# PHOTOMASK

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## Evidence of printing blank-related defects on EUV masks, missed by blank inspection


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### ABSTRACT

In this follow-up paper for our contribution at BACUS 2010, first evidence is shown that also the more advanced Lasertec M7360 has missed a few printing reticle defects caused by an imperfection of its EUV mirror, a so-called multilayer defect (ML-defect). This work continued to use a combination of blank inspection (BI), patterned mask inspection (PMI) and wafer inspection (WI) to find as many as possible printing defects on EUV reticles. The application of more advanced wafer inspection, combined with a separate repeater analysis for each of the multiple focus conditions used for exposure on the ASML Alpha Demo Tool (ADT) at IMEC, has allowed to increase the detectability of printing MLdefects. The latter uses the previous finding that ML-defects may have a through-focus printing behavior, i.e., they cause a different grade of CD impact on the pattern in their neighborhood, depending on the focus condition. Subsequent reticle review is used on the corresponding locations with both SEM (Secondary Electron Microscope) and AFM (Atomic Force Microscope). This review methodology has allowed achieving clear evidence of printing ML defects missed by this BI tool, despite of an unacceptable nuisance rate reported before. This is a next step in the investigation if it is possible to avoid actinic blank inspection


*Continues on page 3.*

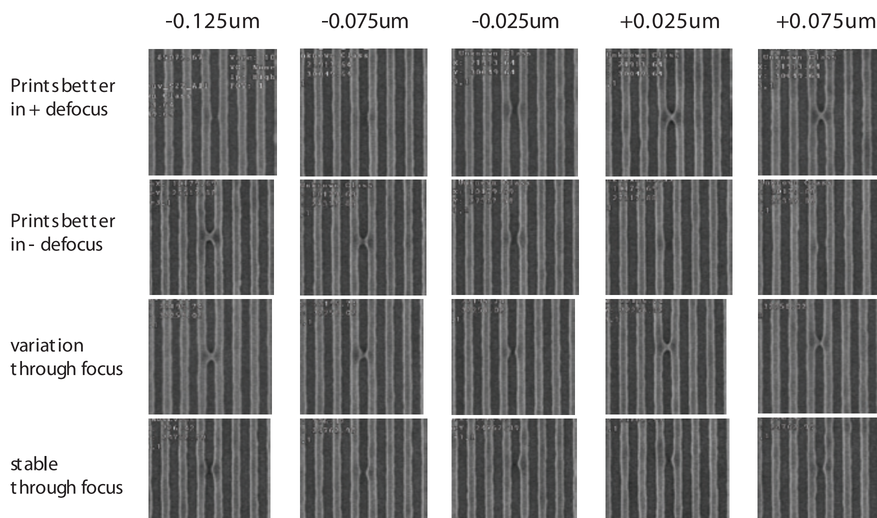


*Figure 1. Demonstration of the variability of printing defects in their through-focus behavior.*

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# EDITORIAL

## SPIE/BACUS and Photomask Japan Affirm Long Relationship

**Brian J. Grenon,** Grenon Consulting, Inc.

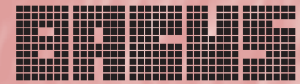
Last month's editorial by Larry Zurbrick expressed the feelings and condolences of many of us in the semiconductor industry and more specifically those of us in the photomask industry concerning the tragedy in Japan. As many of you know, due to this catastrophic event, Photomask Japan (PMJ), which was to be held from April 13 though 15 was cancelled. Over the last two decades, SPIE/BACUS and PMJ have had a strong collaborative relationship with the primary interest and goal in assuring a forum for technical achievements and developments in the photomask industry. Through this long relationship, we exchange representatives annually at each other's conferences and invite the Best Paper Award winners to present their respective papers at each conference.

Unfortunately, as a result of the natural disaster this year, we have another opportunity to affirm our strong relationship. Through the auspices of SPIE, the conference program at the SPIE/BACUS Photomask Symposium in Monterey will start half a day earlier than usual, i.e., on Monday instead of Tuesday, 19 September at 1:00PM. That Monday afternoon there will be a Special PMJ Session in which ten (10) oral papers, originally slated for this year's PMJ Symposium, will be presented. Additionally, the PMJ committee will select the Best Paper Award to present their paper. The attendees of SPIE/BACUS Photomask should plan accordingly, to take advantage of this Special Session.

In addition to this change, SPIE will also still be publishing all of the accepted papers for PMJ2011 in the SPIE Proceedings as usual and at no cost to PMJ, as a further sign of cooperation between the two organizations and conferences.

On the lighter side, Naoya Hayashi of DNP has offered to have the two video skits that were to be presented as entertainment at PMJ be part of the SPIE/BACUS entertainment program this year. For those of you that have had the opportunity to attend PMJ before, I'm sure you will attest to their entertainment value.

We look forward to seeing you in Monterey from 19-22 September.

