Cross-Platform Synergy on Defect Source Identification & Monitoring using PUMA9650 and CIRCL

Authors

Michael CHANG (ChoonWai), Junnee AW, Pek Beng ONG, Amanda TAY

Wafer manufacturers are patterning wafers closer to the wafer edge to use up all available silicon space in help reduce the cost per die. As such the wafer edge profile and defectivity are now critical areas of interest which require new methodologies to measure or inspect. Furthermore, the increased complexity in process steps and variety of materials used poses new difficulties to defect inspection and defect source isolation. This paper aims to develop an effective cross platform investigation between the Laser Scanning (PUMA9650) and SWIFT (CIRCL) tools in identifying the defect source and defect formation mechanisms; as well as to provide effective in-line monitoring solutions, focusing at the edge and bevel areas of the wafer.

Key Words: Cross platform synergy, Puma 9650, CIRCL CV310i, DSA, Yield Engagement; Wafer edge

I. Introduction

Moore's law has driven semiconductor chips manufactures to improve, optimize and even redesign the architectures in order to have more functionality with less silicon real estate. Manufacturing of these chips are becoming increasingly complicated with hundreds of additional steps compared to their predecessors. Despite the increasing cost of manufacturing, chip manufactures are exploring new ways to keep the cost per die low in order to stay competitive in the market. One way is to pattern the wafers closer the wafer edge to use up all available silicon space in order to manufacture as many chips as possible from a wafer. This approach, however, has given rise to new challenges.

Firstly, as the technology node shrinks, the critical dimension of the micro-patterned features also reduces. Small defects that could be nuisance in the past are now defects of interest (DOI). Secondly, as the patterns are printed closer to the wafer edge, the wafer edge profile and defectivity has become critical areas of interest which require new methodologies to measure or inspect. Thirdly, the increased complexity in process steps and variety of materials used pose new difficulties to defect inspection and defect source isolation.

A. *Need for a Collaboration*

Based on the challenges listed above, there is a need to find small defects that originate from the wafer edge which later migrate onto the wafer front side.

Employing the capabilities of both the PUMA9650 and CIRCL CV310i, has proven to be advantageous as information from both tools are put together to provide a comprehensive data set for DSA work as illustrated in Fig. 1. PUMA9650 is able to provide an advanced Laser Scanning

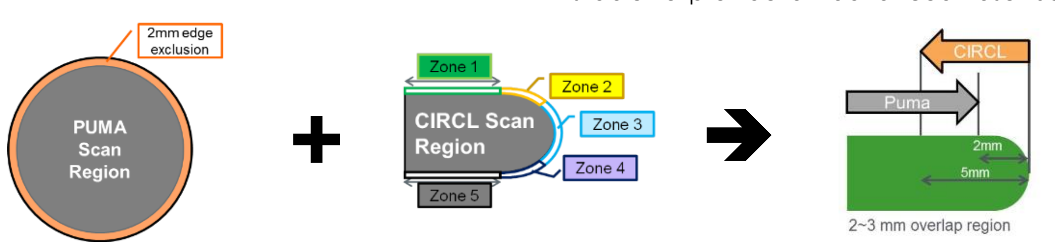

Fig. 1 PUMA9650 and CIRCL CV310i scanning areas used together can provide a full edge to front side defect detection

inspection on the front side of the wafer to a 2mm exclusion. While CIRCL edge module (CV310i) provides edge defect inspection and multi-layer edge metrology ~5mm into the front and backside of the wafer to provide greater coverage and more accurate determination of the film edge.

PUMA9650 and eDR7110 were used for partitioning and review of defects down to 0.2µm. PUMA9650, having a high throughput and sensitivity together with the option to scan the partial die areas has been proven to be instrumental in flagging potential defect cluster areas, identify sources of defects and even indicate where defects could have originated from. Defects of 0.2µm are of interest as they block the contact holes on the wafer and impact the yield. Apart from investigating the front side of the wafer including the partial die area, the edge of the wafer was also inspected as that is potential area where defects are originated. By using the CIRCL edge module (CV310i) one is able to review the cleanliness of the wafer edge and identify defects of interest which could migrate to the front-side of the wafer. CV310i is also able to provide traceline details to flag poor or non-concentric residue coatings, under/over or uneven polishing and check various cleaning processes and their efficiency on the edge.

