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Yoshinori Hagio, Ichirota Nagahama, Yasuo Matsuoka, Hidefumi Mukai, Koji Hashimoto, "Novel mask qualification methodology with die-to-database wafer inspection system," Proc. SPIE 7379, Photomask and Next-Generation Lithography Mask Technology XVI, 73790V (11 May 2009); doi: 10.1117/12.824272

Event: Photomask and NGL Mask Technology XVI, 2009, Yokohama, Japan

Novel Mask-Qualification Methodology with Die-to-Database Wafer Inspection System

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ABSTRACT

Turn around time (TAT) of mask qualification is one of the most important factors for high-end mask installation to LSI production lines. Accurate mask qualification with shorter TAT for mask process updates brings about steep ramp-up of LSI volume production. In this paper, an innovative approach is described for mask qualification with a die-to-database (D2DB) inspection system that can accomplish both qualification accuracy and short TAT in low k_1 lithography. The D2DB inspection system, NGR2100[1], has features satisfying the above requirements owing to larger field of view (FOV) and higher probe current than those of CD-SEM. Compared with the conventional optical inspection tool, the system provided higher accuracy in extracting fatal defects called "hotspots". Also, hotspots extracted by the system covered all killer hotspots extracted by electrical and physical analysis [2]. The contours of hotspots extracted by NGR2100 are transferred to GDS data format to compare hotspots between conventional mask process and updated mask process. If the differences between the contours are within an assumed tolerance, the system provides the qualification for updated mask process. As a result, qualification TAT was reduced by as much as two months compared with the conventional electrical qualification on wafers.

Keywords: Mask qualification, Die-to-database inspection, Hotspot management, DFM

1. INTRODUCTION

Turn around time (TAT) of mask qualification is one of the most important factors for high-end mask installation to LSI production lines. Figure 1 shows development flow of mask and wafer process. Ideally, mask-process development should precede wafer-process development. It means that the mask process should be fixed before wafer-process development starts as shown in Fig.1 (a). Actually, however, mask-process development may still be ongoing after wafer-process development starts as shown in Fig.1 (b). It means that the TAT of mask development becomes shorter owing to acceleration of smaller device geometries. Therefore, from now on, such an acceleration of smaller device geometries compels almost concurrent process development for mask and wafer, and quick mask qualification is required each time its process is updated.

Figure 2 shows the conventional mask-qualification flow. After mask making, the mask is firstly qualified with CD measurement and defect inspection of the mask patterns at the mask house. Then after mask installation to the wafer-fabrication plant (fab), the mask is qualified a second time, with CD measurement and optical inspection of the printed wafer patterns at the wafer fab. After device fabrication, the mask is finally qualified with electrical probing test of devices on the wafer. Up to the test, two to four months will already have passed since mask installation to the wafer fab. In view of the need for shorter development TAT, such a time-consuming mask-qualification flow with electrical probing test is unacceptable.

Photomask and Next-Generation Lithography Mask Technology XVI, edited by Kunihiro Hosono
Proc. of SPIE Vol. 7379, 73790V · © 2009 SPIE · CCC code: 0277-786X/09/$18 · doi: 10.1117/12.824272

