or position of the detected groove/kerf. Due to the difference in depth of laser groove and blades kerf as illustrated in Figure 5, misrecognition of kerf occurs. Laser groove kerf check is included in wafer saw recipe to correctly recognize individual kerf.

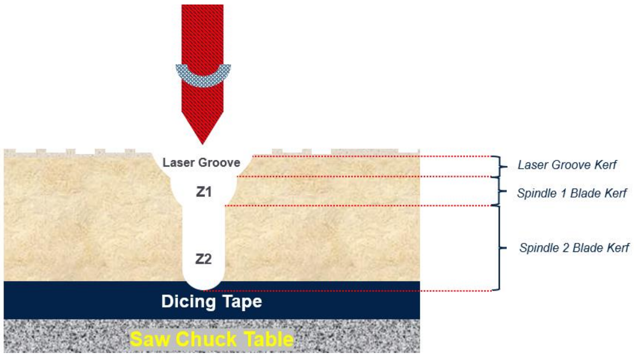


Figure 5. Laser Groove and Blades Kerf

2. 0 REVIEW OF RELATED WORK

Refer to 1.0 Introduction.

3.0 METHODOLOGY

3.1 Test Vehicle Description

The test vehicle stated below on Table 1. The wafer is a 12-inch, low-k device with 40 nm silicon technology. The die size is around 5.060 mm x 3.132 mm with a die thickness of 70 µm. Sawing Street is 80 µm.

Table 1. Test Vehicle Information

Test Vehicle	
Wafer size (mm)	300
Silicon technology	N90 EFLASH
Die size (mm)	5.080 x 3.132
Die Thickness (um)	70
Sawing Street (um)	80 x 80

3.2 Process Flow

The process flow is described in Figure 6. Wafer sawing is the focus of this study. For laser grooving, grooving the wafer on the target requirements and wafer sawing machine requires laser groove kerf check (LGKC) software capability to check both laser groove and sawing kerfs during cutting process.

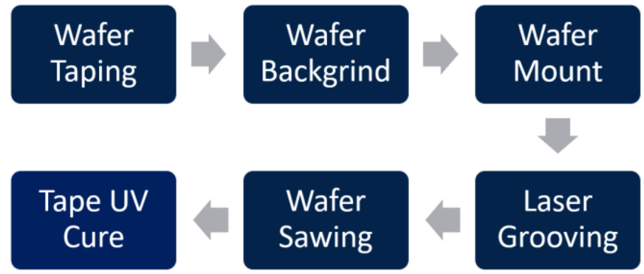


Figure 6. Test Vehicle Process Flow

This study will focus on wafer sawing process as shown in Figure 7 since LGKC data is included in device data of wafer saw given that the machine has software capability. The evaluation result will focus on reducing false alarms or invalid kerf check errors related to machine detection of position, width, and quality of laser groove, Z1, and Z2 kerfs, separately during kerf check process thus reducing machine assist when error prompts and ensure that laser groove and kerf are correctly detected and recognized by machine.

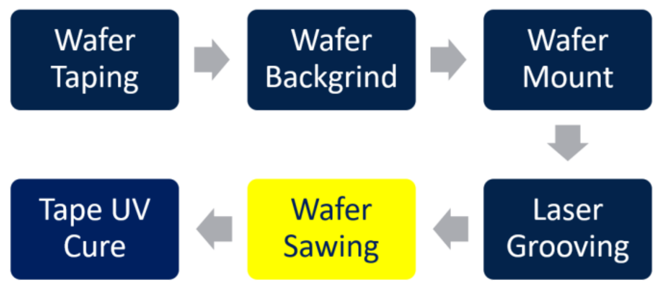


Figure 7. Focused Process of the Study

Based on initial observation, most of machine rejects were attributed to misdetection of kerf due to unoptimized light settings which resulted in detection of laser groove instead of actual sawing blade kerf. For instance, during kerf checking if the wafer is covered with water, camera might misrecognize this as part of the groove and/or kerf resulting in kerf errors.