B. *Process Flow*

A systematic study was carried out to understand the process flow and where the defects were first detected. Suspected defect sources were identified from the process flow and partitioned inspection was carried out. PUMA9650 with its high throughput and sensitivity was used to comb through the suspected layers as a quick means to pinpoint the defect source. The partial die feature coupled with a 2mm edge exclusion enabled the detection of the defect source much earlier as compared to using full die inspection only. At the same time, CIRCL (edge module) was used to inspect the same layers but looking at the edge trace line and defectivity instead. An additional step was inspected with CIRCL prior to the step where the PUMA first saw the defect signature in order to understand the wafer edge or bevel conditions. This cross-platform synergy was proven powerful in nailing down the defect source and the defect formation mechanisms, and further provides effective in-line monitor solutions.

The cross-platform partnership between PUMA and CIRCL also provides as an education to the customers into how to investigate, improve and monitor these areas that were previously disregarded. The new knowledge and establishment of an investigation BKM flow has helped both customers and KT engineers to accelerate the identification and resolution of new yield issues especially at the wafer edge.

The process flow matrix is represented in Fig. 2.

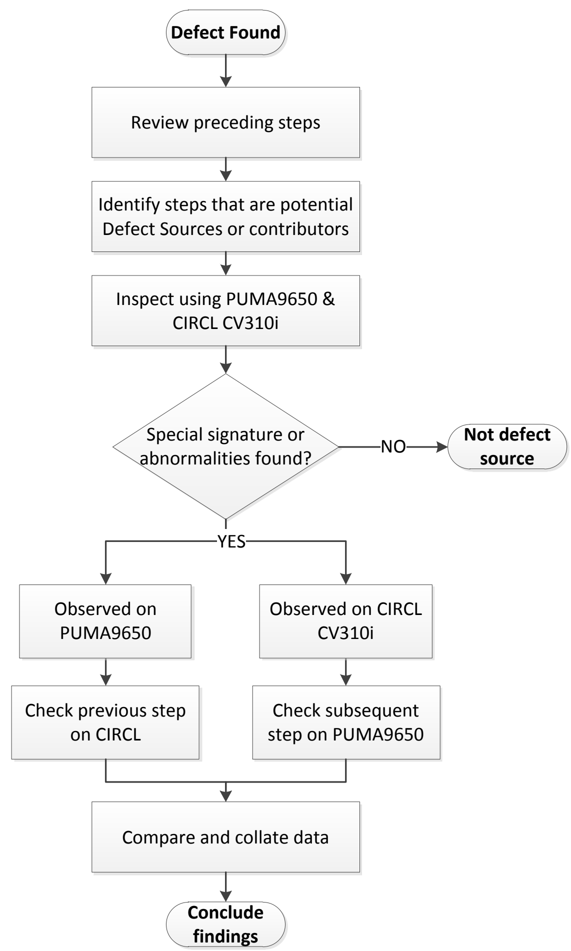

Fig. 2 Process flow Matrix for investigation of defect source

II. Results and Discussion

A. *Use Case*

Streak patterns were identified in the later stages of a particular process loop. Further investigation by the customer revealed that these streaks begin occurring in the steps after

POLY DEP.

After reviewing the preceding steps, the following 11 steps (including the problematic step) in Table 1 were identified for recipe set up on both the PUMA and CIRCL to conduct an in depth investigation.

Step	Step Identified	Recipe Created	
		PUMA	CIRCL
1	CARBON DEP	√	√
2	PHOTO		√
3	CARBON DRY ETCH CLN	√	√
4	INTEGRATED DRY ETCH CLN	√	√
5	INTEGRATED DRY STRIP CLN	√	√
6	POLY WET ETCH	√	√
7	PRE OXIDATION CLEAN	√	
8	OXIDATION	√	√
9	NITRIDE DEP	√	√
10	NITRIDE DEP RINSE	√	
11	POLY DEP	√	√

Table 1 Process Step Identified for Recipe setup

B. *PUMA9650 Results*

Fig. 3a represents the results from the DSA study for PUMA9650. With partial die incorporated, streak signature is noted at the integrated dry etch clean step instead of the original poly deposition step (at the live die), Fig. 3b.

