Introduction of new database reflected tritone algorithm for application in mask production

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1. ABSTRACT

At Photomask Japan 2007 *(1)* the new algorithm of Fast Integrated die-to-die T+R (DDTR) for the views of P90 and P72 for the KLA Tencor TeraScanHR mask inspection system was presented. At the same time a new algorithm for P72 in database tritone mode for reflected light (DBRt) was introduced *(2)*. Both modes can be used together as one combined inspection to detect pattern and contamination defects on production masks.

It was shown that these new algorithms allow for creation of a new inspection strategy with improved throughput and a reduced amount of inspections. Currently an inspection strategy has to cover at first a pattern inspection (normally a combination of die-to-die and additional database inspections) for finding hard defects on a mask and then as second step a contamination inspection (STARlight2™). The hard defects have to be repaired and the contaminations can be cleaned. The new inspection strategy allows for detection of all critical hard and contamination defects on a mask with one single combined inspection, enhancing productivity.

At BACUS 2007 *(3)* the first evaluation of this new kind of inspection strategy for manufacturing of masks was described for two production plates of different design. At that time only the database reflected tritone algorithm for the view of P72 was available. The changes in inspection strategy could only go together with a change of view from P90 to P72.

With view P72 higher overall sensitivity could be reached and smaller secondary features could be inspected. However, these improvements may not be necessary for all plates and may need more time than a comparable P90 inspection.

Today the standard contamination inspection for critical masks is the P90 STARlight2™ (SL2). To do a time effective parallel combo inspection with DDTR and DBRt the same view has to be used.

An extension of the database reflected tritone algorithm to the P90 view is now available. This gives the mask manufacturer the flexibility to change the inspection strategy for P90 and P72 dependent only on feature size on mask or minimal allowed defect size.

The results of the evaluation and the comparison of this P90 database reflected tritone algorithm with the P90 STARlight2™ and P90 Fast Integrated die-to-die T+R will be presented in this paper. It will be shown that comparable results can be expected for P90 DBRt and P90 DDTR versus P90 STARlight2™ without missing any critical defects.

Keywords: database reflected tritone, fast integrated die-to-die T+R, pattern inspection, contamination inspection

2. EXPERIMENTAL DESIGN

A Mask (A) with lines & spaces and mainly pattern defects and a Mask (B) with contact holes and mainly contamination defects were investigated. Both photomasks were manufactured by AMTC.

To prevent defect degradation over time, pellicles were put on the reticles.

The same reticles were used for the investigations presented during Bacus 2007 *(3)*.

KLA-Tencor TeraScan SL587 photomask inspection system was used for all inspections.

For all inspections, the Platetype *Tritone193-NTAR5* and the light calibration values for transmitted "*Quartz: 240 / Shifter: 80 / Chrome: 5*" and reflected "*Quartz: 50 / Shifter: 240 / Chrome: ---*" (so-called clipped Chrome) were used.

Both plates were inspected with the contamination inspection mode (SL2) at the sensitivity settings that are used for standard production. These inspections were used as reference runs.
It was our target to find sensitivity settings for the pattern inspections which show similar defect counts and did not miss any critical or relevant defect compared to these reference runs.

Both plates were investigated with sensitivity settings for defect size >60nm and >80nm. This nomenclature is based on the standard production setting for the SL2 reference inspections that were chosen to find defects of this size and larger.

Both plates were multi-die plates. To reduce the inspection time only 2 dies with significant defect distribution were inspected.

At the end we compared the inspection results of the P90 SL2 inspection with P90 Die-To-Die T+R inspection and P90 Database Reflected Tritone inspection.

3. EXPERIMENTAL RESULTS

3.1 Results of Mask (A), 60nm defect size

At first are presented the comparison of the results of the SL2 inspection vs. DDTR vs. DBRt of Mask (A) for 60nm defect size and above.

This data are shown in two different modes. The first is a distribution map in figure 1 and the second a Venn diagram in figure 2.