Aside from light settings, kerf misrecognition occurs due to difference of individual blade kerf depth. In ideal case, laser groove and blade kerfs must be at the center position with respect to sawing street of the wafer.

Machine's top kerf check errors from last ten wafers processed prior optimization are shown in Figure 8. Machine's window display during event of kerf error is shown in Figure 9. But not all detected rejects by machine are confirmed as valid rejects.

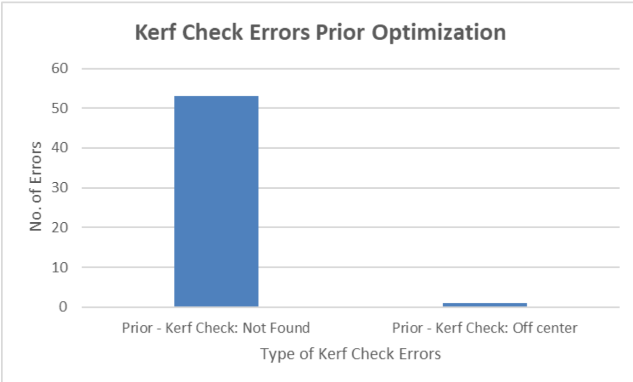


Figure 8. Machine top kerf check errors prior LGKC optimization

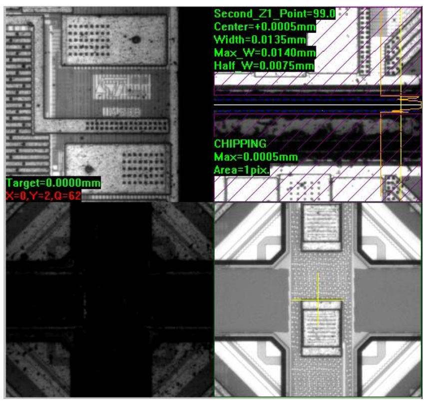


Figure 9. Machine window display with kerf error

Optimization performed is described in Table 2. Each kerf check parameter was optimized to adjust with the machine's camera settings and capability to correctly identify and recognize laser groove and blade kerf.

Table 2. Summary of Kerf Check Parameters Optimized

Parameters	Optimized Setting
Z1/Z2 Sensitivity	2 – less sensitive
Kerf Check Range	90%
Z2 center kerf check mask	5 ums
Kerf Check Algorithm	Reflection
Laser Groove Algorithm	Reflection
Groove Light Level	Dir: 30% Obl: 10%
Blade Light Level	Dir: 23% Obl: 70%

3.3 Laser Groove Kerf Checking Function

When wafer is low-k or there is presence of metal layers in sawing street, usually wafer sawing is performed after laser grooving. The kerf check can be performed relative to the width and position of the detected groove / kerf. This function ensures that laser groove and kerf are correctly detected and recognized by the machine shown in Figure 9 and Table 3. Critical parameters used in the optimization are explained in detail as shown in Table 2.

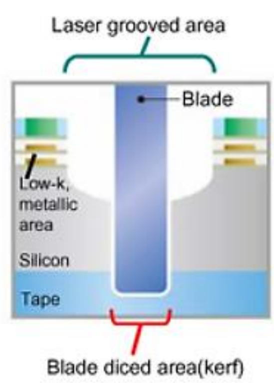


Figure 10. Laser Groove Kerf Checking[6]

Table 3. Types of Kerf Check Function[6]

Type	Description
Conventional kerf check function	The grooved area and the kerf are sometimes misrecognized.
Laser grooving kerf check function	The laser groove and kerf are correctly detected and recognized.

