Comparison of TeraStar SL1, TeraScanHR DDR, DDT and SL2 to identify an efficient mask re-qualification inspection mode for 7Xnm half pitch design node production reticles in advanced memory wafer fab

Koji Kaneko[a], Takanobu Kobayashi[a], Jinggang Zhu[b], Norihiko Takatsu[b], Paul Yu[b], Kosuke Ito[b], Toshiaki Kojima[b] and Yoshinori Nagaoka[b]

[a]Elpida Memory, Inc., Hiroshima, Japan

[b]KLA-Tencor Corporation, San Jose, California, USA

Abstract

This paper discusses the most efficient mask re-qualification inspection mode for 7Xnm half pitch design node production memory reticles in advanced memory wafer fab. By comparing overall performance including inspectability, sensitivity, and throughput for 8 different inspection modes, P150 Pixel Die-to-Die Reflected Light (P150 DDR) was identified to be the most desirable inspection mode for the specific use case where only one inspection mode is available. The evaluation was executed on the most critical layers – active, gate and contact layer. P150 DDR demonstrates the capability of providing early warning for the crystal growth type defects on both quartz and MoSi surfaces. It also showed good sensitivity for capturing small contamination defects in the dense Line/Space or Contact/Hole pattern areas. With a fast inspection scan speed and easy to use set up, TeraScanHR P150 DDR offers the best cost of ownership among all inspection modes. To gain higher sensitivity for smaller design nodes, TeraScanHR P150 DDR can be easily extended to smaller inspection pixels with minimum impact on productivity.

Keywords: TeraScanHR, Reticle Inspection, DRAM, DDT, DDR, SL2

Introduction

As IC technology pushes increasingly challenging design nodes, complexity of the corresponding photomasks increases dramatically as well to meet the stringent requirements. This requires photomask inspection systems to develop advanced inspection modes in order to enable smaller design node development and improve the production yield[1, 2, 3]. One of the key challenges for advanced inspection systems is to

Photomask and Next-Generation Lithography Mask Technology XV,
edited by Toshiyuki Horiuchi, Proc. of SPIE Vol. 7028, 70282M, (2008)
0277-786X/08/$18 · doi: 10.1117/12.793092

meet these requirements by optimizing economic inspection modes to satisfy unique use cases specific to memory, logic and foundry applications. This study identifies the most optimal inspection mode for the DRAM manufacturers to support 7Xnm half pitch design node production reticles where they may have only one inspection mode at high productivity.

Three inspection modes developed by industry leader KLA-Tencor have been widely adopted over many years of use in the industry: Die-to-Database, Die-to-Die and STAR*light*™. Die-to-Database inspection is more suited for mask shop applications requiring the highest sensitivity levels and the large database preparation systems. However a typical DRAM fab's needs are better met with a Die-to-Die or STAR*light* inspection[4]. This paper compares Die-to-Die (DD) and Starlight (SL) inspection strategies. More specifically, STARlight P150 (TeraStar), STARlight P150, P125, P90, Die-to-Die Reflected P150, P125 and Die-to-Die Transmitted (DDT) P150, P125 (TeraScanHR) inspection modes were compared for DRAM application (Figure-1).

In this study, 3 critical reticles were selected from Elpida's 7Xnm half pitch DRAM fab for the optimal mode evaluation. These reticles represented critical layers – active, gate and contact. Inspections were set up and performed on KLA-Tencor's TeraScanHR system and TeraStar system.

The rules used to evaluate an inspection mode are listed below:

a. Good sensitivity – able to capture critical defects of interest and provide early warning for the haze defects.

b. Good inspectability – able to inspect the reticle without generating excessive false defects.

c. Optimal cost of ownership with higher throughput

d. Extendibility – able to be extended to smaller pixel without minimum impact on production for smaller design nodes

Results and Discussion

1. Overview of all inspection modes

The inspection matrix in figure-1 below showed the real defect count and total defect count captured by each inspection mode using different pixel sizes. The larger the real defect count, the higher the sensitivity of the inspection mode. If the ratio of real defect count over total defect count is small, it means false defect count is high and thus the inspectability is poor. For each inspection listed in the table, the recipe is optimized with highest sensitivity settings without generating excessive false defects – the corresponding sensitivity settings are referred to be "highest usable sensitivity". As a general rule, a smaller pixel inspection mode has a lower throughput than a large pixel inspection mode no matter which inspection type it is.