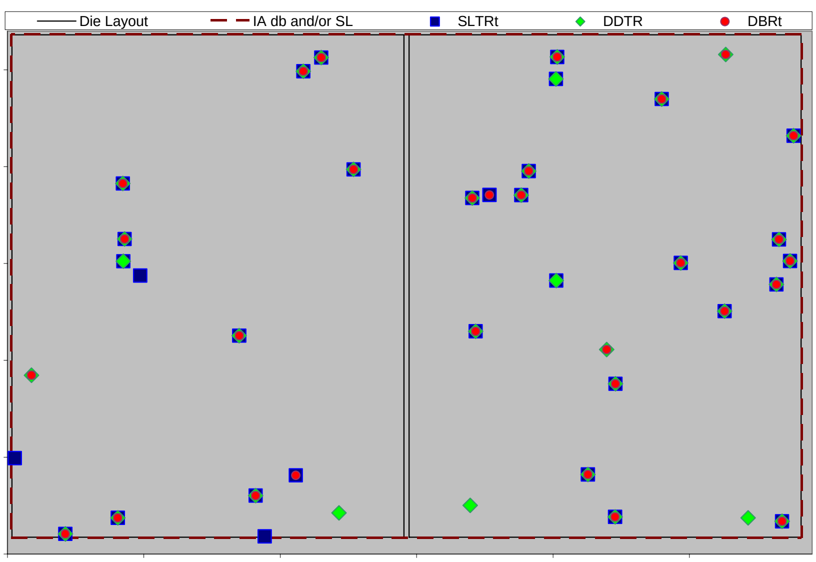


FIGURE 1: Defect Distribution map of all 3 inspections of Mask (A) with sensitivity settings for >60nm defect size

The distribution map shows a good correlation for all P90 inspection with the optimized sensitivity settings. Only some defects were missed in the DBRt and DDTR vs. SL2 inspection.
All of the missed defects are not relevant for lithography. Some missed and suspect defects are measured at AIMS and the results were always below the threshold of lithographically relevancy. Two samples are presented in figure 3.

For a more detailed view we prepared the data in a Venn diagram comparing the 3 inspection modes, as shown in figure 2. This diagram shows the SL2 inspection found only 3 additional defects.

The variation of total counts of all inspections is in a range of the 12%.

There is a good correlation of the triggered defect at all inspections. With a count of 25 in all inspections detected defects we have 26% non-reliable defects. All this are nuisance defects and always close to the detection threshold.

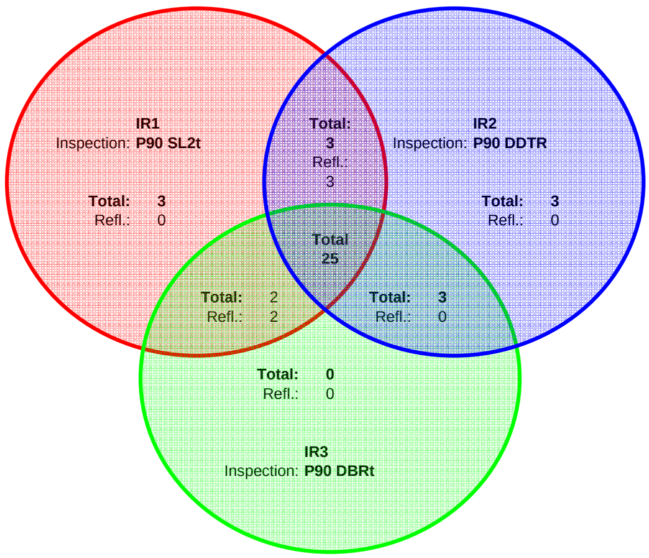
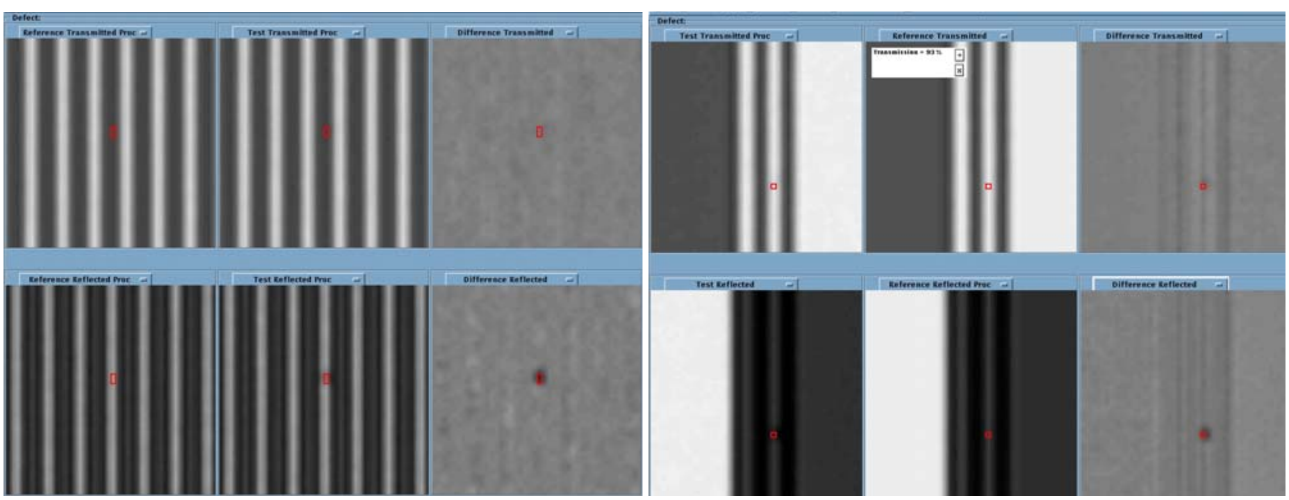


