PHOTOMASK

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Best Paper Award

# Development and Characterization of a Thinner Binary Mask Absorber for 22 nm node and Beyond

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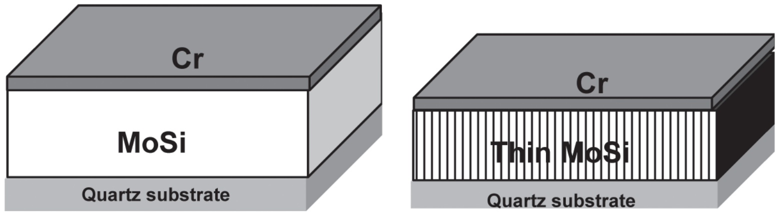
## ABSTRACT

The lithography challenges posed by the 22 nm node continue to place stringent requirements on photomasks. The dimensions of the mask features continue to shrink more deeply into the sub-wavelength scale. In this regime residual mask electromagnetic field (EMF) effects due to mask topography can degrade the imaging performance of critical mask patterns by degrading the common lithography process window and by magnifying the impact of mask errors or MEEF. Based on this, an effort to reduce the mask topography effect by decreasing the thickness of the mask absorber was conducted. In this paper, we will describe the results of our effort to develop and characterize a binary mask substrate with an absorber that is approximately 20-25% thinner than the absorber on the current Opaque MoSi on Glass (OMOG) binary mask substrate.

For expediency, the thin absorber development effort focused on using existing absorber materials and deposition methods. It was found that significant changes in film composition and

*Continues on page 3.*



a. Current OMOG Blank

b. New Thin OMOG Blank

*Figure 1. a. Process of Record OMOG mask blank with 5 nm chrome hard mask and 60 nm thick MoSi absorber. b. New thin OMOG blank with 5 nm chrome hard mask and 47 nm thick MoSi Absorber.*

## Take A Look Inside:

# EDITORIAL

## Controlling the Expansion

**Paul W. Ackmann,** GLOBALFOUNDRIES Inc.

We have entered another time period when we must narrow the options among lithographic approaches to use on sub-22 nm half pitch designs. The use of single patterning for advanced 193 nm immersion ends or ended at 44 nm DRAM pitch or 40 nm Logic. The use of spacers and other technology has extended 193 nm immersion lithography a few nodes, but in this editorial I want to discuss other options that could be considered as disruptive alternatives. The costs of lithography and reticles have increased as the design rules have gone from a few pages to a few 'volumes'. All of these factors drive the need to discuss how we can use new technologies to reduce the disruption to the market.  We must increase the value to the customer to get more products to use the new nodes below 20 nm half pitch.

In the most recent Bacus Symposium, the extension of 193 nm, Direct Write, Nano Imprint, and EUV were all discussed as the possible replacements for advanced lithography. The introduction of a full replacement method will be difficult and take many years—for this reason I would like to look at these technologies as a constructive or destructive event to keep this in lithographic terms.

To understand the trends, we must go back in history and review how we have gotten here. Early on, lithography changed from contact printing to the first scanner. Perkin – Elmer and others allowed the industry to use 1X Masks to build small to 150 mm wafers. The use of 1X scanners for lithography represented the first major change in wafer lithography. Mask defectivity could be easily tracked, improved, and finally driven to near-zero. Pellicles provided the way to keep the mask defectivity down. Many companies and many small mask shops dominated the technology in this period.

The next disruption was the move to reduction steppers. David W. Mann / GCA started with 10X reduction steppers using 436 nm (G-line) exposures in the early 1980s. The reduction stepper was the greatest thing since sliced bread. Reticle defects could now repeat but CD control, overlay and wafer signatures could be addressed in a straightforward manner. The next transition was lowering the wavelength from 436 nm to 365 nm (or I-line). The I-Line stepper was adopted by some but others stayed with G-Line.

The invention of the MicraScan introduced the next disruption. The tool needed to be fast. The light source was still a big bulb. To get the throughput up, only a few millijoules could be used to expose the wafers. Solution: chemical amplification of the resist at 248 nm exposure—it was a big switch. The novalak family of resists we had learned to love would soon be replaced. Regardless of the cause, this was the step that allowed the rethinking of k1 factor resolution and move to k1s in the previously unreachable 0.3 range for manufacturing. The cost of reticles had increased, but much of the cost of enhanced reticles was won back with higher throughput, large wafer volumes, and smaller features.

Now, we have moved to the end of 193 immersion lithography at 1.35 NA. It does not appear that a higher NA will be developed. The improvements are driven by more content on the reticle with complex and complementary illuminators.  At some point we will have triple and quadruple patterning to reduce pitch and resolution.  The technology may have slowed but the innovation with 193 nm optics continues.  Moore's law has been at work for all these many years. As I look at wafer volumes of a given design, many of the non-leading edge customers can run significantly fewer wafers than the DRAM or MPU producers. It has been reported by others that the volumes can go from 100,000s wafer to 100s of wafers. While the technology has scaled in keeping with Moore's law, the wafer volumes may not support the cost reduction due to the high cost of introduction which causes a bifurcation of the industry into VERY high volume and NOT high volume products.

The introduction of  EUV, Direct Write and Nano Imprint all have an opportunity to restore some cost balance at the introduction of new technologies without displacing the primary work horse. The more players we have at the advanced nodes, the better it is for the industry and ultimately the consumer. As we move forward I would like to see the new technologies show how they can help expand the pie and not drive a disruptive event but a constructive event. The more (solutions), the merrier we shall be.

The dialogue is critical and success is the only option. As Edison said, "Genius is 1% inspiration, and 99% perspiration." We got the 1% done for all the new technologies. We now have many working on the sweat equity portion to complete the 99% requirement and drive the technology insertion for each.