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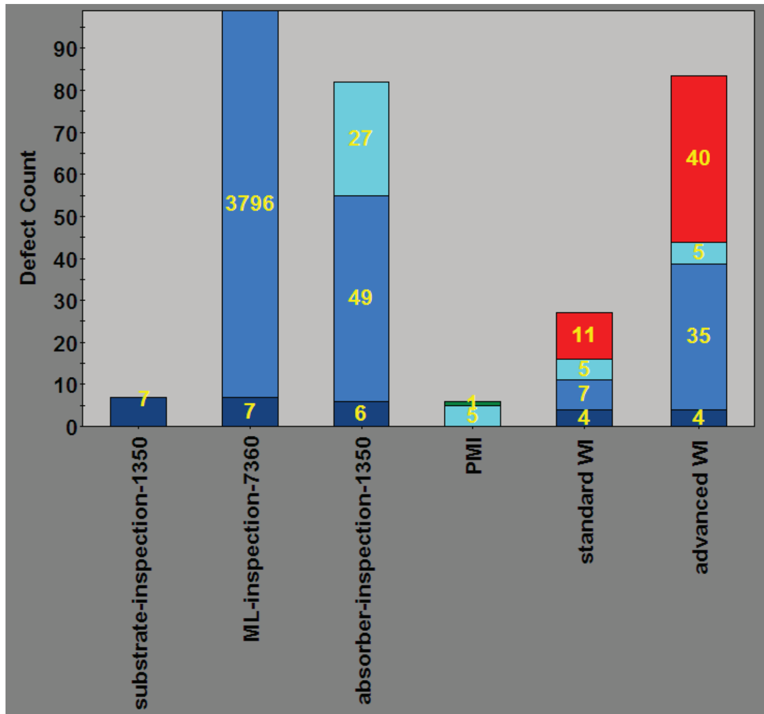


Figure 2. Defect source analysis for defects found on reticle.

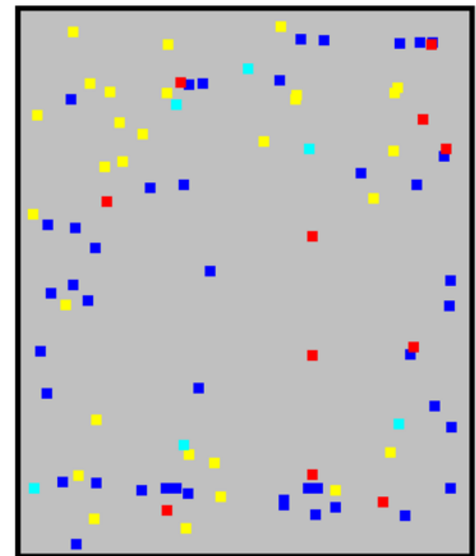


Figure 3. Comparison of (incremental) defect map obtained by the variation of wafer inspection tools used, with and without the separate repeater analysis per focus.

(ABI) at all, the only presently known technique that is expected to be independent from the presence of a (residual) topography of the ML-defect at the top of the EUV mirror, in detecting those defects. This is considered an important asset of blank inspection, because the printability of a ML-defect on the EUV scanner and its detectability by ABI is determined by the distortion throughout the multilayer, not that at the surface.

## Introduction

As shown before EUV reticle defectivity has several aspects, beyond the conventional absorber type defects.[1-3] EUV reticles have a specific material stack with its own impact on the reticle defectivity. The focus of this investigation continues the previously reported endeavors[3-9] to assess defects of the multi-layer (ML) mirror. These so-called MLdefects are the most EUV-specific type of reticle defects. Previous work has shown by simulation[2,3,5] that their printability is triggered from just nanometer height or depth onwards.

In recent work[3,4,6,8] it has become possible to visualize a number of such ML-defects. Our approach focuses on natural defects for a number of reasons. ML-defects are not obvious to use the programmed approach, but in a previous publication[3,5] this approach was used to demonstrate their printability experimentally. Programmed ML-defects are tedious to fabricate, and the danger lies in the fact that the fabrication approach taken limits the degree of freedom for certain qualification parameters that may occur in practice. For example the focus can be on a certain height, square or round shapes, certain fixed slope, etc., but is difficult to have a variation of all relevant parameters on the same mask.

Previous simulation work[2,3,5] has shown that the printability of ML-defects is not dominated by the phase shift caused by the shallow height distortion of the ML mirror. The printability of programmed ML-defects with a given height close to quarter wavelength, resp. half wavelength, considered to generate 180 degree phase shift, resp. 360 degree, did print largely similar,[5] which indicates that the slope of a ML-defect has a dominant role in determining its printability. This is the reason why, unlike other researchers on this topic, this paper rather refers to these defects of the ML-mirror as MLdefects and not as phase defects. The printability of these ML-defects is found mostly due to the fact that they disturb the reflection of the incoming EUV light locally, by scattering it in all directions, such that it is lost in the reflected image of the reticle.

A ML-defect is not readily repaired by addressing the defect itself.[5] For example removing the bump in the ML by restoring the flat surface by "shaving off" the bump does not make it non printable, on the contrary. Yet, some limited capability has been shown by simulation[5,9] to compensate for the presence of the ML defect by trimming the nearby features of the absorber pattern and therewith restore some of the lost reflected light.