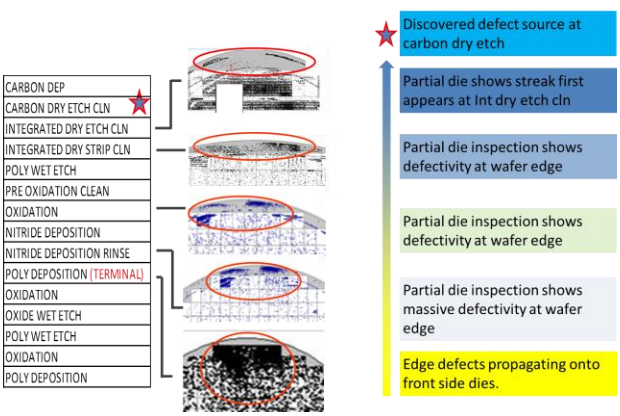

Fig. 3a DSA Study for PUMA9650

Fig. 3b Effect of Partial Die Inspection

Effective in-line monitoring can thus be implemented at the integrated dry etch clean step by monitoring of particle counts at the partial die region. iDO is used to bin out the particle defects at the partial die and monitoring chart can be setup based on this binning.

C. *CIRCL CV310i Results*

Using the CIRCL to conduct the DSA study, a comprehensive overview of the edge condition and the transformations of the defects from step to step can be reviewed. Fig. 4 shows the transformation of the edge condition to form a trench on the edge of the wafer. An eDX test done to determine the material composition of the material in the trench revealed that the material composition corresponds to the material of the particles that creates the streaks.

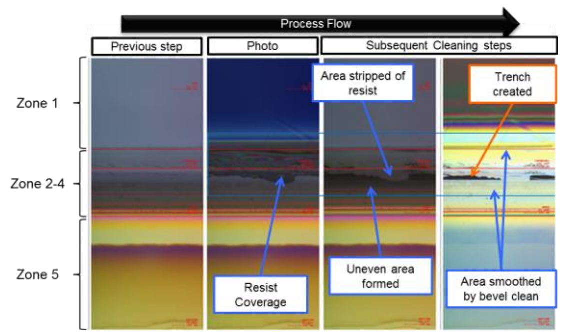

Fig. 4 Wafer Edge Review (WER) Images. From left to right, the first image shows the wafer condition prior to application of resist at PHOTO step; the second image shows the wafer condition after the application of resist. The third and fourth images show how the condition of the edge changes during subsequent cleaning steps.

Fig. 5 shows Zone 2-4 (apex region) of the wafer. From the diagram, it can be seen that there is a large additional layer of material from the 90° to 0° (from left to right) on the apex. An eDX test on the area revealed the material composition of the area also corresponds to the particles that contribute to the streaks.

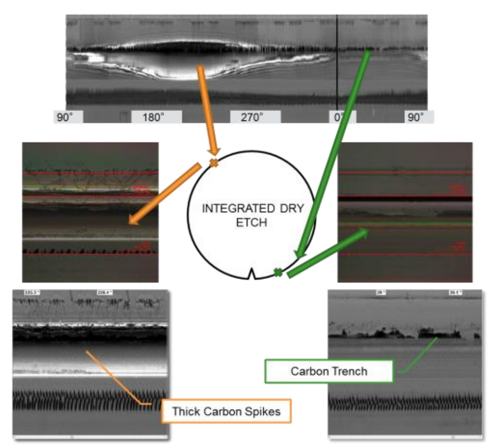

Fig. 5 Top: Panoramic image of the Apex of the wafer, Left: WER image and a zoomed in section of the carbon Spike region at 225°. Right: WER image and a zoomed in section of the carbon Spike region at 30°

From these two images, it can be hypothesized that there are two mechanisms by which the DOIs for the streak patterns are formed (Fig. 6). The DOIs coming from the carbon trench follows Mechanism 1 while the DOIs coming from the Thick Carbon Spikes between 90° to 0° follows Mechanism 2.