Good luck and God Speed.

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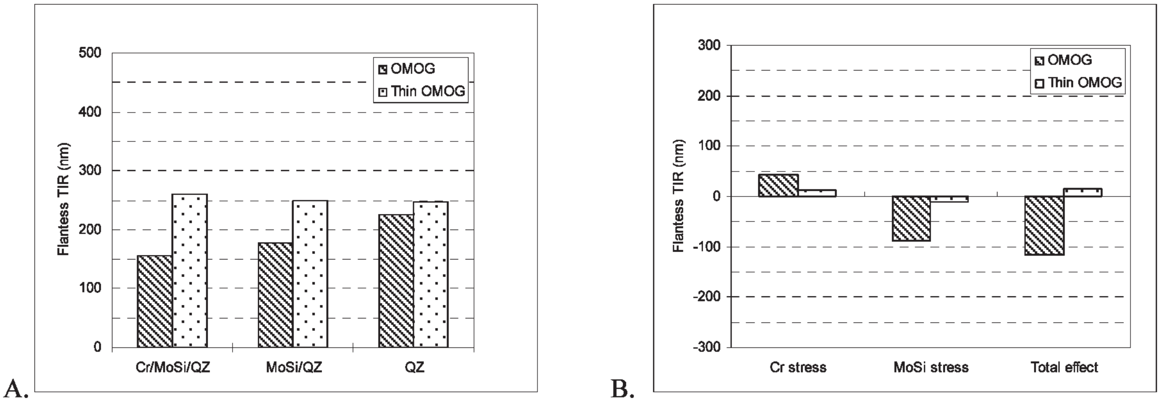

*Figure 2. a. Flatness comparison of OMOG and thin OMOG after removal of each film on the substrate. b. Film stress comparison of OMOG and thin OMOG.*

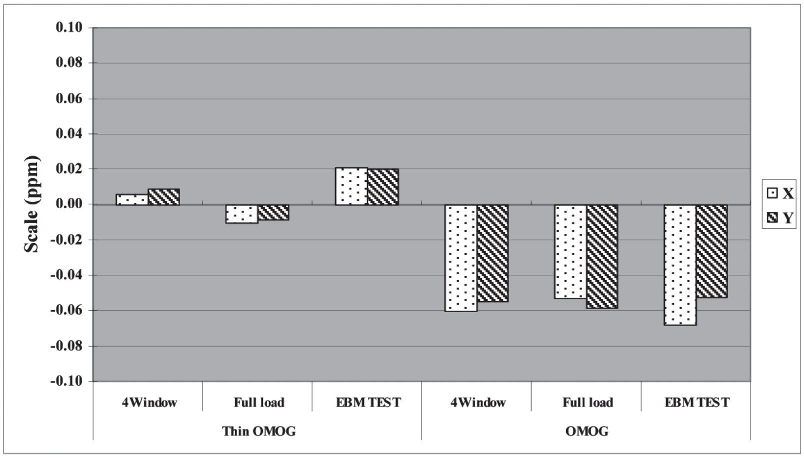

*Figure 3. Scale factor of process-induced distortion computed by vector subtraction of resist and final MoSi image placement.*

structure were needed to obtain a substantially thinner blank while maintaining an optical density of 3.0 at 193 nm. Consequently, numerous studies to assess the mask making performance of the thinner absorber material were required and will be described. During these studies several significant mask making advantages of the thin absorber were discovered. The lower film stress and thickness of the new absorber resulted in improved mask flatness and up to a 60% reduction in process-induced mask pattern placement change. Improved cleaning durability was another benefit. Furthermore, the improved EMF performance of the thinner absorber[1] was found to have the potential to relieve mask manufacturing constraints on minimum opaque assist feature size and opaque corner to corner gap.

Based on the results of evaluations performed to date, the thinner absorber has been found to be suitable for use for fabricating masks for the 22 nm node and beyond.

## 1. Introduction

During early development of optical lithography for the 22 nm node, it was found that residual mask electromagnetic field (EMF) effects due to mask topography were causing a significant degradation in the common lithography process window. Based on this, the IBM and Toppan mask development program was asked to investigate the potential for reducing these damaging mask topography effects by further reducing the film thickness of the mask absorber used on the Opaque MoSi on Glass (OMOG) binary mask blank. As shown in figure 1a the MoSi absorber thickness on the process of record OMOG mask blank is 60 nm. For expediency, it was decided to pursue further thinning of this MoSi absorber to reduce EMF effects. After much discussion with the 22 nm lithography and OPC teams it was determined that a thinner binary mask absorber would need to have the same optical density of 3.0 as the existing OMOG absorber. Based on this, a large development effort to fabricate a thinner binary MoSi absorber with significantly improved EMF performance and an optical density of 3.0 was initiated. In order to have a thinner MoSi absorber and maintain an optical density of 3.0, changes to the current OMOG MoSi film composition were required. Fundamentally, the thinner MoSi absorber needed to have increased amounts of molybdenum and silicon which also had the effect of increasing the reflectivity of the mask blank. Optimization work on the film stack was performed to keep both the front side and backside reflectivity within acceptable limits.[1] Numerous film samples were created and evaluated for EMF and optical lithography performance as well as mask making performance. Figure 1b shows the final optimized version of a thinner OMOG mask blank that is a result of this work. As the figure indicates the MoSi absorber thickness is 47 nm which is about 22% thinner than the process of record (POR) OMOG absorber shown in figure 1a. Furthermore, the thinner OMOG mask blank uses the same 5 nm chrome hard mask as the thicker OMOG blank. The results of detailed studies of the mask making performance of the new thin OMOG blank and its suitability for use for building 22 nm node