Another approach to mitigate such ML defects is to hope that blank vendors can assure blanks to be defect free. However, this requires that the appropriate tools are available to detect all such defects that would print, as a first step to initiatives to indeed assure that such defects can be avoided on EUV mask blanks. In another approach one attempts to make known ML-defects non printable,[10] by assuring that they will be covered by absorber, i.e., the opaque part of a given layout. This blank picking procedure requires low enough blank defectivity to begin with, but also requires good enough positional information that the mask pattern can be aligned to the defect map such that all ML-defects would be covered. A set of so-called fiducial marks must be present on the blank used. First automated software for this pattern shift exercise has been reported.[11]

The weakness of the latter two mitigation techniques is that they are limited by the available blank inspection technology. Unless there is a "good enough" blank inspection (BI) tool, one cannot yet know how many printing ML-defects are on a given mask. The crucial question is whether the blank inspection tools used by the blank vendors is detecting all these blank defects that matter

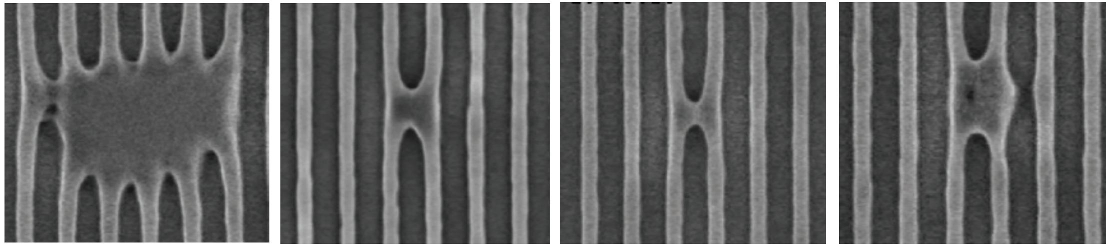

*Figure 4. Printing behavior of substrate defects confirmed by wafer inspection, showing the relative large and solid nature of those found by the basic blank inspection tool as they print as bridges between (several) lines.*

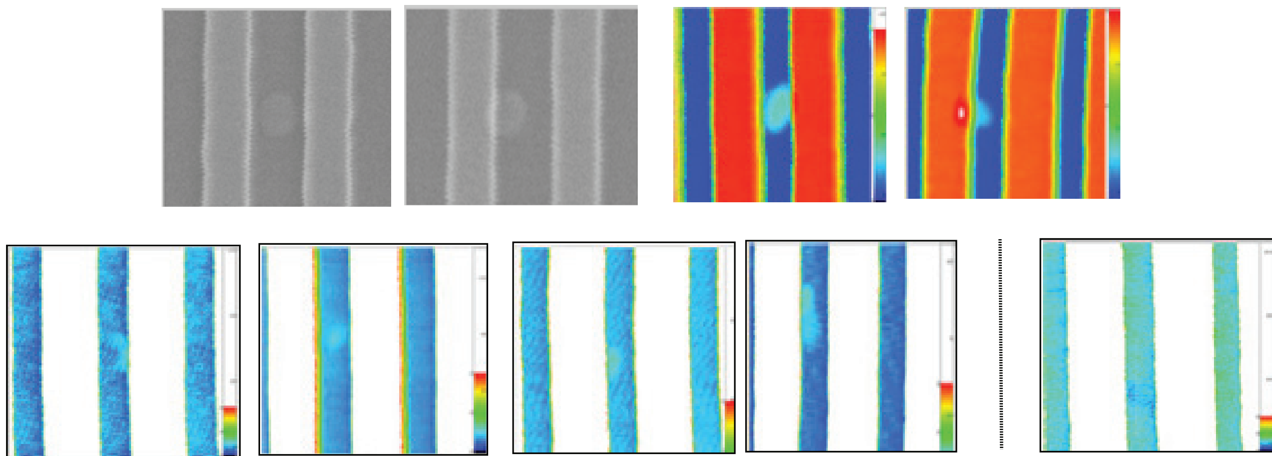

*Figure 5. Example of printing ML-defects as visualized by reticle review (reticle DEFECT40FF-B). Top row: For such examples SEM still shows a faint impression of the defect (left) and AFM typically shows a height exceeding 10nm; Bottom row: examples by AFM results for ML-defects that could not be visualized by SEM, found shallower than 10nm, mostly bumps, but one example of a pit (far right).*

in view of printing. The present paper reports a further part of a larger attempt to find evidence of printing ML-defects that were missed by dedicated blank inspection tools, with the intention to demonstrate the gap in tool capability, such that it can be mitigated in time before EUV lithography will be used in production.

Other researchers on this topic often are satisfied by starting from a given blank inspection defectivity map and checking whether these defects are found to print. The danger of this forward correlation only between blank and wafer is that it does not disclose the need to mitigate such defects by assuring proper tool development. In the view of the authors it is essential to correlate backwards from defects found on wafer as well, and check if they were detected by the dedicated blank or reticle inspection. As will become clear from the next section, there is far less reason to be concerned that many absorber-type defects are missed by dedicated patterned mask inspection (PMI) tools. The concern mainly lies in the lack of maturity of the blank inspection tools in detecting all printing ML-defects.

For the methodology used in this work the reader is referred to a previous publication.[4] Here just a summary is given: The reticle layout used for the reticle defectivity assessment is basically an exposure field full of vertical lines and spaces for a given half-pitch (hp). So far typically 32nm and 40nm hp were used. As to avoid line collapse on wafer, support bars are added, in a perpendicular direction to the lines. Wafer inspection (WI) is used to inspect multiple exposed dies on a wafer. Subsequent repeater analysis flags which defects most likely are due to defects on the reticle. Mask review is used to evaluate the nature of the defect. Overlaying defect maps as obtained by blank inspection, patterned mask inspection and wafer inspection allows to make statements of limited printability of certain detections made during blank - or mask inspection (by forward correlation using wafer review). It also helps to provide evidence of printing mask defects that should have been detected during blank – or mask inspection (backward correlation starting from wafer inspection).