FIGURE 2: Venn diagram for comparison of the 3 different inspection modes with sensitivity settings for >60nm defect size



AIMS: 3.35 / 1.18 AIMS: -4.09 / -2.36

FIGURE 3: Sample of missing defects in DBRt inspection sensitivity settings for >60nm defect size

3.2 Results of Mask (A), 80nm defect size

The same data analysis and presentation was done for Mask (A) with sensitivity settings for 80nm Defect size and above. The distribution map is shown in figure 4 and the Venn diagram in figure 5.

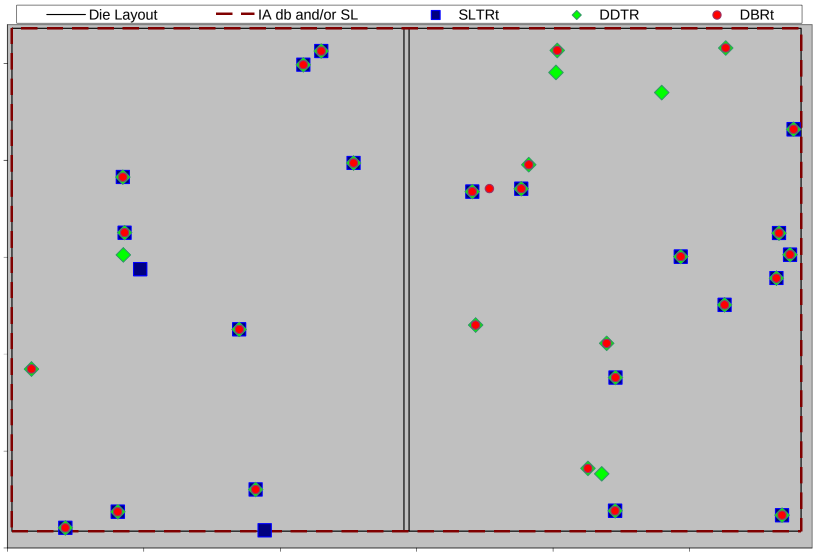


FIGURE 4: Defect Distribution map of all 3 inspections of Mask (A) with sensitivity settings for >80nm defect size

With the reduced sensitivity settings compared to the 60nm defect size we found less than 18% of the defects. This is a sign that on the mask defects with different defect sizes available.

The variation of total counts of all inspections is in a range of the 29%. Cause of the relative high number is that the total count of the DDTR and DBRt is slightly higher than the SL2. This can be explained by the used increment between the sensitivity steps and by the reduced capability of the SL2 algorithm to catch pattern (hard) defects or contaminations with pattern like behavior. As for the inspections above, the defects that were not found reliably turned out to be not relevant. This conclusion was drawn by AIMS verification of several representative defects. One sample is shown in figure 6.