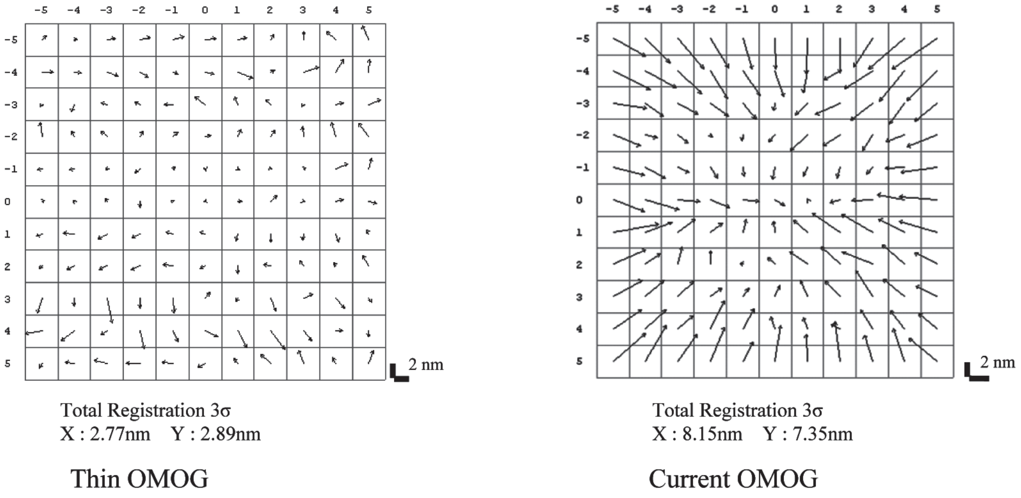

*Figure 4. Vector plots of process-induced image placement change for thin OMOG and current OMOG for a 4-window test pattern built with NCAR resist.*

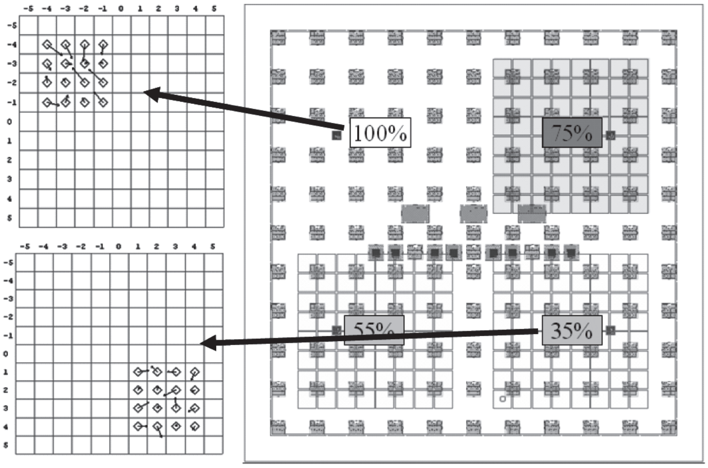

*Figure 5. Example of the 4-window test mask pattern used for studying the local pattern density effect on image placement.*

critical level masks will be shown in this paper.

## 2. Film Stress, Flatness, and Image Placement

One significant advantage of the new thin OMOG MoSi film is that it has lower film stress and less flatness change than the current thicker OMOG absorber. An assessment of the film stress of each layer on the mask blank was performed by measuring mask blank flatness before and after removal of each individual film layer on the blank as shown in Figure 2a. In the case of the current thicker OMOG film, the flatness gets worse after each film is removed. However, thin OMOG shows almost no change in flatness after each film is removed. Figure 2b shows the point by point difference in flatness that occurs due to each film removal step and is a measure of film stress. In this figure a positive TIR means tensile stress, and a negative TIR means compressive stress. As the figure indicates, the chrome hard mask film used on these mask blanks has a tensile stress, and the MoSi films tend to have compressive stress. However, it is clear from the figure that the MoSi stress of the thin OMOG blank is much smaller than the current thick OMOG. The Total effect of both the chrome and MoSi film stresses shown in the figure represents the combination of the stress of both the OMOG blank data shows much better performance.

An assessment of the effect of the lower film stress and thickness of thin OMOG on mask image placement was performed by measuring the process-induced in-plane distortion performance. This technique has been used previously to study stress-induced pattern placement effects on X-ray masks.[2] A laser metrology system was used to measure mask pattern placement. For this study, the mask pattern placement was measured in resist (immediately after the develop step) and on the finished mask in the fully patterned MoSi absorber film. The process-induced distortion was computed by vector subtraction, point by point, of the resist pattern placement and final MoSi pattern placement data. The 3 sigma residual of the difference is given as the process-induced distortion value. Figure 3 shows a summary of the scale factor of the process-induced distortion for thin and thick OMOG for three different bright field mask patterns. Each test mask was built using negative tone chemically amplified e-beam resist (NCAR). Figure 4 is an example of a vector plot of the process-induced image placement change on the 4-window test mask pattern for both thin and thick OMOG. The data in figures 3 and 4 clearly show the beneficial effect of thin OMOG's low film stress on image placement. The scale factor change on thin OMOG is improved by 60 -80% versus thick OMOG.