## 1. Previous Searches for Experimental Evidence of (Natural) ML-Defects

By continuously attempting to include more inspection tools (each of the three types, i.e., BI, PMI and WI) a way was found to increase the number of known printing defects. Of course at all times it is avoided that newly added particle defects, caused by handling of the reticle, can be considered as additionally detected defects of interest.

Previous work[4,8] compared the percentage of 48 known natural defects on a given reticle for one blank inspection tool (Lasertec M1350), multiple patterned mask inspection tools and multiple wafer inspection tools. The analysis was separated between absorber defects and ML-defects, which was possible from previous mask review work to identify the nature of these 48 defects. The main conclusion was that the best patterned mask inspection tool was capable of finding all printing absorber-type defects, and even had a clearly better performance than the described wafer inspection technique. This illustrates that also wafer inspection is limited. It is certain that even with the combined use of all inspection tools there are still an unknown number of printing defects that have not been found. Yet, with inspection of the printed wafer it was clearly possible to find multiple ML-defects missed by the blank inspection used. This proves the existence of a capability gap to be closed by blank inspection. The best capable patterned mask

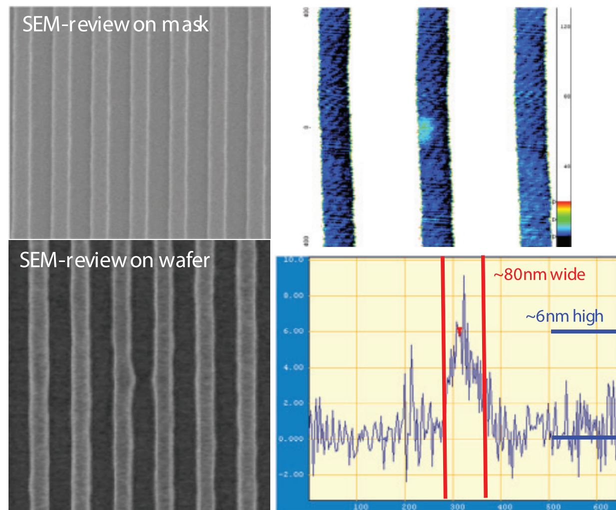


*Figure 6. Detailed analysis of a printing bump-type MLdefect that was missed during blank inspection on a M7360 (reticle Defect40FF-A). Bottom left: causing a CD error on wafer (shown at best focus); top left: not visible on mask SEM; top right: top view as obtained by AFM; bottom right: cross-sectional view giving indications for height and width.*

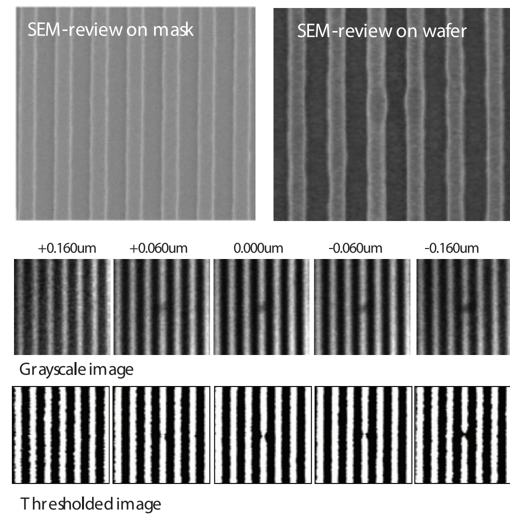


*Figure 7. Detailed analysis of a second printing ML-defect that was missed during blank inspection on a M7360 (reticle Defect40FF-A). Top right: causing a CD error on wafer (shown at best focus); bottom: through-focus visualization on the AIT, confirming likelihood of the presence of a ML-defect.*

inspection typically detected only a limited number of printing ML-defects, which illustrates that this is not a realistic expectation for this inspection technique. If a blank defect were detected by patterned mask inspection, it would still be too late. It is blank inspection that should detect it, as to allow using the technique described by Refs 10-11.

The described approach allowed to identify a number of printing ML-defects that were missed by the Lasertec M1350 tool typically in use by the blank vendors.[4,8] As reported they could be visualized by AFM, and experimental evidence of the critical printability of 3nm high or deep ML-defects (bumps and pits respectively) was confirmed by examples of natural defects, beyond the earlier results based on simulation and experimentally by programmed occurrences.[3,5]

One major challenge during such exercise is to ensure that the correlation between defectivity maps can be done with about micrometer accuracy. This is a challenge, since blank inspection maps have no usable "origin" and blank fiducials as prescribed by Ref 10 are not in use yet. For the scope of the reported investigations, adding local references such as the EUV-printable markers 4 was found very useful.