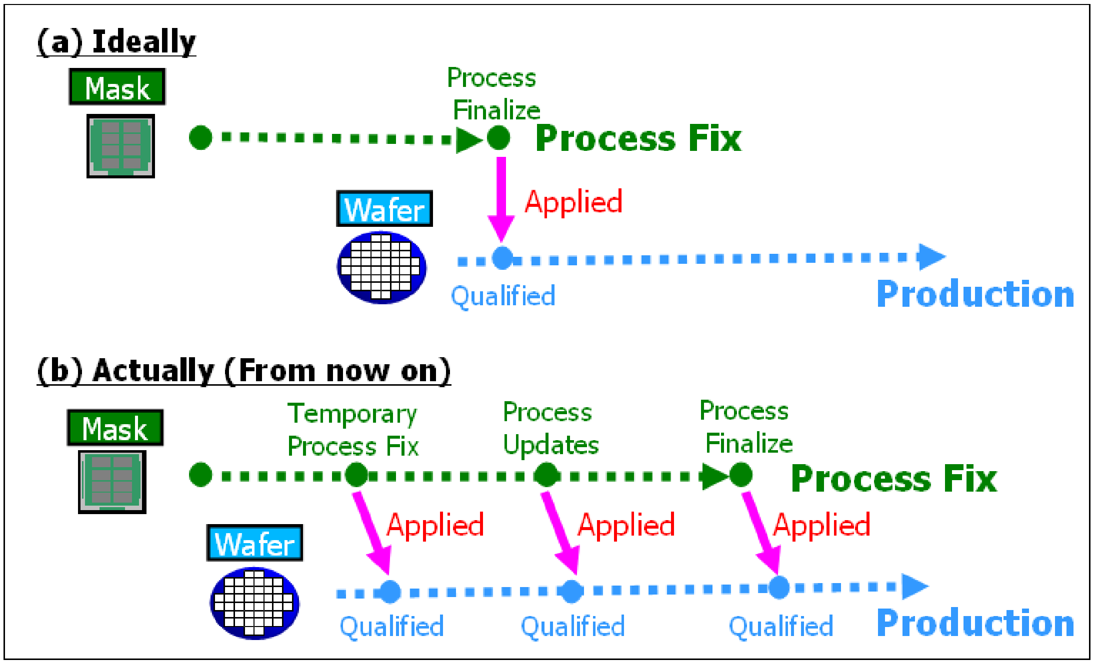

Figure 1. (a) Ideal mask process qualification. (b) Actual mask process qualification.

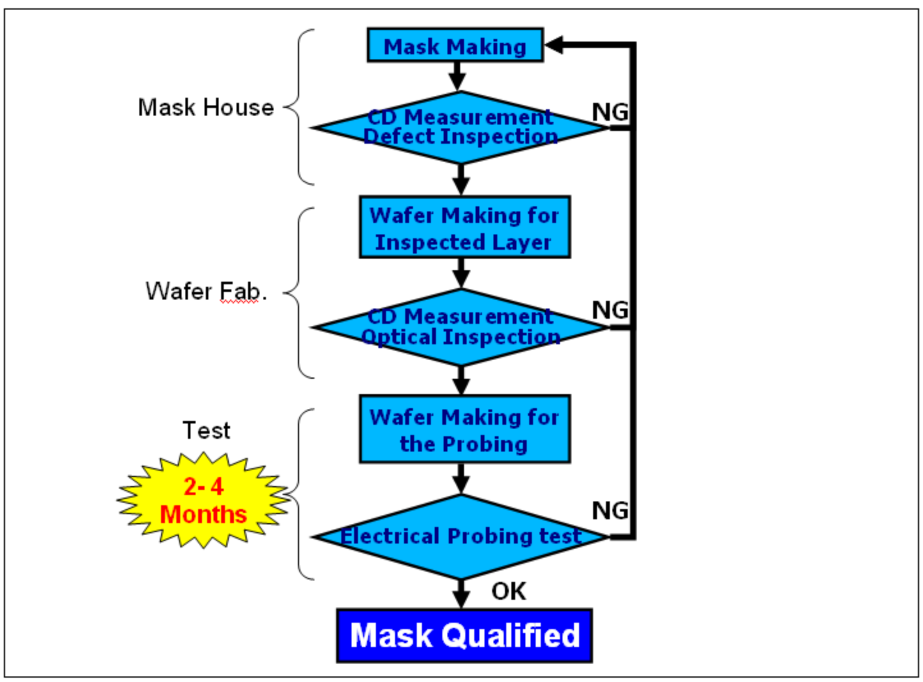

Figure 2. Conventional mask-qualification flow

2. MASK QUALIFICATION FLOW WITH EB-DIE-TO-DATABASE WAFER INSPECTION SYSTEM

Figure 3 shows the principle of the Electron-Beam (EB)-Die-to-Database (D2DB) inspection system. The EB-D2DB inspection system has potential to exactly extract hotspots by comparing SEM images of printed wafer patterns and target CAD data. Patterns having a large deviation from the target data are defined as hotspots. High-resolution pattern image of electron beam enables accurate hotspot extraction and also enables CD measurement of patterns. Compared to conventional optical inspection, EB-D2DB inspection has three advantages. Firstly, an accurate hotspot extraction is achieved by the electron beam resolution and D2DB algorithm. Secondly, CDs of wafer patterns can be measured concurrently with hotspot extraction. Thirdly, using the D2DB algorithm, a precise contour of SEM image can be output as GDS data. Owing to the function, two-dimensional hotspots are easy to estimate. In view of these advantages, all the patterns can be verified on their own layers, and therefore we think the EB-D2DB inspection is usable for mask qualification without electrical probing test. Figure 4 shows the proposed mask qualification flow with die-to-database inspection compared with the conventional one. For quick mask qualification, we introduce the D2DB inspection system without electrical probing test. The introduction of the system can reduce mask qualification by about two months by omitting the electrical probing test and result in development TAT reduction.