Looking at the inspection matrix, it is clear that SL1 P150 (STAR*light* on TeraStar system) inspection mode caught more false defects than real on both plate A and plate B although. So SL1 P150 is not a good inspection mode to inspect all 7Xnm half pitch reticles for Elpida DRAM application.

Inspection Matrix

Plate A	SL2 TeraScanHR	DDR TeraScanHR	DDT TeraScanHR	SL1 TeraStar
P150	0/84	3/3	1/5	1/65
P125	1/4	2/2	3/3	
P90	7/8	11/11		
Plate B	SL2	DDR	DDT	SL1
P150	1/3	132/132	0/2	1/96
P125	22/22	440/440	1/4	
P90	1014/1014	3208/3219		
Plate C	SL2	DDR	DDT	SL1
P150		8/8	1/1	
P125	0/0	12/12	2/2	
P90	24/24			

*The number x/y means x=real defect count, y=total defect count

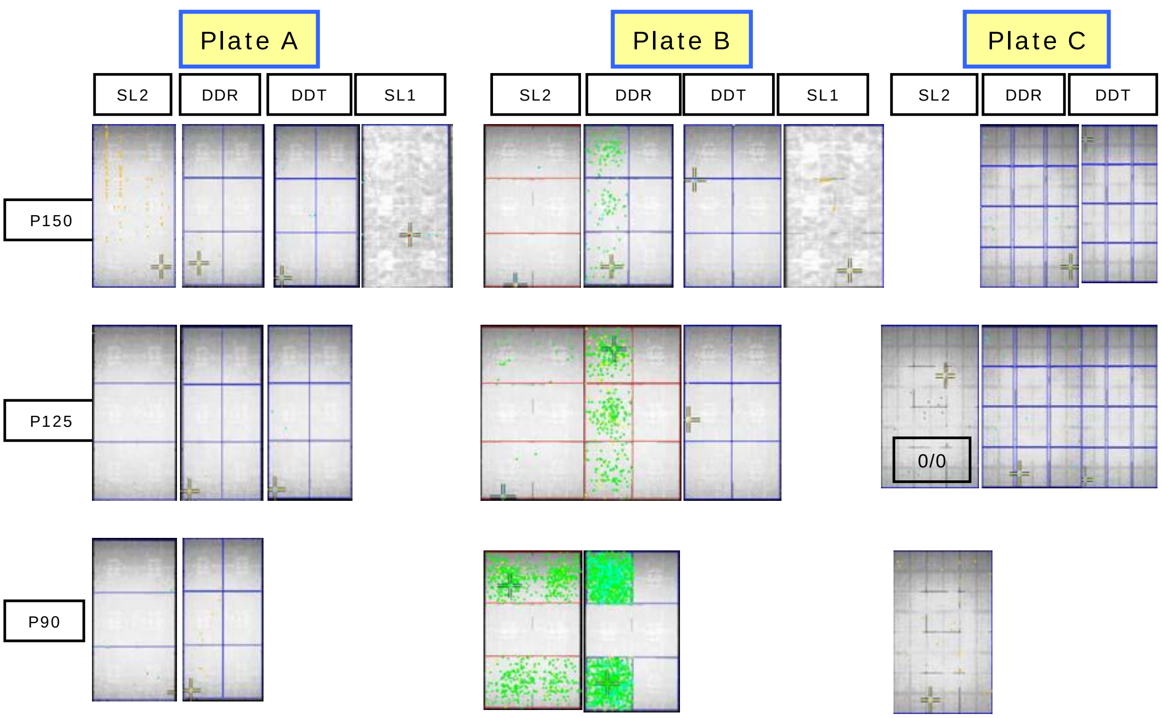

Figure-1. Inspection matrix and defect maps of DDR, DDT SL2 and SL1 on 3 critical reticles

Secondly, SL2 (STAR*light* on TeraScanHR system) P150 and P125 are not able to capture most of the real defects on the reticles with the highest usable sensitivity on plate A, plate B and plate C. This eliminates both of them as candidates in the comparison. The main problem here is the highest usable sensitivity is low due to false defect appearance.