In any of the previous work of the authors it had not been possible so far to find evidence for printing ML-defects that were missed by the second generation blank inspection tool, i.e. the Lasertec M7360. In view of the previous understanding that the printability of a ML-defect at EUV wavelength is determined by its nature through-out the multilayer, not just at the surface, it was clear that, as this tool uses a shorter wavelength which has a smaller penetration depth, the technique could even be more depending on the presence of topography at the surface of the EUV mirror. The nuisance rate of the M7360 was previously found somewhat alarming.[4,8] In the former reference only a small fraction of all detections were found printable. Yet, as it will be further explained below, one should review the detections on wafer prints made through-focus. In such case[8] an estimate was made that still only a few percent of the M7360 detections really print, and it was still possible to give evidence of detections made with a large number of pixels that yet were not found to print.

In previous work[4] this through-focus behavior was used during wafer review to identify candidate ML-defects, even just based on the baseline wafer inspection available at imec (KLA 2800), and not the more advanced tools included in the previous correlation between multiple inspection tools, including multiple wafer inspection tools. Anyhow it has already led to finding more evidence of Lasertec ML1350 missers, i.e., printing ML-defects missed by the M1350. There was no proof yet for similar M7360 missers until then.

The next section reports the use of the through-focus printing behavior during wafer inspection, as to improve its sensitivity to detect printing ML defects.

## 2. Investigation for ML-Defects on a second Defect4OFF Reticle

By circumstances which are not relevant for the discussion, a similar analysis as reported in Ref 4, was continued on another version of the same reticle layout (Defect40FF). The inspection techniques, and tools, compared are the following:

- This time also mask substrate inspection was included (Lasertec M1350).
- For ML-blank inspection only the newer Lasertec M7360 is reported, although also results of a M1350 were available, which are considered a subset of those of the M7360.
- Blank inspection results after absorber deposition was again available (also M1350).
- Likewise patterned mask inspection, yet not an advanced tool, was also included.
- For wafer inspection results of imec's baseline wafer inspection tool were available.
- As an advanced wafer inspection tool AMAT's DUV laser based UVision 4 was included.
- For wafer inspection we used a modified analysis technique, making use of the typical through-focus behavior of ML-defects, as now discussed first.

Figure 1 illustrates a clearly variable printing behavior through-focus for the detections made by the advanced wafer inspection. Some had increased printability at positive focus, other at negative focus, yet other had a stable or irregular printability. This behavior, as forecast by Ref 7, was exploited: The repeater analysis following the wafer inspection was done separately for each focus setting

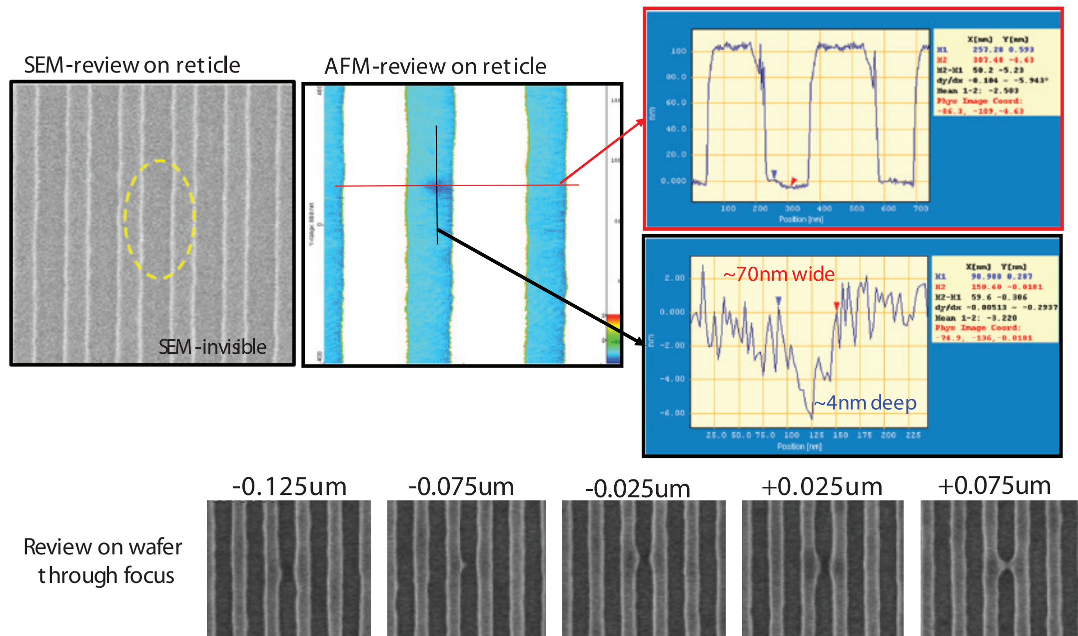


*Figure 8. Detailed analysis of a printing pit-type ML-defect that was missed during blank inspection on a M7360 (reticle Defect40FF-B). Top row: Left: not visible on mask SEM; centre: top view as obtained by AFM; right: cross-sectional in parallel and perpendicular direction of the lines, view giving indications for height and width. This defect is estimated as a ~70nm wide pit, ~4nm deep. Bottom row: printing behaviour through-focus on ADT.*

used for wafer printing. Previous assessment[4] only used wafer inspection of wafer prints made at best focus.

Figure 2 summarizes the results of the so-called defect source analysis for this new evaluation.