To realize the proposed flow, we introduced NGR2100, the EB-die-to-database wafer inspection system. NGR2100 consists of wide field-of-view (FOV) SEM and geometry verification software. Wide FOV and high scan rate of secondary electron acquisition realizes high-speed inspection with SEM resolution. Figure 5(a) shows a view of NGR2100. Systematic defect, which is difficult to detect by die-to-die inspection, can be extracted by the algorithm as shown in Fig. 5(b). The mask-qualification methodology with NGR2100 is described in Fig. 6. Printed wafers by updated mask processes were inspected by the NGR2100 from three viewpoints of metric: “mean CD measurement”, “hotspot extraction” and “hotspot-CD measurement”. Of course, the metrics have reasonable specifications based on lithography target, process assumption and device characteristics. Passing these inspections results in completion of mask qualification for the updated mask process.

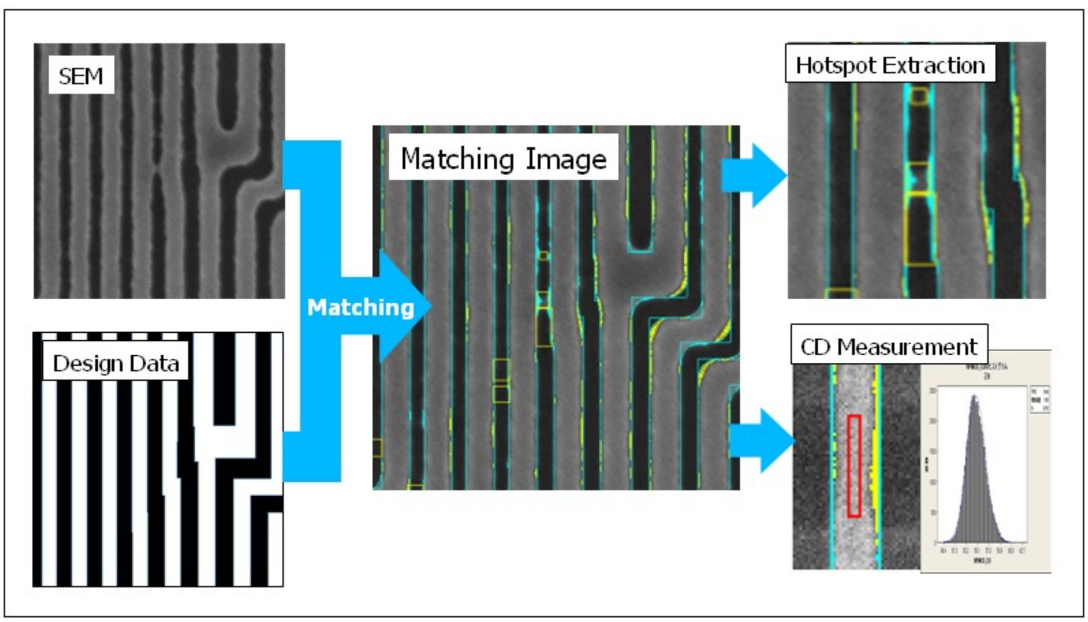

Figure 3. Principle of Die-to-Database (D2DB) inspection.