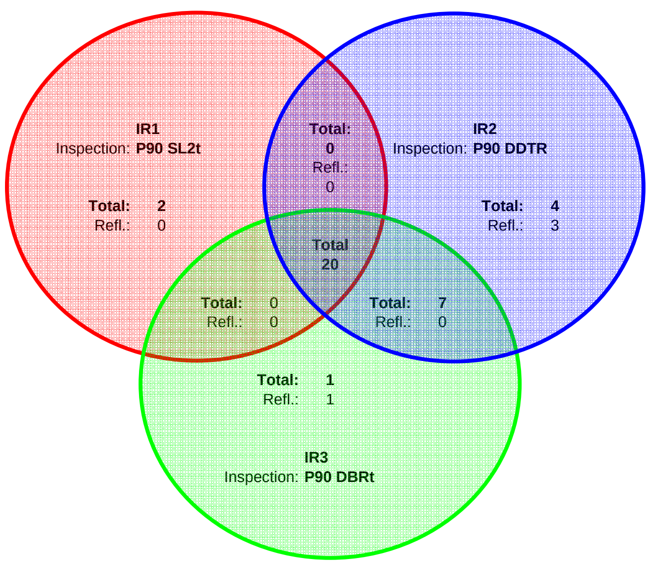
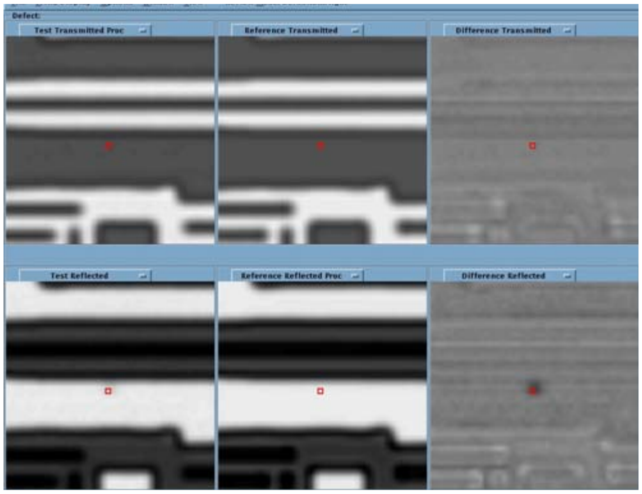


FIGURE 5: Venn diagram for comparison of the 3 different inspection modes with sensitivity settings for >80nm defect size



AIMS: - / -

FIGURE 6: Sample of missing defects in DBRt inspection sensitivity settings for >80nm defect size

3.3 Results of Mask (B), 60nm defect size

Mask (B) only showed contamination defects with a significant size distribution in the inspection area. This is presented in the defect distribution map in figure 7.

Also for this plate the same investigations like for Mask (A) were done and are presented here in the same way.
The comparison in the defect distribution mask and in the Venn diagram shows a good correlation between the P90 SL2 standard and the new ddTR and dbRt algorithms. The variation of total counts of all inspections is in a range of the 18%.

All missed defects in one or two inspections are small, on Shifter defects (contaminations) and far away from an edge. All this leads to the conclusion that these defects do not have an influence of lithographical results. A sample is shown in figure 9.

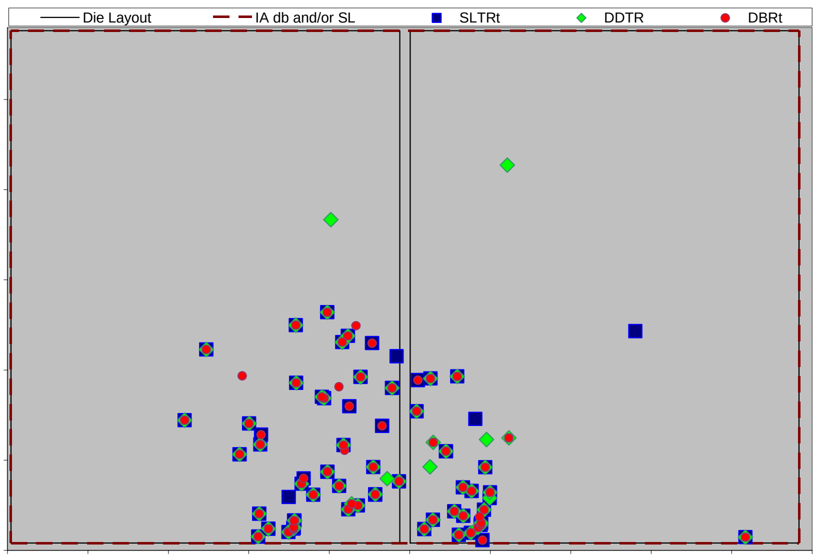


FIGURE 7: Defect Distribution map of all 3 inspections of Mask (B) with sensitivity settings for >60nm defect size