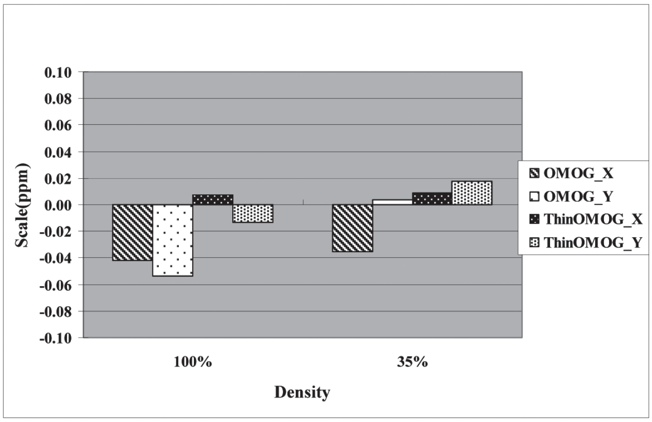

*Figure 6. Scale factor comparison between thin OMOG and current OMOG for changes in across-mask pattern density.*

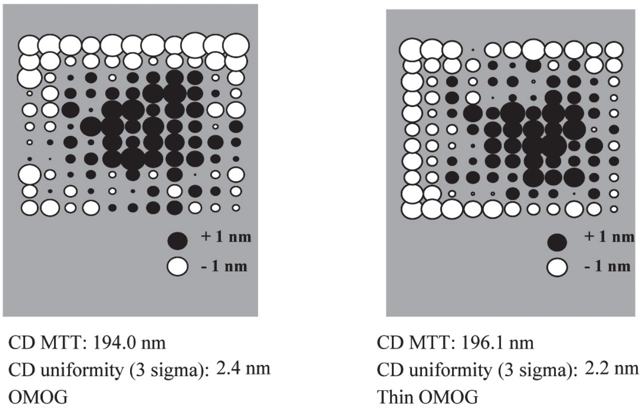

*Figure 7. Comparison of the final MoSi CD maps of OMOG and thin OMOG for a 4-window test pattern built with 150 nm thick NCAR resist.*

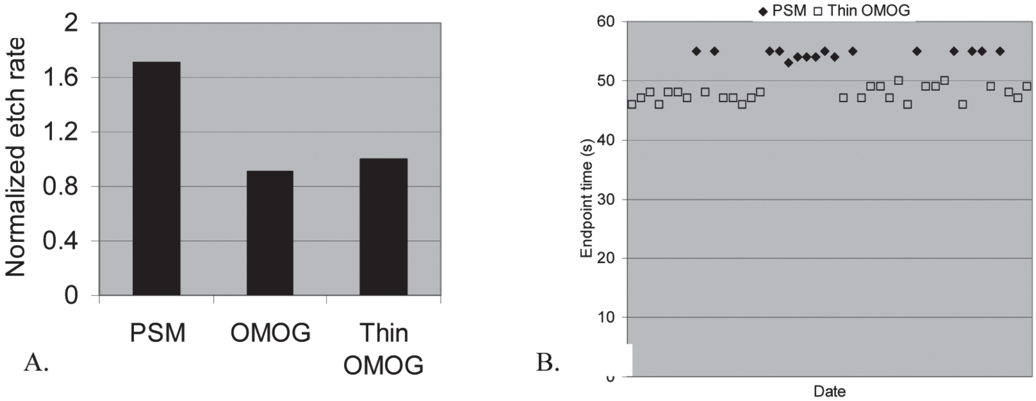

*Figure 8. a. MoSi etch rate comparison between PSM, thin OMOG and current OMOG. b MoSi etch endpoint time comparison for PSM and thin OMOG.*

In addition to studying the effect of the lower film stress and thickness of the new thin OMOG blank on the global image placement performance, an assessment of the difference in local image placement scale factor for two different types of pattern density regions within a mask was performed. The local pattern density study was done using a 4-window test pattern which has four different density areas on the mask as shown in Figure 5. The scale factor change on the 100% pattern density region and the 35% pattern density region was measured, and the results are shown in Figure 6. In this case the thick OMOG mask shows a different scale factor in each density region. The low open area region (35% density) shows smaller scale than the large open area region (100% density). On the other hand, the new thin OMOG blank shows much less scale factor difference between the two pattern density regions on the mask. This result shows another benefit of the lower film stress and thickness of thin OMOG.

## 3. Dry Etching Performance

### Initial Results

A comparison of the dry etching characteristics of the new thin OMOG blank and the current OMOG blank was performed. Initial dry etching tests were conducted using identical chrome and MoSi dry etching conditions on test masks patterned with both 150 nm thick positive chemically amplified resist (PCAR) and NCAR e-beam resist exposed using a 50 keV e-beam writer. Figure 7 below shows a comparison of the across-mask CD uniformity results achieved on a 4-window test pattern built with NCAR resist. This test pattern is described in figure 5 above. A 200 nm isolated opaque feature was measured. As the figure indicates the final MoSi across mask CD uniformity map of the thin OMOG is nearly identical to the CD map of the current OMOG blank. This indicates that there was no significant thin OMOG blank when it was processed under identical dry etching conditions as the current OMOG blank. In addition, the CD mean-to-target for thin OMOG was only 2 nm different than the current OMOG blank. This is due to the shorter MoSi etching time required for thin OMOG which reduces the etching bias.

During these studies, MoSi etching was performed using a fluorinated chemistry in a conventional inductively coupled plasma (ICP) etch chamber. It was observed that the same etch processes used for phase shift mask (PSM) and conventional OMOG films were effective for etching thin OMOG with good results for CD uniformity, etch bias, linearity, and thru-pitch. The thin OMOG MoSi film etched at a significantly lower rate than PSM and at a slightly higher rate than OMOG as shown in figure 8a. thin OMOG MoSi films are shown in figure 8b. The TEM cross sections in figure 9 show that the thin OMOG MoSi sidewall profile is similar to conventional OMOG.