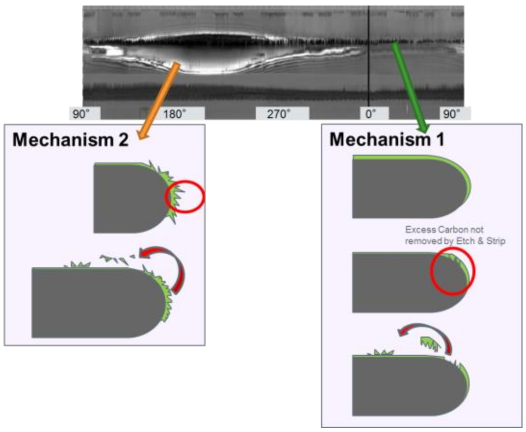

Fig. 6 Areas on the edge that corresponds with the different mechanisms by which DOIs are formed.

D. *Combined Results & Proposal*

By using a combination of the results from the PUMA and CIRCL, the customer was able to quickly pin point the process that is causing the problem and through a series of tests was able to confirm Mechanism 1. It was found that the trench created by Mechanism 1 could be solved by changing the Edge Bead Removal (EBR) process parameter. This change led to a significant reduction of defects on the front side of the wafer proving the hypothesis (Fig. 7). Effective monitoring of the process in this case is to introduce in-line monitoring with PUMA partial die monitoring as well as EBR traceline monitoring on the front side of the wafer using the CIRCL.

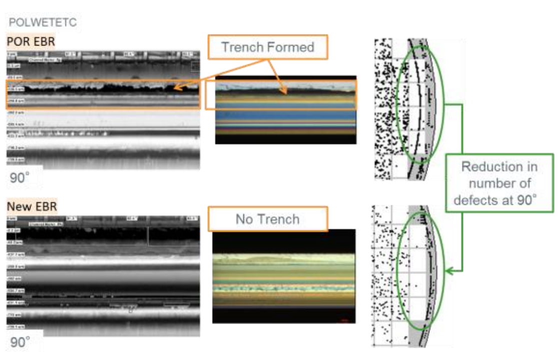

Fig. 7 Left and center images from CIRCL, Right images from PUMA. Change of process parameter prevented Mechanism 1 from occurring and reduced the number of defects on the front side of the wafer significantly.

The carbon spike region that triggers Mechanism 2 was found to exist on all subsequent steps after a number of cleaning steps with no change to the size and shape of the region. The issue was tracked back to the CARBON DEP step, where it was found that carbon deposition on the wafer was not uniform causing varying thickness of carbon material to be deposited on the edge of the wafer (Fig. 8). The thicker coated regions will become the area where carbon spikes will form as it moves through the process. Though the findings were mostly realized by CIRCL for Mechanism 2, PUMA with partial die turned on also played a crucial part in identifying the DOIs and suspected area of origin without which the building of these hypotheses would not have been possible. Effective monitoring of the process in this case is to introduce in-line Residue traceline monitoring on the edge of the wafer using the CIRCL.

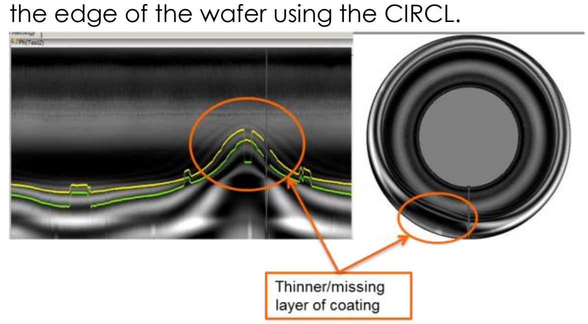

Fig. 8 Zone2-4 (Apex) region of wafer after CARBON DEP

III. Conclusion

Despite the challenges mentioned earlier, the Yield Engagement Project which initiated the cross-platform initiative was successful in fulfilling its purpose. To help the customer resolve the issue in a timely manner, to help the customer identify and implement meaningful and comprehensive in-line monitoring of their process and to set a platform for similar projects in the future.

Acknowledgment

The authors of this paper would like to recognize and acknowledge the following people for their support and inputs:

KT:

Michael CHANG, Pek Beng ONG, Wee Teck CHIA, Willie NG

MICRON:

Thomas LEE, Eric PNG, Andy KHOR