SL2 P90 demonstrated good sensitivity and inspectability on all test reticles as shown above. Technically, it is a good inspection mode to Elpida use case. But SL2 P90 throughput is the lowest.

On the other hand, DDT P150 and P125 showed good inspectability on all test reticles. The same is true for both DDR P150 and P125. To find out the best inspection mode, it is necessary to look deeper to see the difference of sensitivity between DDR P150, P125 and DDT P150, P125 which all demonstrated good inspectability. The rule of thumb is to find the critical defects and provide early warning for haze defects with highest throughput and manageable false defect counts.

2. Comparison between DDR P150 and DDT P150

Figure-2 is the head to head comparison of sensitivity between DDR P150 and DDT P150. The first row is the images from selected defects captured by DDR P150 and the second row is the images from selected defects detected by DDT P150. All critical defects and representative haze defects are shown in the figure. The red circles in the image show the defect locations.

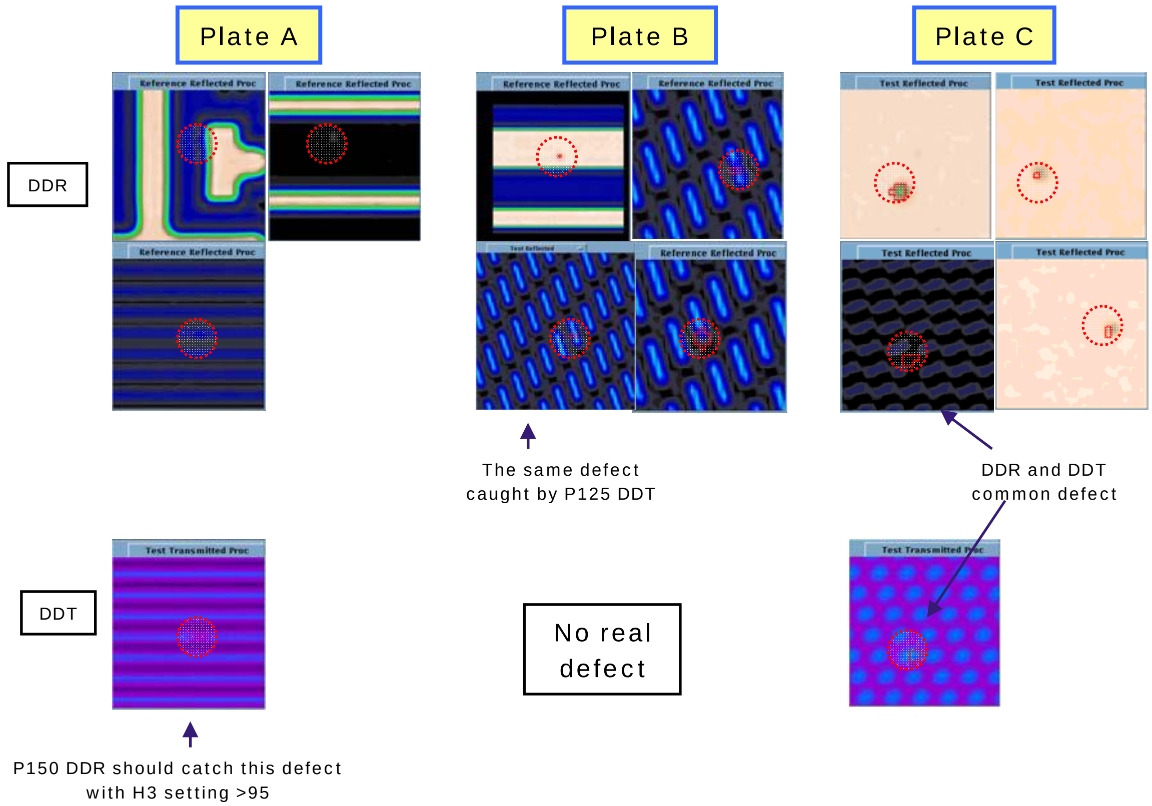

Figure-2. Comparison of DDR P150 and DDT P150 inspections on test reticles

It is found from the figure-2 that DDR P150 captured all the critical defects detected by DDT P150. But DDT P150 missed all critical defects in the dense pattern area on the plate B and these defects are important to be found. Even further, DDT P150 did not detect any haze defects on the MoSi due to the very small modulation of those defects in the transmitted images. So DDT P150 is not a good inspection mode to provide early warning for the haze control and it is eliminated from the candidate list from now on.

3. Comparison between DDR P150 and DDR P125

Next step is to compare DDR P150 and P125 as shown in figure-3. The first row is the images of selected defects captured by DDR P150. The second row is the images of selected defects captured by DDR P125.