3.3.1 Z1/Z2 Sensitivity

This data determines the check sensitivity of Z1 and Z2 axes. The allowable value is 0 to 3, with 0 as the most sensitive. This parameter is used if the central part of the wide kerf is reflected by water, it reduces the sensitivity to prevent the central part from being misrecognized as a kerf.[7]

3.3.2 Kerf Check Range

This parameter specifies the allowable area of the wafer where kerf checking is done, excluding wafer edge dice. Recommended value is 90% minimum and depends on die size. [7]

3.3.3 Kerf Check Mask

The function that the machine does not recognize images as a kerf within the specified area is called "masking", which is useful for avoiding incorrect recognition. The "masking" will be done according to the specified values based on the center of a hairline.

When 0 is set, the "masking" will not function. If the edge of the kerf is not found within the recognition area, request for retrial or an error occurs. [7]

3.3.4 Kerf Check Algorithm

This function uniquely identifies blade kerf from other items present within saw street area (laser groove, metal pads, etc.). Recommended setting if saw street area is with design is Reflection, if with metal remain after laser groove or TEG (test element group) outside kerf use Reflection + TEG. [7]

3.3.5 Laser Groove Algorithm

This function uniquely identifies laser groove from other items present within saw street area (kerf, metal pads, etc.). Recommended setting if saw street area is with design is Reflection, if with metal remain after laser groove or TEG (test element group) outside kerf use Reflection + TEG. [7]

3.3.6 Grooving Light Level

The value used determines the direct and oblique light intensity of laser groove for each channel. Optimized light level supports machine's camera to correctly detect and recognize laser groove. [7]

3.3.7 Blade Light Level

The value used determines the direct and oblique light intensity of blade kerfs for each channel. Optimized light level supports machine's camera to correctly detect and recognize blade kerfs. [7]

3.4 Process Critical Output Response

As additional checking, below critical output response shown in Table 4 will be considered after optimizing kerf check data.

Table 4. Wafer Saw Output Response

Criteria	Wafer Saw Output Response
	Specification
Visual Inspection	Topside chippings (not touch seal ring)
Visual Inspection	Topside Peeling (not exceeding seal ring)
Visual Inspection	Backside Chippings (No Crack)
Visual Inspection	Crack (any amount)
Kerf Offset	+/- 3 um

4.0 RESULTS AND DISCUSSION

Below summarizes the results of the optimization performed in the test vehicle and the improvement in the wafer sawing process.

4.1 Laser Groove and Blade Kerf Checking

Laser groove and blade cutting conditions (width, position with respect to saw street, quality, etc.) are being assessed if within specified limit and specifications during machine kerf checking. Figure 11 shows machine's window display prior and after kerf data optimization, green values indicate that laser groove and kerf are correctly recognized by the machine and are within required limit while red values indicate kerf error.

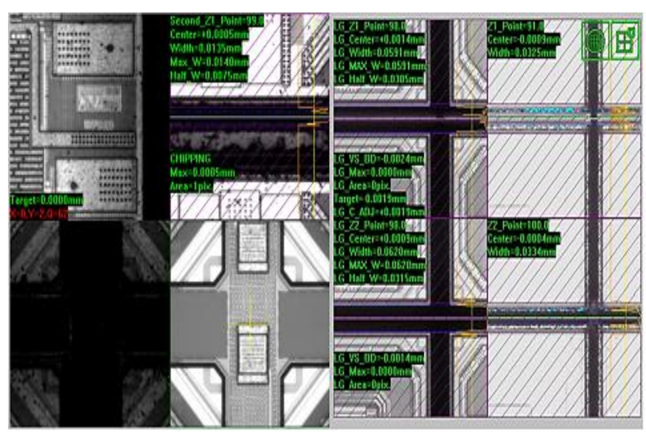


Figure 11. Laser groove and kerf checking conditions prior and after optimization (green is passed, and red is failed).

4.2 Kerf Check Errors and Process Time After Optimization

Kerf check data optimization was performed to support the machine's camera to correctly detect and recognize valid rejects and/or out of specifications groove and kerf as shown in Figure 11. Data shows that kerf check errors significantly decrease after optimization was performed.