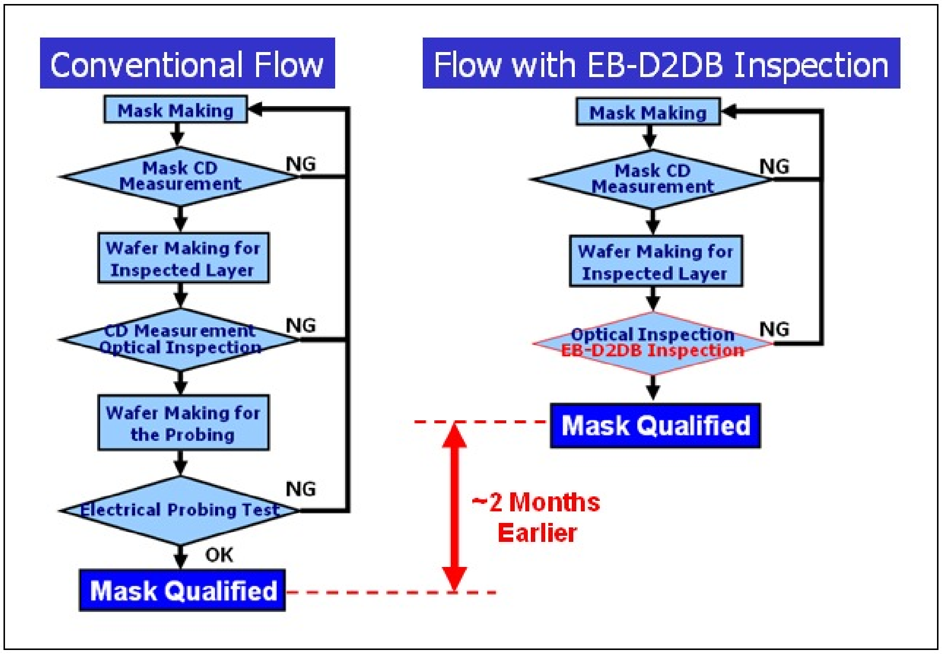

Figure 4. Effect of mask-qualification flow with D2DB inspection compared with the conventional flow.

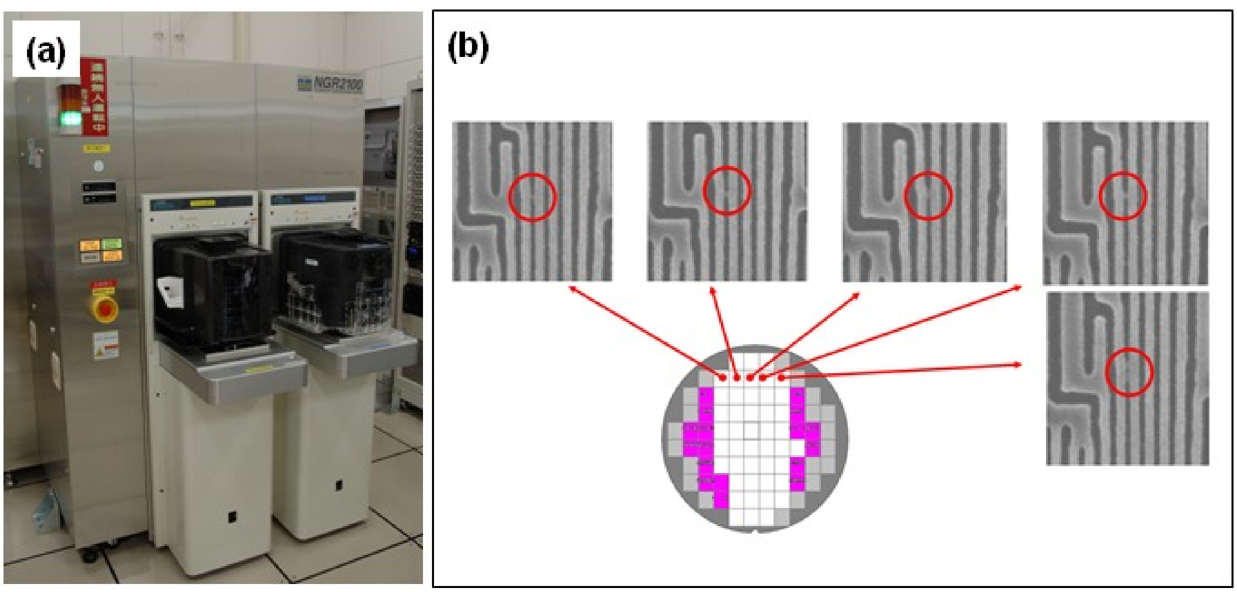

Figure 5. (a) A view of NGR2100. (b) Hotspots extracted by NGR2100 that were not extracted by optical inspection.