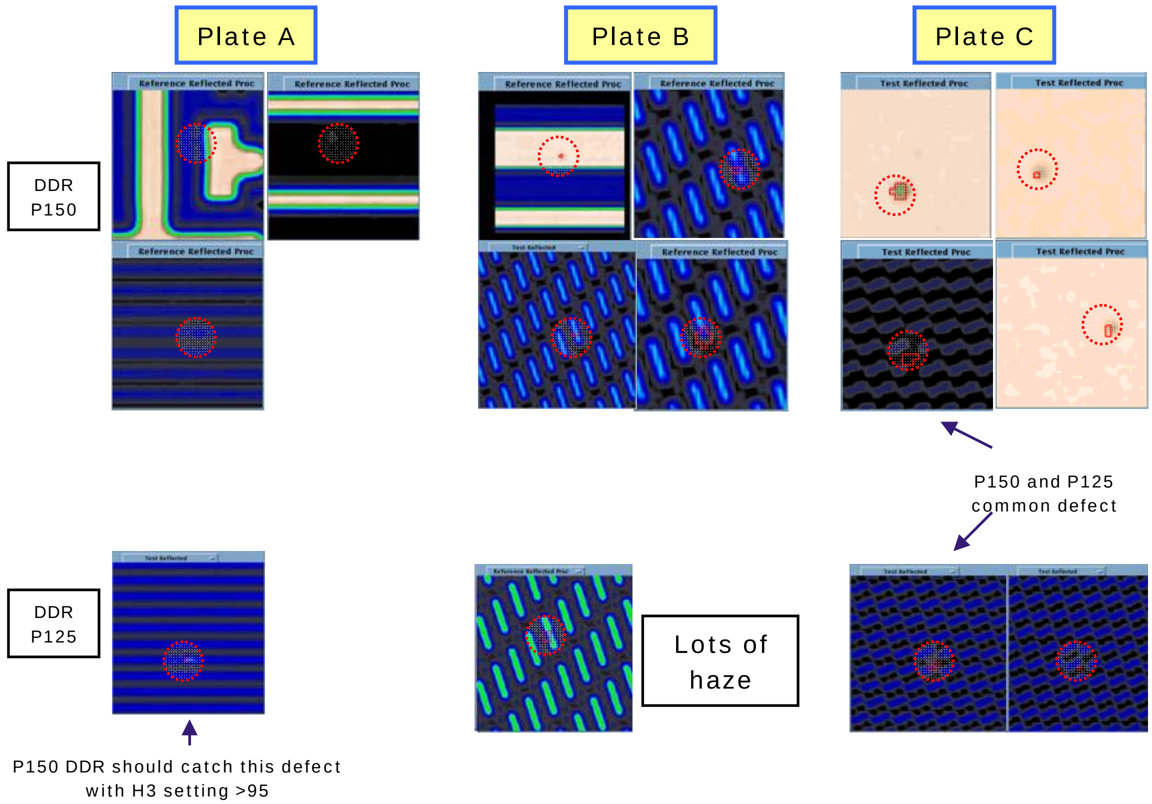

Figure-3. Comparison of DDR P150 and DDR P125 inspections on test reticles

In figure 3, DDR P150 detected some of critical defects in the dense pattern area as reported by DDR P125 on plate B and plate C. These defects are generally important defects. At the time of this study, those defects were not printed on the wafer so DDR P150 is thought to provide enough sensitivity in the dense pattern area by detecting some of those critical defects. DDR P150 also detects lots of haze defects which can provide enough early warning on the haze plates such as plate B and plate C. DDR P125 did report more defects than DDR P150, but those defects detected are small haze defects and can not be printed on the wafer. So DDR P150 has demonstrated good enough sensitivity in the dense pattern area and can provide early warning on test reticles. DDR P125 can provide extra sensitivity but it is not critical for this use case.

Conclusion

We evaluated various inspection modes on 3 critical layer reticles for 7Xnm half pitch DRAM application. After side-by-side comparison, each inspection is scored based on their performance on all test reticles and the results are shown in figure-4.

Score	Throughput	Inspectability	Sensitivity	Extendibility	Total Score
SL1 P150 TeraStar	High	Good	Low	No	Low
SL2 P150 TeraScanHR	High	Low	Low	Yes	Low
SL2 P125 TeraScanHR	Moderate	Moderate	Moderate	Yes	Moderate
SL2 P90 TeraScanHR	Low	Good	High	Yes	Moderate
DDR P150 TeraScanHR	High	Good	High	Yes	High
DDR P125 TeraScanHR	Moderate	Good	High	Yes	Moderate
DDT P150 TeraScanHR	High	Good	Moderate	Yes	Moderate
DDT P125 TeraScanHR	Moderate	Good	Moderate	Yes	Moderate

Least desirable
Moderate desirable
Most desirable

Figure-4. Scorecard comparing different inspection modes