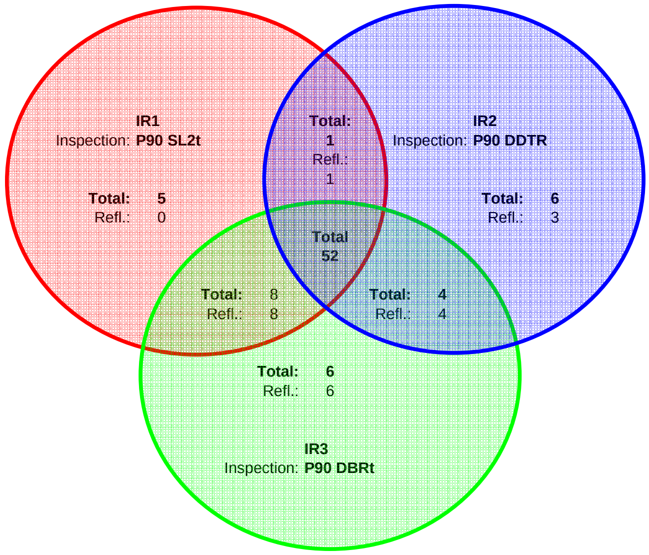
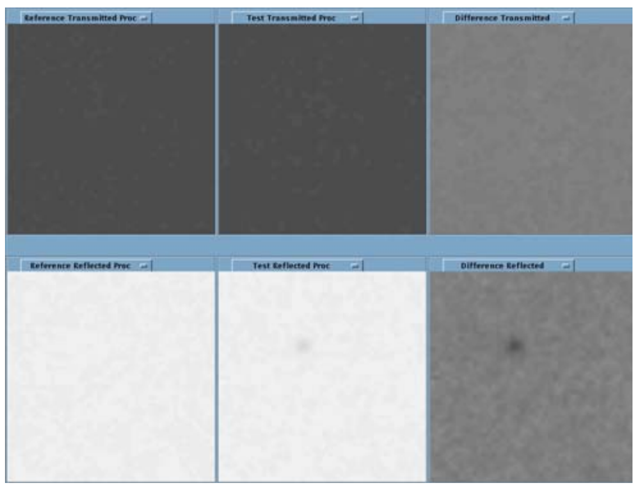


FIGURE 8: Venn diagram for comparison of the 3 different inspection modes with sensitivity settings for >60nm defect size



AIMS: - / -

FIGURE 9: Sample of missing defects in DBRt inspection sensitivity settings for >60nm defect size

3.4 Results of Mask (B), 80nm defect size

At the end the same investigations were made on Mask (B) with sensitivity settings for >80nm defect size. Also for these results the defect distribution mask and the Venn diagram are prepared and shown in figure 10 and 11. Both pictures show a good correlation between all three inspection modes. The variation of total counts of all inspections is in a range of the 22%.

All the additional defects are on Shifter material, far from an edge and have a small size and therefore not relevant for lithography and similar to the one in figure 9.
Also on this mask the reduced sensitivity settings show a reduction of the count of the reliable defects by 25%. This shows there is also a good defect size distribution on this mask.

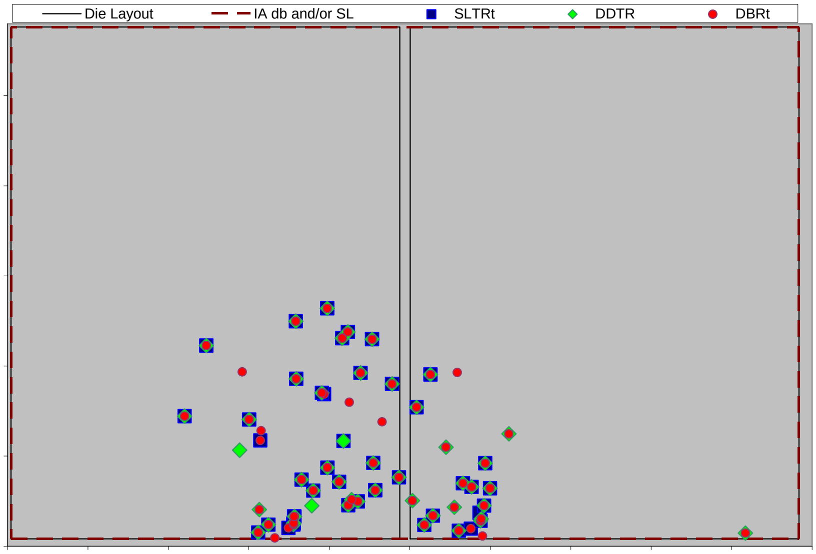


FIGURE 10: Defect Distribution map of all 3 inspections of Mask (B) with sensitivity settings for >80nm defect size