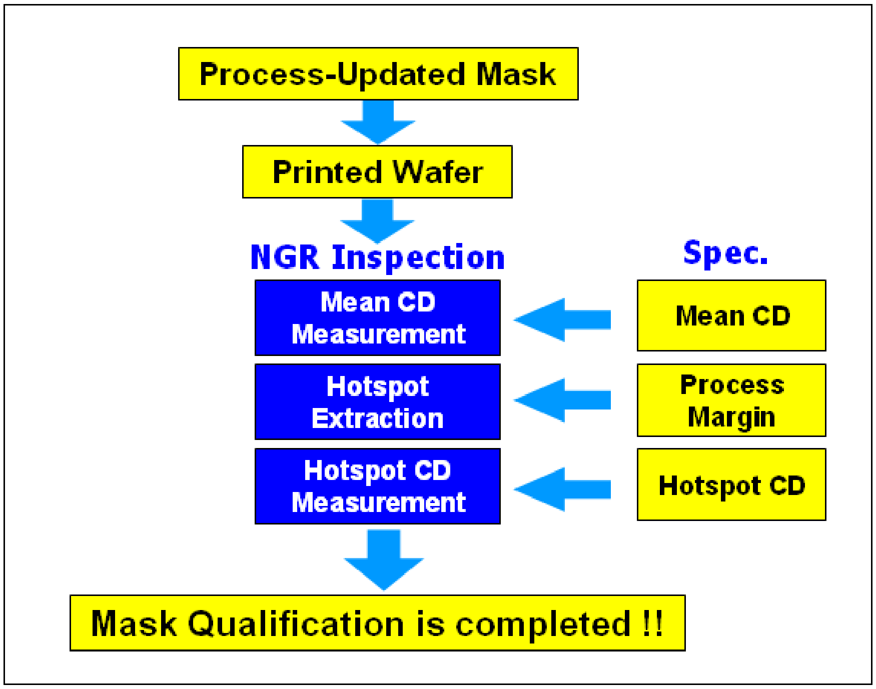

Figure 6. Mask-qualification methodology with NGR2100.

3. EXPERIMENTAL RESULTS IN THE EB-D2DB INSPECTION

Figure 7 shows the method of mask qualification in this experiment. In some cases of mask-process update, the metric of qualification is the reference mask that is already qualified. Therefore, the specs in this qualification were determined as deviation from reference wafer printed by reference mask. A wafer printed by process-updated mask was inspected from the three above-mentioned viewpoints and compared to their spec determined from the reference. Then, referring to these results, the mask qualification was performed. Finally, to verify the reasonableness of the proposed method, we compared the qualification results to those of the conventional electrical probing test.

Figure 8 shows a result of CD measurement. Three kinds of wafer patterns designed as 55, 88 and 128nm were measured. Figure 8 (a) shows a distribution of line patterns designed as 88nm. Red line shows a distribution of the patterns printed by process-updated mask, and green line shows that of reference mask. The mean CD deviations between two wafers are shown in Fig.8 (b). The deviation was defined as mean CD of patterns printed by reference mask minus that of process-updated mask, and the spec of the deviation was within 3nm from the patterns printed by reference mask in each design size. The mean CD was standardized to be the same in both wafers at 55nm lines. From the result, CDs of patterns from process-updated mask were within the assumed spec in each pattern size.

Figure 9 shows the result of hotspot extraction. Assumed lithography window in this experiment was 15% of exposure dose and 0.2um of focus, indicated by blue arrows in Fig.9. As a result of hotspot extraction, there were no hotspots within the lithography window for both wafers, shown as the blue area in the shot map. In addition, a resist short appeared at the same focus-exposure condition in both wafers, shown as the yellow area. This result indicates that the lithography windows of the two windows for hotspots are comparable.

Figure 10 shows hotspot-CD measurement by comparing contours of hotspots from the two wafers. Contours of extracted hotspots were output as GDS data and merged for comparison in terms of local CD at hotspot. Figure 10 (a) shows merged contour-GDS data of an extracted hotspot. Contour in red shows patterns printed by process-updated mask, and contour in green shows that of reference mask. Since the circled pattern in the figure was much narrower than the target design size, the pattern was judged as hotspot by D2DB algorithm in both wafers. And three kinds of patterns were extracted as hotspots. Figure 10 (b) shows hotspot-CD deviation, standardized at 55nm line. The local CD deviations between the two wafers at three hotspots were within the spec.