- On the mask substrate only 7 defects were found.
- ML-blank inspection did also detect those, but detected several thousands additional ones. This is in the first place due to the increased sensitivity of the M7360. As discussed before,[4] and also confirmed on this reticle, this tool may make many more detections than actually can be confirmed to print, but this is not analyzed again on this reticle.
- Blank inspection after absorber deposition detected 6 out of the 7 substrate defect detections, confirmed 49 detections made on the ML-blank inspection, and detected 27 additional defects which are likely due to the absorber layer itself.
- Only 5 of the latter were confirmed by the (basic) patterned mask inspection, as it showed up as a pattern defect, and just 1 additional pattern related defect was detected.
- Imec's baseline wafer inspection detected in total resp. 4, 7, 5 and 0 of the previous four classes. On top of this, it detected 11 additional defects, which according to the reasoning used in Ref 4are considered as 11 candidate ML-defects that were missed by blank inspection.
- The advanced wafer inspection (AMAT UVision 4 at vendor site), using the additional technique of running separate repeater analysis per focus detected resp. 4, 35, 5, and 0 of the first four classes. It could clearly confirm more ML-blank detections to print. And on top of that 40 additional detections were made, i.e., clearly disclosing many more that can be considered as candidate ML-defects.

Figure 3 illustrates the improved detection capability. Whereas a similar analysis as used for the Defect40FF-A reticle in Ref 4 only detected 27 printing defects, the new procedure allowed increasing this number to 84. The substrate defects that were also found by wafer inspection are illustrated in figure 4. They are mostly relatively large defects. Although this was not attempted as such, it is expected that the more advanced M7360 would be capable of finding more substrate defects, yet again probably with a high nuisance rate of detections that cannot be confirmed printing.

Out of the 84 defects detected by the extended wafer inspection approach, 34 could be confirmed of the ML-type. This was mainly based on the absence of an obvious flaw of the absorber pattern. Only 8 of them could be visualized by mask SEM review. AFM showed that these were bumps of more than 10nm height. Not all 26 other ML-defects could be analyzed by AFM yet, but none of them were visible by SEM on mask. The AFM results available showed that most of them are bumps, all of less than 10nm height, and a few were pits, also of less than 10nm depth. Figure 5 illustrates a number of these natural ML-defects.

The 40 additional defects found by the advanced wafer inspection including the variable focus wafer inspection technique were checked by wafer review for a distinct through-focus behavior. 10 out of these 40 were withheld for more thorough analysis.

Analysis of all detections considered with high certainty as ML-defects is not yet complete. Yet among the 10 with a clear through-focus behavior we have been able to find evidence for at least one clear case that was NOT detected on the Lasertec M7360. Figure 6 illustrates that this defect was visualized as a 6nm high bump, with around 80nm lateral size.

At least one other detection is a strong candidate as well (figure 7). Yet, AFM evidence has not yet been obtained. Whereas one of the challenges is to assure highly accurate coordinate information for a blank defect on a reticle (see introduction) it has been possible to confirm this second printing defect that was as not visible by mask SEM review. Based on the same coordinates input, the AIT (actinic inspection tool, actually an AIMS like review tool) at Lawrence Berkeley National Labs has been able to confirm this as a focus sensitive defect.

Similar analysis as described in the present paper has led to additional evidence on the previous Defect40FF – A reticle used in recent work.[4] A further proof by AFM of a printing ML defect missed by the Lasertec M7360 is shown in figure 8.

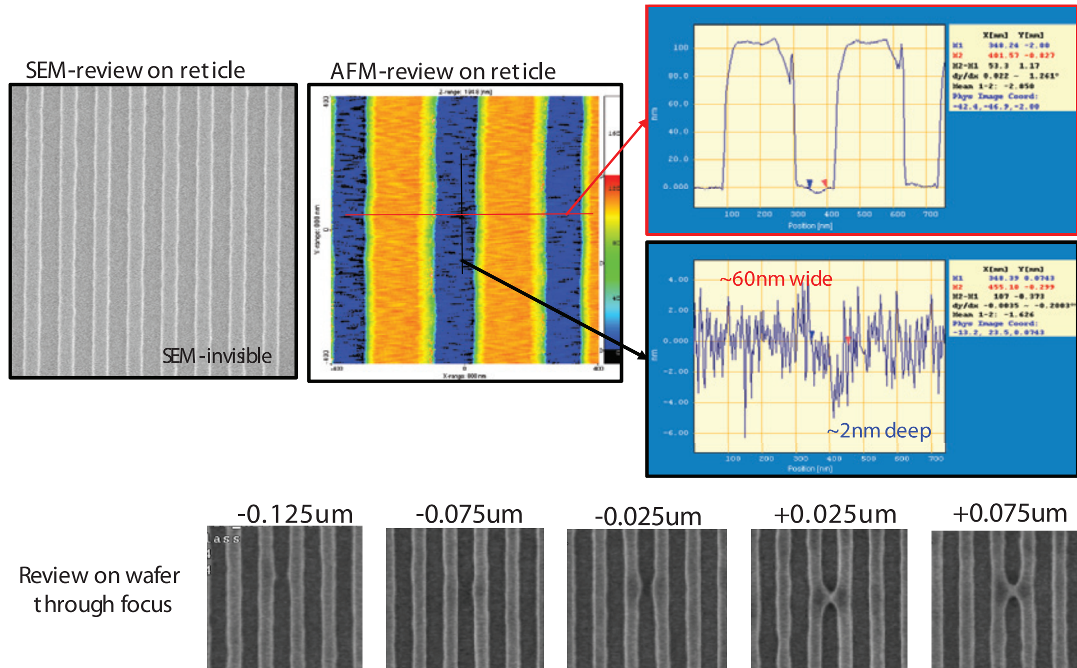


*Figure 9. Detailed analysis of a second printing pit-type ML-defect that was missed during blank inspection on a M7360 (reticle Defect40FF-B). Left: not visible on mask SEM; centre: top view as obtained by AFM; right: cross-sectional in parallel and perpendicular direction of the lines, view giving indications for height and width. This defect is estimated as a ~60nm wide pit, ~2nm deep. Bottom row: printing behaviour through-focus on ADT.*