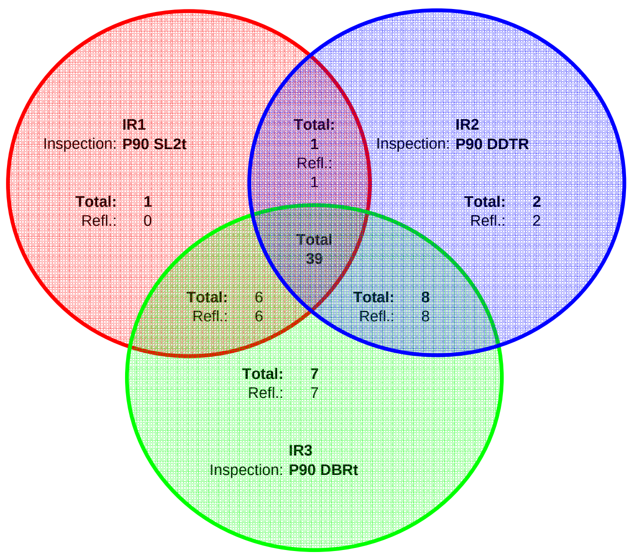


FIGURE 11: Venn diagram for comparison of the 3 different inspection modes with sensitivity settings for >80nm defect size

4. CONCLUSION AND SUMMARY

During PMJ 2007 *(1), (2)* the new algorithms for the fast integrated T+R pattern inspection and the new die-to-database reflected tritone algorithm for KLA-Tencor TeraScanHR inspection systems were introduced. The possibility was shown to enhance the productivity by reduction of the number of inspections with improved or same sensitivity. At BACUS 2007 *(3)* the first production like investigations with the new DDTR and DBRt were presented. It was shown that a combination of DDTR and DBRt could replace the SL2 with improved sensitivity. During that time the DBRt algorithm for P90 was not available. Only a full inspection strategy for the P72 view could be created. Since late 2007 also the DBRt algorithm for P90 is available. This gives now the possibility to setup an inspection strategy for combined pattern and contamination inspections at both views P90 and P72. The opportunity is now given to use fully the enhanced productivity on the KLA-Tencor TeraScanHR inspection tools for these two views.

In this paper we showed the results of the investigations on the DBRt algorithm for P90 and DDTR algorithm for P90 compared to the results of the standard production mode with the SL2 algorithm and demonstrated that the combination of the DBRt and the DDTR could replace the SL2 in a production environment of a mask house.

The investigations were done on two representative production plates. These production masks were of different design. One was a contact hole the other a lines & spaces design. Both were inspected with two different sensitivity settings to find defects with a size of >60nm and >80nm. The first inspection was the SL2 with view P90 which was used as reference for the other inspections.

All data showed that the reflected pattern algorithm could find all relevant defects. Advantage of these inspection modes vs. SL2 inspection is contamination and pattern defects will be found in one inspection.
All of the defects that where missed by on of the pattern inspections were not relevant for lithography, which means that they would not print. All of them are small and, for the most part, close to the inspection threshold. Some of these missed defects were measured by AIMS and it could be shown that they are not relevant for lithography.
The defects missed in SL2 are mainly pattern or pattern like defects. This kind of defect will be found by a standard pattern inspection during the normal process flow in production.

We could present in this paper comparable data for the different inspection modes on two different masks with different design.
In the end the conclusion is that for multi die masks a combination of a DDTR and DBRt pattern modes can replace the SL2 also for P90 view.

5. LITERATURE

1. *Enhancing productivity and sensitivity in mask production via a fast integrated T+R pattern inspection and STARlight-2 contamination inspection on critical layers*
   Jean-Paul Sier, Eric Haodong Lu, Kaustuve Bhattacharyya, Swapnajit Chakravarty, Michael Lang, Heiko Schmalfuss, Jan Heumann and Thomas Schulmeyer
   Proc. SPIE 6607-2C (2007)

2. *Field results from a new die-to-database reticle inspection platform*
   William Broadbent, Ichiro Yokoyama, Paul Yu, Kazunori Seki, Ryohei Nomura, Heiko Schmalfuss, Jan Heumann and Jean-Paul Sier
   Proc. SPIE 6607-14 (2007)

3. *Sensitivity comparison of Fast Integrated Die-to-Die T+R pattern inspection, standard database inspection and STARlight2TM contamination mode for application in mask production*
   Heiko Schmalfuss, Thomas Schulmeyer, Jan Heumann, Michael Lang and Jean-Paul Sier
   Proc. SPIE 6730-74 (2007)

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