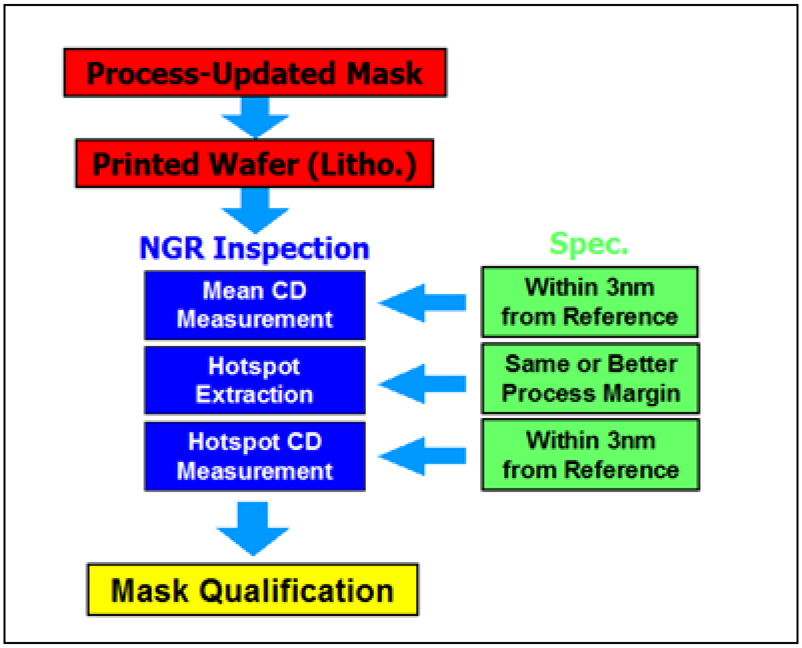

Figure 7. Method of mask qualification in this experiment.

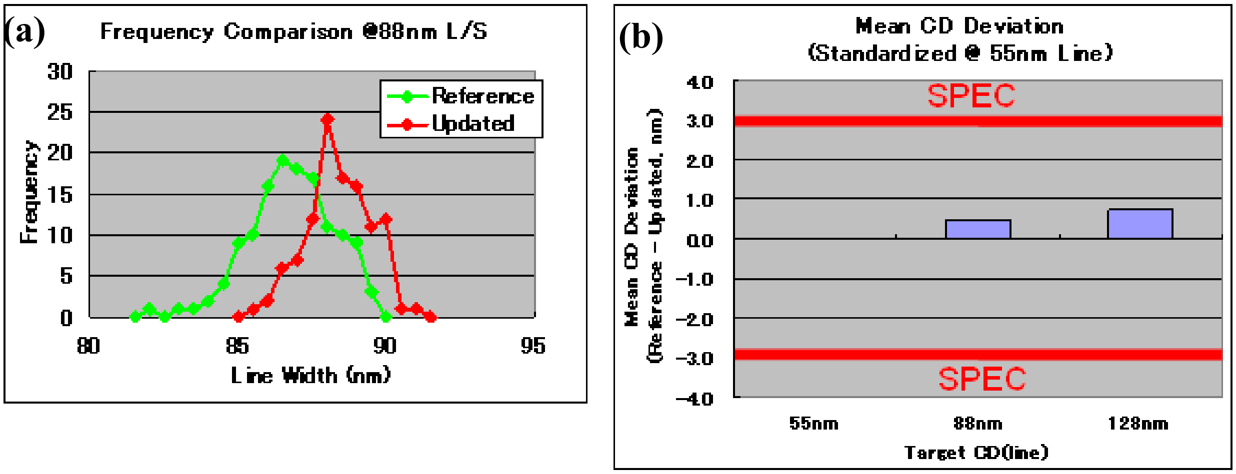

Figure 8. (a) Histogram of CD distribution. (b) Mean CD deviation of wafer patterns standardized at 55nm line.