### Results After Optimization

Work to further improve the dry etching performance of the thin OMOG blank by optimizing both the chrome and MoSi dry etching conditions was conducted. This work was focused on developing

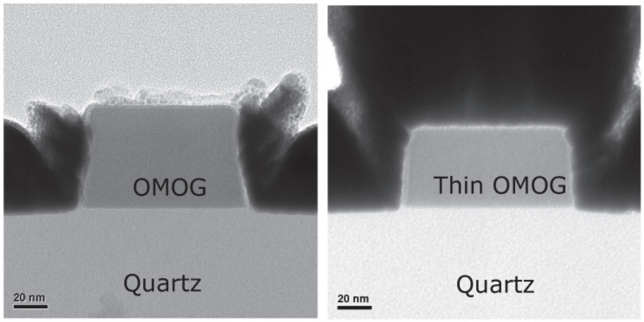

*Figure 9. TEM sidewall comparison of OMOG and thin OMOG on a 100 nm feature.*

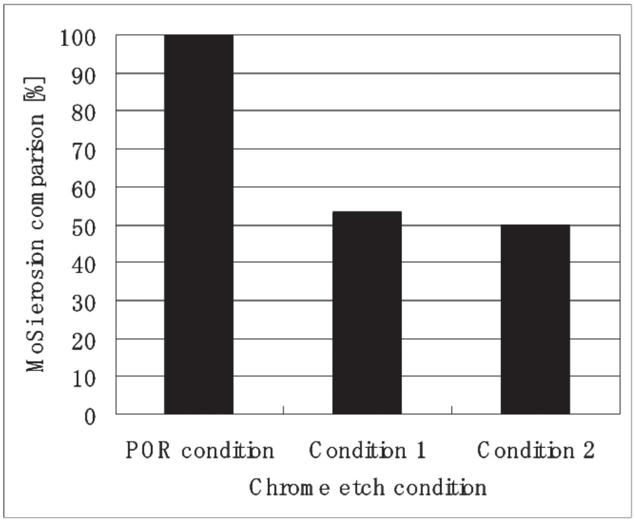

*Figure 10. Comparison of MoSi film erosion during chrome etching at different etch conditions.*

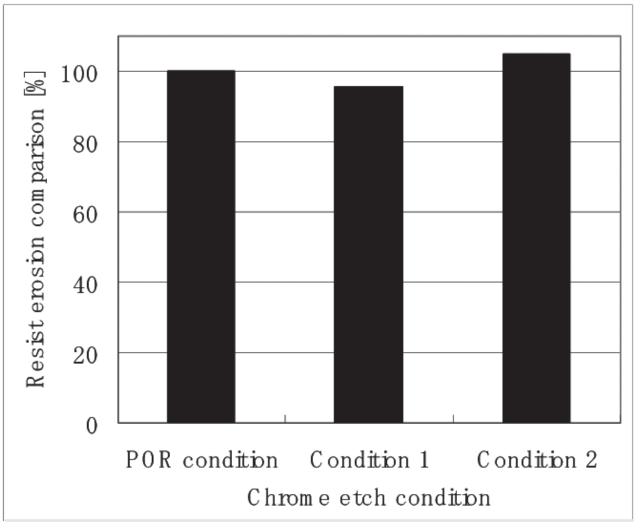

*Figure 11. Comparison of resist erosion at different chrome etch conditions.*

etch suitable for use with 100 nm thick NCAR and PCAR resist with the goal of obtaining processes that would meet the CD uniformity and minimum feature size requirements of 22 nm node. Our previous work indicated that use of the current OMOG material with thinner resists and a thinner chrome hard mask and an optimized chrome etching process showed good CD performance for 32 nm node and early 22 nm node masks.[3] During etch optimization work for the new thin OMOG blank it was discovered that the thin OMOG MoSi film had a higher etching rate in the chlorine/oxygen chemistry used for chrome etching than the current OMOG film. This is due to the higher metallic composition of the thin OMOG MoSi film and had the effect of causing a significant amount of MoSi etching to occur during the over etch step of the chrome hard mask etching process. Based on this result, work to reduce the amount of thin OMOG MoSi etching during the chrome hard mask etch process was conducted.

In order to minimize thin OMOG MoSi erosion during chrome etching, the effect of several etching parameters was studied, and two types of etching conditions were selected and tested. Resist erosion and MoSi erosion were measured by atomic force microscopy (AFM) before chrome etching, after chrome etching and after resist strip. Figure 10 shows the MoSi erosion comparison of each chrome etch condition. By using condition 1 and condition 2, MoSi erosion during the chrome etch process was reduced by about 50%. Using condition 1, resist erosion was improved about 5%, but by using condition 2, resist erosion was 5 % worse than POR as shown in figure 11. Based on these results, chrome etch condition 1 was selected as the best process for use with the thin OMOG mask blank.

After chrome and MoSi etch process optimization work for the thin OMOG mask blank was completed, an assessment of the across mask CD uniformity that could be achieved using the thinner mask blank and 100 nm thick NCAR and PCAR resists was performed. The test patterns used for this a 12. As the figure indicates two basic test pattern types were used. The first test pattern contained bands of varying pattern density across the mask. The second test pattern consisted of an array of 12 chips. For the case of PCAR resist the product chips were a typical metal level design. In the case of NCAR resist the product chips were a typical gate level design. Figure 13 shows the final MoSi across mask CD uniformity results achieved on these patterns. In all four cases the CD uniformity is less than 2 nm (3 sigma) and clearly demonstrates the capability for meeting the 22 nm node mask CD uniformity requirements.