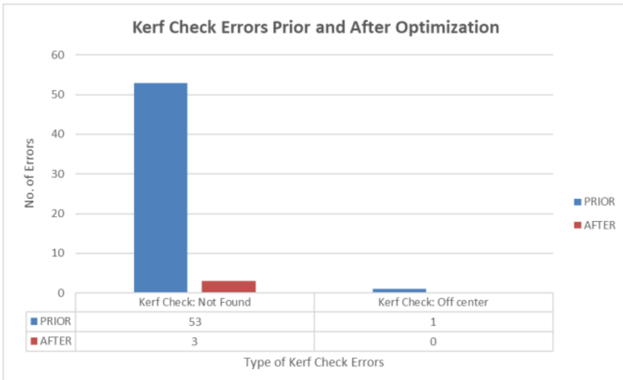


Figure 11. Kerf Check Errors Prior and After Optimization

Process Time is the amount of time it takes to complete the cutting process of one wafer. However, if kerf check data was not optimized, process time will increase due to multiple errors that require line personnel's assist. Based on the data from first ten lots processed after optimization shown in Figure 12, process time after kerf data optimization improved.

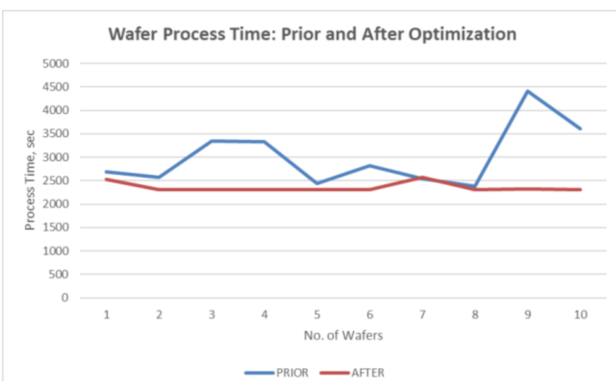
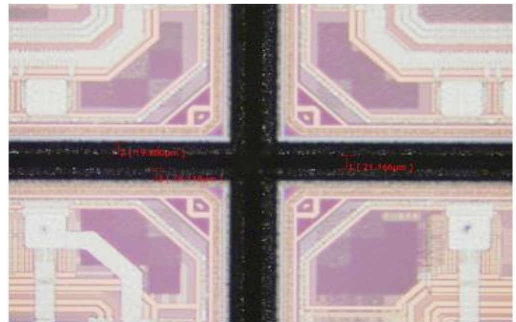


Figure 12. Wafer Process Time: Prior and After Optimization

The average wafer process time prior optimization is 3011.1 seconds, and after optimization is 2359.9 seconds which improved by 21.62%.

4.3 Kerf Offset

Kerf Offset refers to centering of blade kerf with respect to laser groove and sawing street. Required criteria for kerf offset is +/- 3 ums. Based on Figure 13, minimum kerf offset is 0.7 um and maximum is at 0.3 um which means that blade kerf is centered to laser groove and saw street.



Item	Spec	Min	Max	Average
Kerf Offset with respect to LG center	+/- 3 um	0.3 um	0.7 um	0.07 um

Figure 13. Kerf Offset

4.4 Visual Inspection

As additional checking, post process visual inspection results shown in Figures 14 and 15 show no major issue after laser groove and kerf check data optimization. Kerf width is centered and within specifications based on blade type requirement. No out of specification topside chipping, backside chipping, crack, and peeling observed.