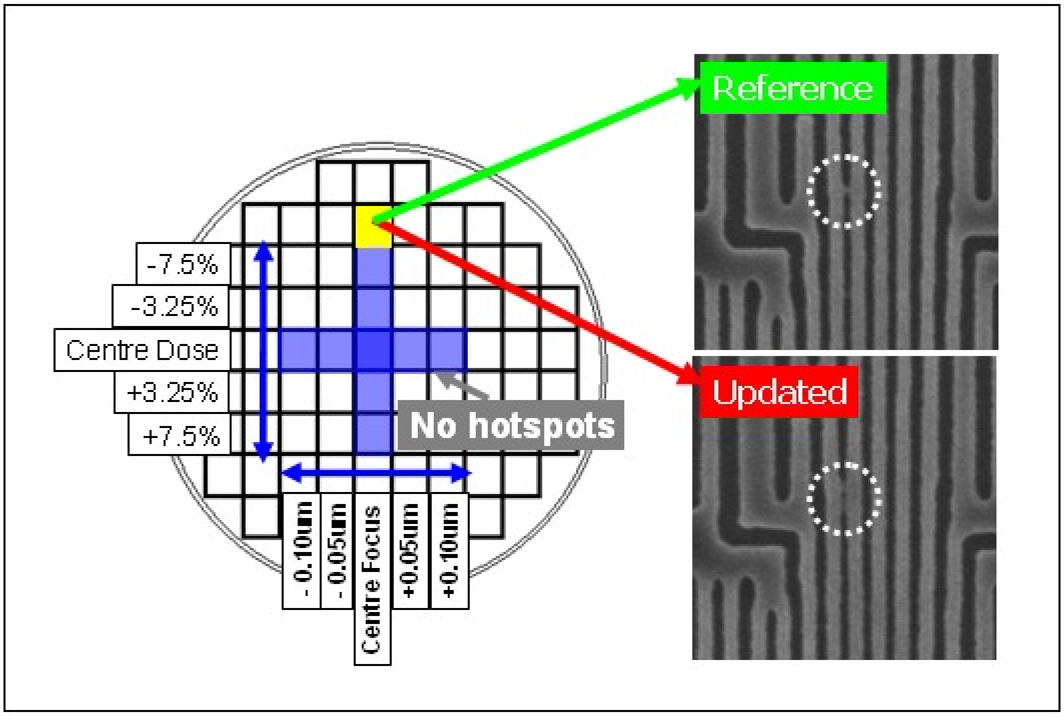

Figure 9. Result of hotspot extraction.

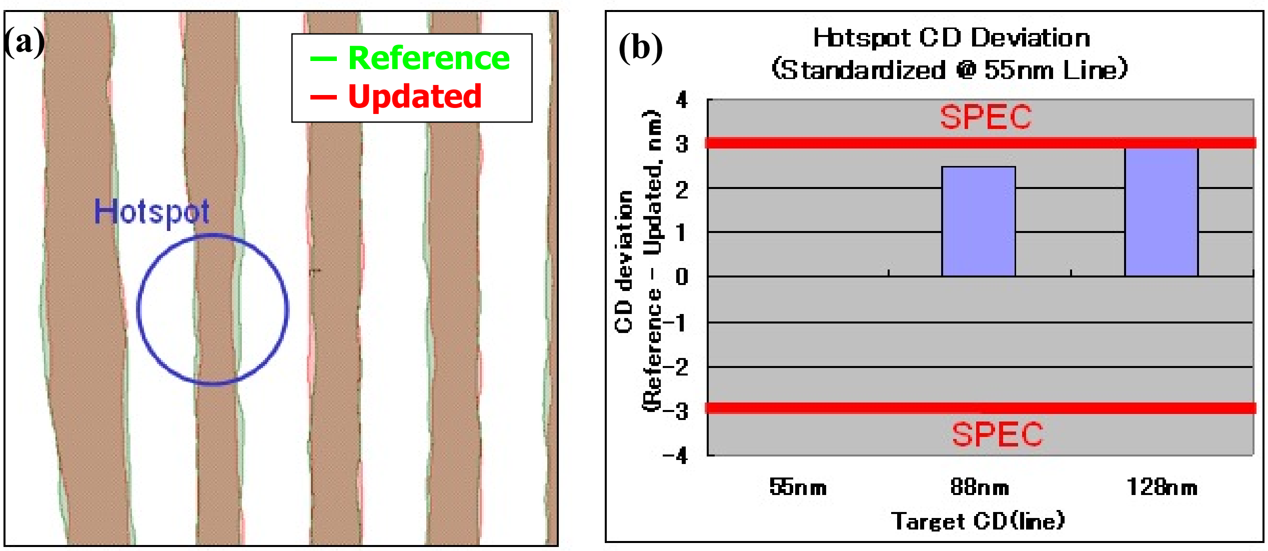

Figure 10. (a) Merged two contour-GDS data of two wafer patterns from two different mask.
(b) Hotspot-CD deviation standardized at 55nm line.