## 4. Minimum Feature Size

The importance of improving mask minimum feature size is increasing with each technology generation. It is especially crucial for critical level masks for 22 nm due to the increased use of Source Mask Optimization (SMO) and Inverse Lithography techniques (ILT). The ability to pattern both 60 nm (4x) clear and opaque features on the mask is crucial. Previous papers have shown that improved resolution can be achieved with OMOG binary mask blank materials compared to PSM blank materials because the OMOG blank allows for low process bias and the use of thinner e-beam resist films.[4] The resolution performance of the new thin OMOG mask blank for simple space and line features for positive tone and negative tone resist processing is shown in figure 14. Using a 100 nm thick positive tone resist film, 48 nm nested clear, 47 nm isolated clear, and 94 nm nested contact features in final MoSi are resolved (figure 14A). Using a 100 nm negative tone resist film, 55 nm nested opaque and 32 nm isolated opaque features in final MoSi are resolved (figure 14B). Beyond simple native tone structures, source mask optimization (SMO) designs demand pattern fidelity of complex feature structures along with dual tone (clear and opaque) assist features. Figure 15 demonstrates thin OMOG pattern fidelity of more complex SMO structures and shows successful resolution of 62 nm assist feature holes. In Figure 16, dual tone assist features are shown for a positive tone resist process. As the figure indicates, 43 nm clear assist features are formed (figure 16B and 16C), and also the more challenging non-native tone 60 nm opaque assist features are resolved (figure 16A). These results clearly demonstrate that the new thin OMOG blank and 100 nm thick e-beam resists are capable of achieving minimum feature size performance that meets 22 nm requirements. It is expected that additional resolution improvements can be achieved by further optimization of the e-beam resist and dry etch processes.

## 5. Cleaning

Although continued development of more gentle cleans that remove less film and damage fewer features is an ongoing project in mask manufacturing, a material's ability to withstand the challenges of cleaning chemistries and processes is a necessary property that must be assessed before it can be released to manufacturing. Because each mask is cleaned multiple times during its manufacturing history, the absorber film must be particularly resilient to the cleaning process. Properties such as CD loss and assist feature damage are important parameters that must be verified. Aqueous ozone and dilute SC-1 with megasonics were the primary chemistries and processes used for these experiments. In addition, some tests were run using a binary spray nozzle without the use of megasonics.

Figure 17 shows the effect of the basic clean on the CD of standard OMOG, thin OMOG, and attenuated PSM absorbers. The clean used in this evaluation was simply a short exposure to aqueous ozone to condition the surface followed by dilute SC-1 with megasonics and subsequent rinses. The thin OMOG shows a 21 percent improvement over the standard OMOG blank in this basic cleaning chemistry, which is very beneficial for mask manufacturing. In addition, both OMOG and thin OMOG show much less CD change versus the PSM absorber.

As technology nodes progress and the feature sizes continue to shrink, feature damage becomes increasingly important. Even though new cleans are being developed to be more gentle, they are still not widely implemented, and in most cases, cleaning efficiency is sacrificed in order to prevent damage on small features. It is very desirable for any new film that is developed to show improved resiliency to feature damage with existing cleaning technology. Our standard cleaning process was used to test the feature damage resiliency of the thin OMOG. The first process tested was the binary spray process, followed by an array of SC-1/megasonics tests with increasing megasonics power (i.e. MEG 1<MEG 2<MEG 3). The frequency of the megasonics process was 1.0 MHz. Figure 18 shows the results from the damage tests for 65 nm opaque sub resolution assist features (SRAF). For the binary spray and lower megasonics power processes, the feature damage is zero, but as the megasonics power increases, the SRAF damage likewise increases for both standard and thin OMOG. As the figure indicates, the thin OMOG is more resilient at higher megasonics power cleans. It appears that the thinner OMOG film experiences less damage because the assist features have a smaller aspect ratio OMOG. In addition, the unique thin OMOG film composition could be another factor that contributes to better feature damage performance.

## 6. Defect Inspection

The e-beam exposure, resist, and dry etch processes currently used in mask making produce some very small and subtle differences between the actual final mask pattern and the ideal database reference pattern used by the die to database defect inspection

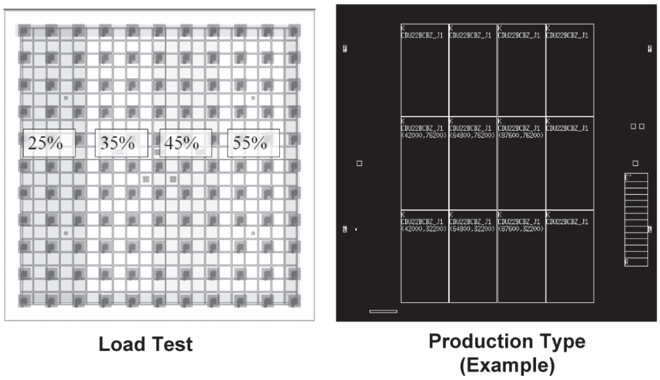

*Figure 12. Test patterns used for across mask CD uniformity evaluations.*

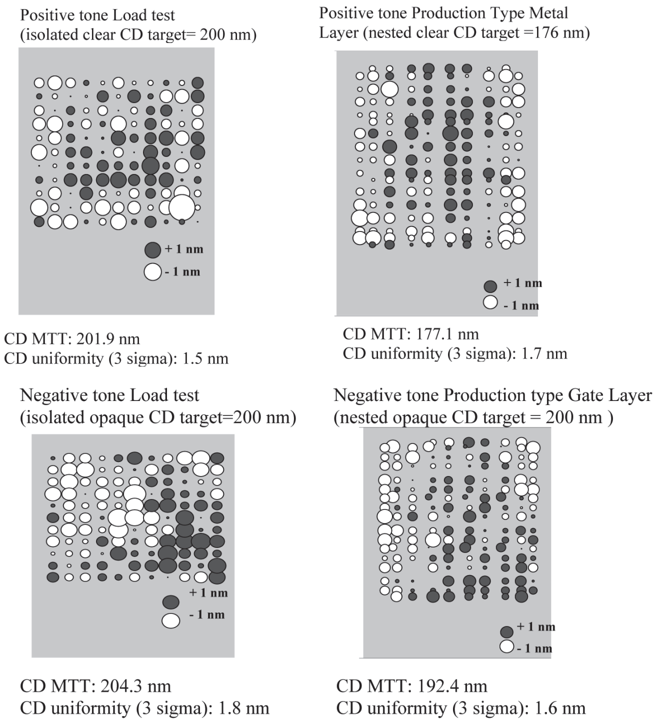

*Figure 13. Thin OMOG final MoSi CD uniformity results achieved on four different test masks using 100 nm thick PCAR and NCAR resists.*