Overall, for this use case, SL1 P150 scored low due to its low sensitivity and no extendibility. SL2 P150 scored low due to relatively poor inspectability and sensitivity on selected reticles even though their throughputs are high. SL2 P90 scored moderate due to lower throughput. DDR P125 and DDT P125 scored moderate due to lower throughput than P150. DDT P150 scored medium because of limited sensitivity in the pattern area and to provide early warning for the haze control.

In conclusion, DDR is the best inspection mode for the Elpida 7Xnm half pitch DRAM applications based on the comparison of inspections on 3 critical test reticles. It provides good sensitivity, early warning for haze defects, highest throughput and best cost of ownership. It also has extendibility to smaller pixel size for smaller design rule reticle inspection needed for next node generation.

Acknowledgements

KLA-Tencor authors would like to express deep appreciation for the help provided by Elpida memory, Inc. during this study.

Reference

1. Andre Poock et al., “Wafer Fab Mask Qualification Techniques and Limitations”, 26th Annual BACUS Symposium on Photomask Technology, Proceedings of the SPIE Vol. 6439, pp63490U-1 to 63490U-12.

2. Stephanie Maelzer et al., “High-resolution Mask Inspection in Advanced Fab”, 26th Annual BACUS Symposium on Photomask Technology, Proceedings of the SPIE Vol. 6439, pp63490S-1 to 63490S-12.

3. Arndt C. Durr et al., “Inspectability and printability of lines and spaces halftone masks for the advanced DRAM node”, 26th Annual BACUS Symposium on Photomask Technology, Proceedings of the SPIE Vol. 6439, pp63490O-1 to 63490O-9.

4. Do Young Kim et al., “Implementation of Reflected light Die-to-Die Inspection and ReviewSmart to Improve 65nm DRAM Mask Fabrication”, 25th Annual BACUS

Symposium on Photomask Technology, Proceedings of the SPIE Vol. 5992, pp599209-1 to 599209-11.