This time it is a shallow pit that is missed by the M7360 (around 4nm deep). Last minute in the preparation of this manuscript also a second pit could be visualized (figure 9), although it also demonstrates how critical it can be to bring vibration noise down to virtually zero, as this ~2nm deep pit is hard to disposition from the noise of the AFM image.

Figure 10 illustrates that the through focus behavior of bumps and pits on the AIT and as analyzed by ADT printing is comparable. ML defects that print more severely at positive focus are found to be bumps and defects with a stronger printability at negative focus are found as pits. It is not fully understood in which conditions some ML-defects appear not to have a clear through-focus behavior, although they were confirmed as pits or bumps by AFM.

These findings highlight the benefit of AFM review for detailed EUV defect characterization. The AFM tool used here is a Zeiss SMS in-house improvement on a low-end commercial platform used for roughness and layer thickness measurements. It uses whisker tips, commercially available, in a non-contact mode. This tool has an optical microscope and a micrometric stage allowing for positioning within 1 to 2 µm over the area of a mask. The images are un-filtered, except from the subtraction of a plane and a histogram leveling along the Y-direction. Typical resolution values are 256x256 pixels over an area of 800x800 nm$^2$, as scanned at 0.5 line/s. Since this tool is measuring in air and separately from the main test vehicle used for SEM-review and focused-electron-beam-induced repair Zeiss SMS is currently implementing a vacuum-compatible AFM head in the MeRiT HR platform. This will allow for rapid AFM visualization of SEM-invisible multilayer defects in a single tool, and minimize the possible impact of vibration noise.

One of the challenges in the present work, due to the use of lines and spaces all across the exposure field, is the lack of locally unique reference points. The blank inspection results so far had no usable reference to the mask pattern. The accuracy of the coordinates of the defect positions, as translated onto reticle scale from wafer review, limits the analysis. The example is figure 9 shows that the (vibration) noise in the AFM analysis can become a problem to interpret correctly that no height distortion is apparent. In such case the inaccuracy of the defect coordinates is also a possible explanation. Then the AIT can confirm the presence of a printing defect. In such case this may be evidence for a (near-) zero height, printing ML defect.

The results also emphasize again how critical these ML-defects are and how extremely difficult it can be to find these defects without trying to find evidence on wafer exposures. Yet it is repeated that also wafer inspection presently is still limited. Improving that will quite likely show even more evidence of printing blank defects that were missed by blank inspection.

## 3. Conclusions and Final Remarks

In this follow-up work of an earlier publication, the main result is the visualization of a handful of printing ML-defects found on state-of-the-art reticles, that were missed by the more advanced Lasertec M7360 blank inspection tool. This has been achieved by a continued endeavor to further improve the total vision, by adding additional tools in the correlation between defect maps obtained by individual tools, and also by improved procedures. A clear example of the latter lies in the exploitation of the through-focus behavior of ML-defects, by the individual repeater analysis of the wafer inspection results for each focus setting separately. This allowed collecting evidence for defects that could not be detected when only using exposures made at best focus.

The experimental visualization of such printing defects, that fail the blank inspection infrastructure in place today, was achieved by the combination of thorough coordinates transformation from printed wafer to mask, clever transposition of blank defectivity maps, mask review by SEM and AFM assuring accurate review placement, and confirmation of the latter by the AIT using the same coordinates on the mask.

The M7360 missers are typically shallow and narrow pits or bumps, i.e., with height/depth and lateral size typically in the range