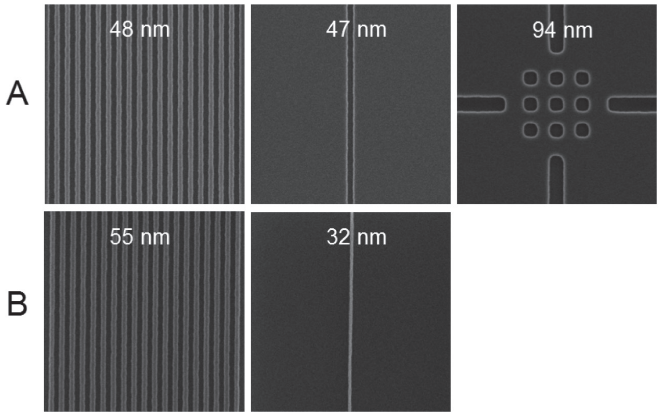

*Figure 14. Resolution performance (post MoSi etch) of thin OMOG of (A) spaces built with 100 nm thick positive tone resist and (B) lines built with 100 nm negative tone resist.*

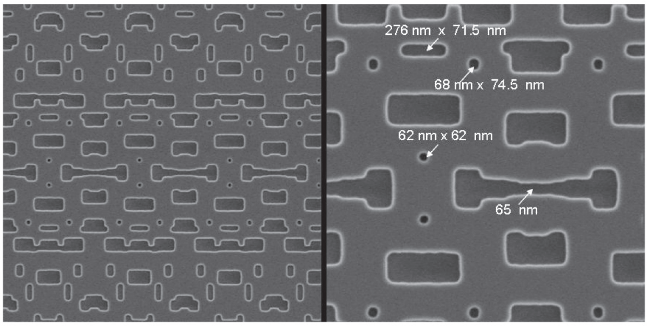

*Figure 15. Examples of small features on an SMO mask achieved with the thin OMOG substrate.*

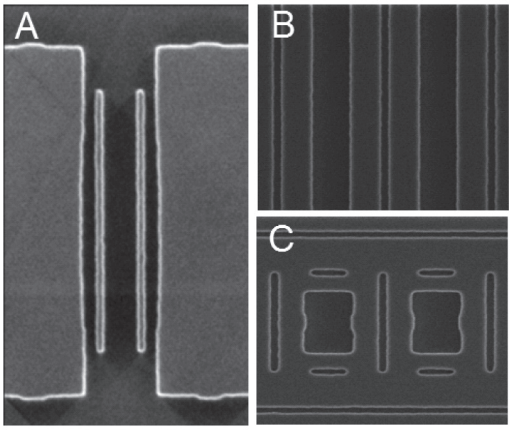

*Figure 16. Examples of dual tone assist features in thin OMOG built with positive tone resist. A) 60 nm opaque assists, B) 43 nm clear assists, C) 43 nm clear assists.*

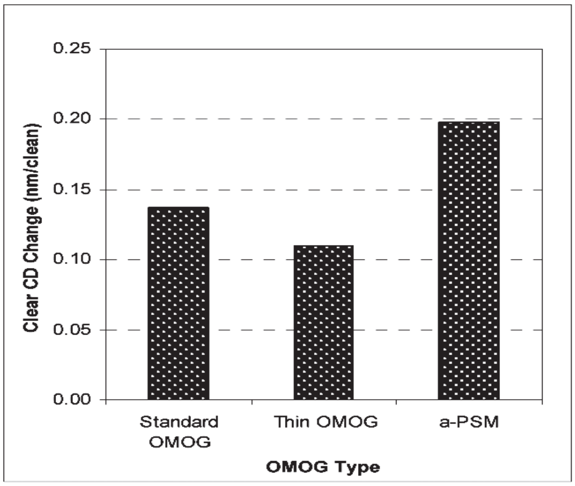

*Figure 17. Mask cleaning process effect on final mask. CD for Standard OMOG, Thin OMOG, and PSM*

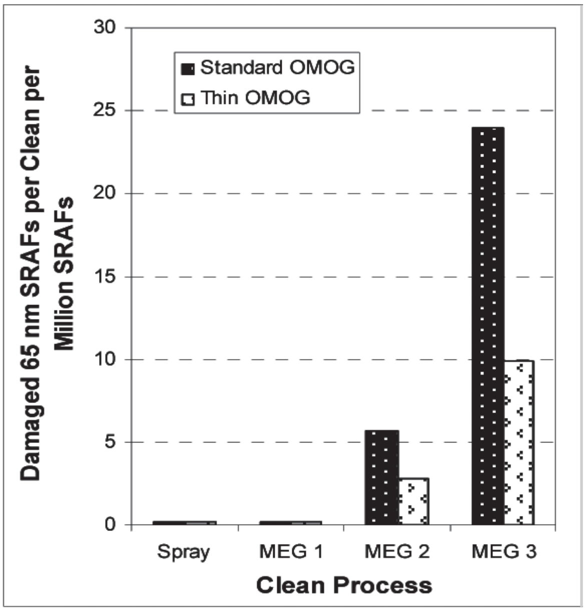

*Figure 18. Cleans Effect on 65 nm SRAF Damage. CD for Standard and Thin OMOG.*

tool. Differences in line edge roughness, corner rounding, and line end shortening are examples of very small non-critical errors that can be detected as nuisance defects. Figure 19 is a comparison of the visual edge quality of the same defect test mask design built in standard OMOG and thin OMOG. As the figure illustrates, the image quality of the thin OMOG mask is comparable to the image quality of the thicker standard OMOG mask with no obvious differences in corner rounding, line end shortening or line edge roughness performance.