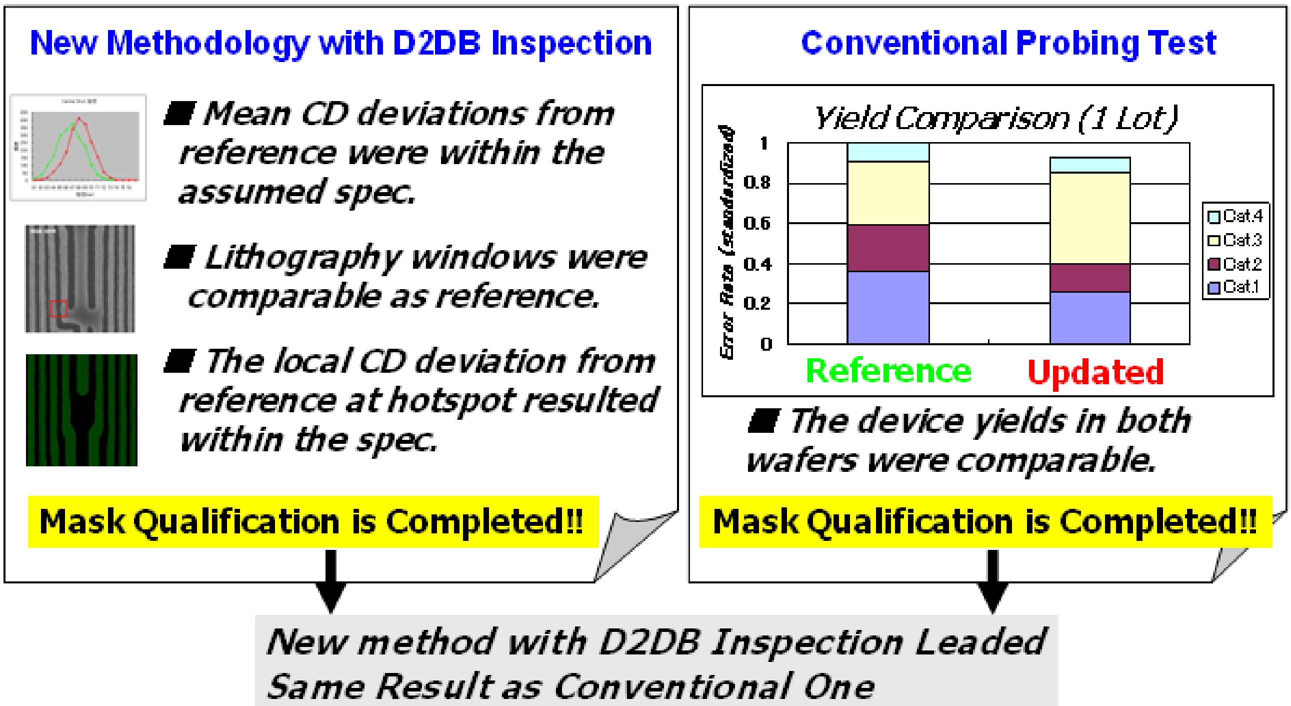

Figure 11. Verification of new mask-qualification methodology.

From all the results shown, we performed verification of proposed mask qualification methodology as shown in Fig.11. To verify the new methodology, we also performed a conventional mask qualification by electrical probing test. In the case of the new methodology with D2DB inspection, all of the deviations from reference were within the spec, and therefore the updated process can be judged as qualified. According to the electrical probing test, the error rates of the devices printed by two different masks were comparable, and therefore the updated mask process was also qualified. Considering all the results, it is concluded that the new methodology with D2DB Inspection led to the same result as the conventional one. Therefore, we concluded that the new methodology with D2DB inspection was verified with the accuracy equivalent to the conventional method in terms of device yield.

4. CONCLUSIONS

We have developed a mask qualification methodology with Die-to-Database (D2DB) wafer inspection system, NGR2100. A wafer pattern printed by process-updated mask was printed and inspected from three viewpoints of metric: “mean CD measurement”, “hotspot extraction” and “hotspot-CD measurement”. The proposed methodology can reduce the qualification TAT by two months compared to the conventional method with electrical probing test. And the methodology was verified with the accuracy equivalent to the conventional method in terms of device yield.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Hiroshi Takagi and Mr. Kazunori Tsurui of Meitec Corporation for making the lithography samples and obtaining the CDSEM images. They are grateful to Mr. Seiro Miyoshi, Mr. Shinji Yamaguchi, Mr. Makoto Kaneko and Mr. Hiroyuki Morinaga of Toshiba Corporation for providing experimental data. They are indebted to Ms. Rieko Sakai of Meitec Corporation for experimental assistance.

REFERENCES

[1] T.Kitamura, K.Kubota, T.Hasebe, F.Sakai, S.Nakazawa, N.Vohra, M.Yamamoto and M.Inoue: Proc. SPIE **5756** (2005) 73.

[2] K.Hashimoto, S.Usui, K.Yoshida, I.Nagahama, O.Nagano, Y.Matsuoka, Y.Yamazaki and Soichi Inoue: Proc. SPIE **6925** (2008) 17-1