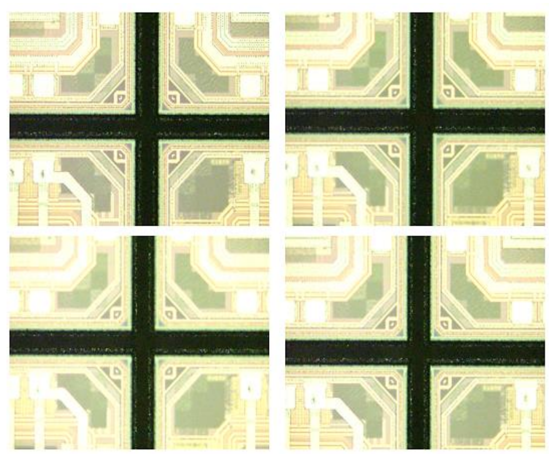


Figure 14. Post Saw Topside Visual Inspection Results

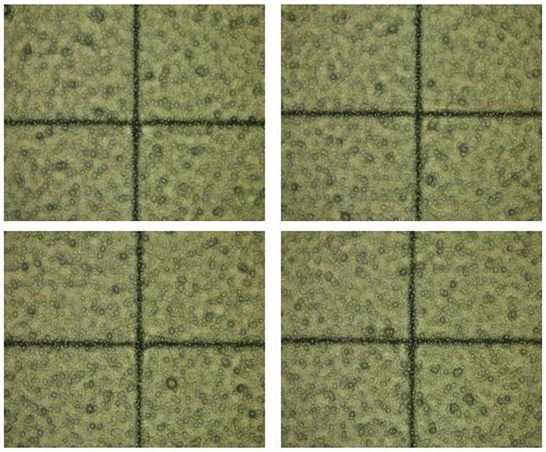


Figure 15. Post Saw Backside Visual Inspection Results

4.5 Process Critical Output Response

Based on the assessment of the optimization results, shown in Table 5, critical output response at wafer sawing passed all the defined requirements.

Table 5. Summary of Wafer Saw Output Response

Criteria	Wafer Saw Output Response	
	Specification	Results
Visual Inspection	Topside chippings (not touch seal ring)	Passed
Visual Inspection	Topside Peeling (not exceeding seal ring)	Passed
Visual Inspection	Backside Chippings (No Crack)	Passed
Visual Inspection	Crack	Passed
Kerf Offset	+/- 3 um	Passed

5.0 CONCLUSION

In this study, it has been shown that overall performance of wafer sawing process was improved. Valid kerf check errors were precisely identified by the machine thus minimizing error assist by operator, machine down time due to prolonged assist, improved UPH (units per hour) in production, and mostly improved over-all performance of wafer sawing process.

6.0 RECOMMENDATIONS

Based on the result of this study, that authors recommend inclusion of laser groove kerf check software to sawing machines and perform optimization of kerf check data to all devices with laser groove. Use the defined parameters for the test vehicle as reference and perform further optimization and monitoring based on machine's camera capability, saw street dimension, and device metal layer.

7.0 ACKNOWLEDGMENT

The authors would like to thank the leadership of ST-Calamba NPI and OPS1 for the help extended to make this study a success.

8.0 REFERENCES

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9.0 ABOUT THE AUTHORS

Engr. Vianriz Marini B. Bautista, ECE is a graduate of Bachelor of Science in Electronics Engineering at Polytechnic University of the Philippines – Sto. Tomas Branch. She passed the Licensure Examination for Electronics Engineers and Electronics Technician last October 2017. She started working as Process Engineer (Line sustaining) at Amkor Technology Philippines Inc. P3 handling Die Preparation Processes. She is currently assigned under New Production Development & Introduction at STMicroelectronics Inc., responsible for process optimization to support new packages and materials at Pre-assembly station.

Francis Noel A. de Erit is a graduate of Bachelor of Science in Computer Engineering at the STI College Santa Rosa. He started working in the semiconductor industry on WLCSP (fan in and fan out) package as Engineering Technician on the backgrind process. He is currently working at the New Product Development & Introduction at STMicroelectronics Inc. as a Process Technician.

Jan Kurt A. Bulayungan is a graduate of Electronics and Communications Engineering at Saint Louis University. Currently employed as Senior Engineer and leading the wafer preparation process engineering sustaining team of STMicroelectronics Calamba.