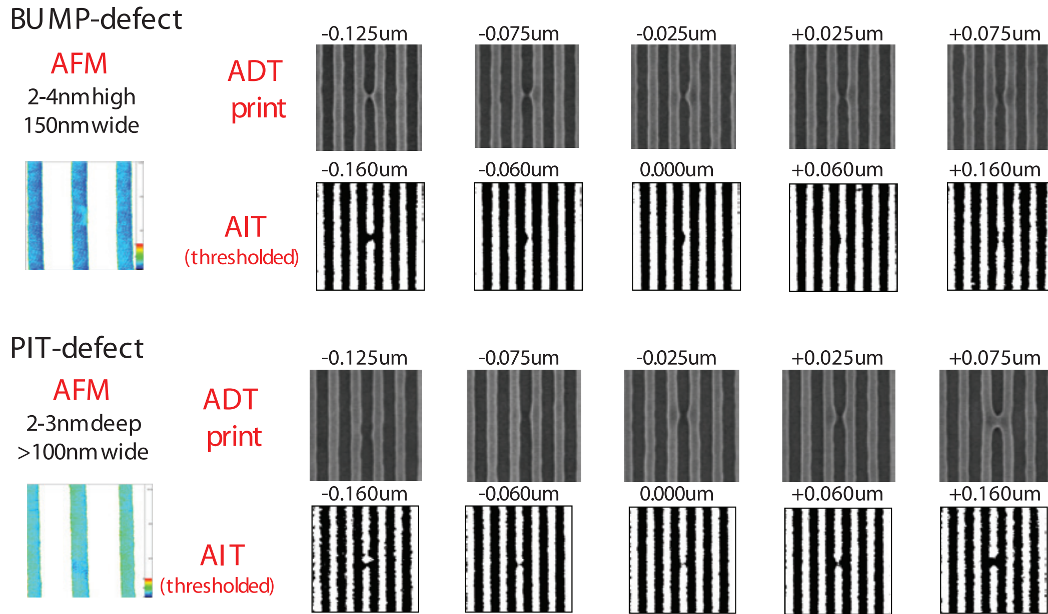


*Figure 10. Comparison of through-focus behaviour as found for wafer printing on ADT and visualized on the AIT (mimicing ADT settings), for an example of a bump- and pit-type ML-defect, as visualized by AFM.*

2-6nm and 60-90 nm respectively. The M1350 missers as reported in Ref 4 were typically rather wider laterally.

Of the available blank inspection tools, clearly the 488nm - and 266nm wavelength based tools were not satisfactory in detecting all printing ML-defects. It is even more worry-some that for the M7360 this is at the cost of a relatively high nuisance rate of detections that cannot be confirmed to print.[4] Two further candidate tools families are respectively using 193-199nm wavelength and actinic EUV wavelength. In view of the fact that the former is even more surface sensitive than those evaluated until now, and the fact that certain printing ML-defects may not even have surface topography, it is not unlikely that it can also miss printing ML-defects. Such evidence is not yet in place because such tool could not yet be included in our analysis. Neither could we include actinic blank inspection such as in Ref 12, but as it mimics the scanner reasonably well by at least using the same wavelength, it is less likely that it will fail to detect all printing ML-defects, unless lateral resolution may be a limiting factor. These statements summarize the inspiration for future work.

As a final conclusion this work shows an important limitation of state-of-the-art blank inspection: If it cannot detect ALL printing ML-defects and/or it is not capable of reaching a low enough false count rate, existing practices[10] to deal with ML-defects by blank picking or design will have too limited success. Yet, ML-defects not found in time (not on the blank, nor on the mask, but after first wafer prints) likely can be overcome (unless they are too solid) by compensation repair 5.9. Such experimental work is ongoing and will be presented at a future conference.

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# Industry Briefs

## Mask Business on the Rebound

After three years of decline in volume and price on the mask market, there are two recent reports that counter than trend. EETimes' Mark LaPedus reports that increased design activity is being driven by the growing number of new consumer electronics such as tablets and smartphones. The result is a cyclical rebound in the photomask industry started in 2010 and believed to extend over the next 2-3 years, according to Edwin Mok, an analysis with Needham & Co. LLC.

Following declines from 2007 to 2009, the IC photomask market rebounded from $2.7 billion in 2009 to $3.0 billion in 2010, according to Needham and is expected to hit $3.15 billion in 2011. Of that figure, the merchant market is about $1.90 billion.

"The increased complexity of leading edge designs is driving the costs and prices of leading-edge masks higher," Mok said. ''A leading-edge 45-nm mask set requires 70 percent more time to define (due to write time) and has five more layers than a 65-nm mask set." The average write times for a 65-nm mask set are 130 hours, compared to 230 hours for a 45-nm mask set, according to the report.

An EETimes article by Peter Clarke reports that the price of wafers fabricated at foundries jumped by 5 percent in the fourth quarter of 2010, turning round a falling trend from the previous two quarters, according to a survey conducted by the Global Semiconductor Alliance (GSA).

Median fab pricing for both 300-mm and 200-mm diameter CMOS production wafers increased by about 5 percent quarter-over-quarter, to $3,211 and 200-mm to $821 respectively, according to GSA. In contrast, median pricing for 150-mm wafers decreased by 53.2 percent, to $338. In a similar manner to wafers, survey participants reported that after decreasing for two consecutive quarters, there was a sequential increase in the median mask set cost for 200-mm CMOS wafers. Participants indicated that the median cost, at $79,200, increased 21 percent QoQ and 20 percent YoY. Mask sets for 300-mm wafers had a median cost of $510,000, a decrease of 1.8 percent QoQ, but up 2.0 percent YoY.

## ISPD spots 3-D, maskless-lithography trends

*By* **R. Colin Johnson**

Next generation trends in the physical fabrication of semiconductors, including 3-D and maskless lithography, were recently laid out at this year's 20th annual International Symposium on Physical Design (ISPD 201) in Santa Barbara, Calif.. The contest this year concentrated on the global routing congestion problems that plague lithographic placement algorithms below the 65-nanometer node. Instead of judging placement algorithms based on wire length or spreading capabilities, the contest used "routability" as evaluation metric. Best paper went to University of Texas (Austin), for innovative adaptation of e-beam lithography to production environments. Today, e-beam lithography is mostly used for prototyping, but it was argued that e-beam can compete with the increasingly expensive masks used for double, triple or even quadruple exposure lithography. Pan and Yuan from UTA recommend using the stencil planning and optimization algorithms to speed up e-beam lithography for production.

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