Failure to compensate for minor image quality differences during mask inspection, will result in residual noise and excessive nuisance detections. One approach to reducing high-residual nuisance detections is to consciously desensitize the inspection tool. The obvious consequence of this is the inability to meet required defect sensitivity for the mask. Another approach is for the tooling suppliers to carefully model all of these small image quality non-uniformities into the input database. This would require the creation of very sophisticated and complex models and would use an extensive amount of computing power and cycle time. This approach would result in a very expensive and slow inspection system with reduced productivity. None of these are attractive choices for the mask maker.

The use of the new thin OMOG absorber was found to reduce the impact of residual image quality nonuniformities and eliminate the need for complex and time-intensive modeling during mask inspection. This is due to the fact that thinner absorber films tend to have fewer errors in the modeling than thicker absorber films. Fewer modeling errors results in lower residual noise. Lower residual noise leads to the ability to inspect the mask at higher sensitivity settings without the penalty of complex modeling algorithms and excessive cycle time. Figure 20 depicts a comparison of residual noise between standard OMOG and thin OMOG at a 193 nm inspection wavelength. The figure clearly shows a significant reduction in noise in the reflected light residual inspection image for the thinner OMOG film.

Having established that the thin OMOG substrate provides improved mask inspectability through superior database modeling, defect sensitivity tests were conducted on a programmed defect test mask (PDM) built with the thin OMOG absorber. The base designs of this PDM represent both conventional and SMO patterns. The target sensitivity is 12 nm CD errors and 32 nm edge defects as dictated by the ITRS roadmap. The test mask was inspected at both 257 nm and 193 nm wavelengths, and the results of the sensitivity tests are shown in figure 21. At the 257 nm wavelength adequate defect sensitivity was not achieved. However, at the 193 nm inspection wavelength, edge defect detection was between 24 nm and 32 nm, meeting the 32 nm target. For CD errors, the 193 nm inspection results far exceeded the target spec of 12 nm with actual performance in the 7 nm to 9 nm range.

Overall, the transition to the thin OMOG absorber at mask inspection was relatively seamless. As noted above, at the 193 nm inspection wavelength, use of the thinner film results in improved modeling and lower residual values, specifically in the reflected light image. Consequently, inspectability is improved. Finally, defect sensitivity on a thin OMOG conventional and SMO programmed defect test mask is more than adequate to meet the ITRS roadmap targets of 32 nm edge defects and 12 nm CD errors.

## 7. Summary and Conclusions

A new thinner absorber version of the OMOG binary blank has been successfully developed for use for the 22 nm and 20 nm logic nodes and beyond. Detailed mask making evaluations comparing the thinner OMOG and regular OMOG showed that the new thin OMOG substrate was compatible with existing mask making processes without major modification. The thinner OMOG absorber demonstrated improved film stress, flatness, image placement, and cleaning durability versus the standard OMOG. In addition, it was demonstrated that use of 100 nm thick PCAR and NCAR e-beam resists in conjunction with the thin OMOG blank could meet the CD uniformity and minimum feature size requirements for 22 nm and 20 nm node critical level masks. Finally, the thin OMOG blank was found to have significant mask defect inspection benefits.

## 8. Acknowledgments

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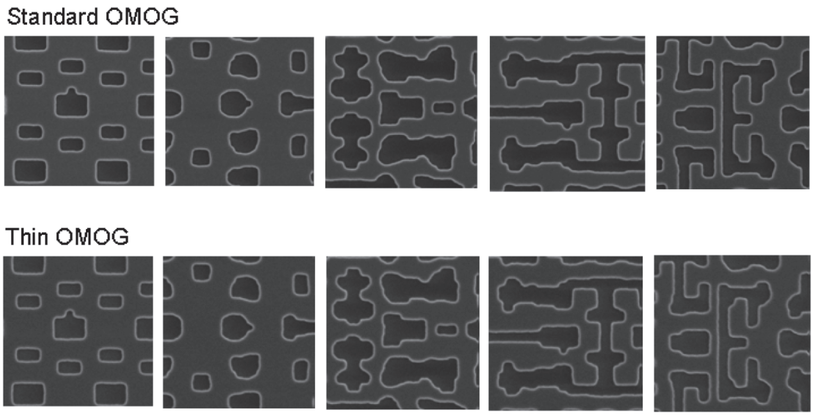

*Figure 19. Visual edge quality comparison between standard and thin OMOG images.*

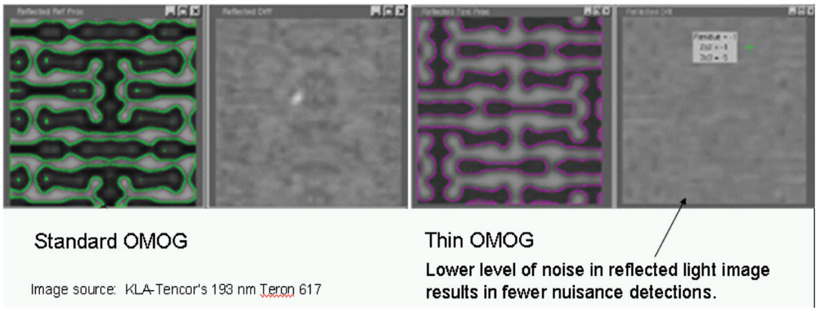

*Figure 20. Comparison of noise in the rendered inspection image for standard OMOG and thin OMOG.*

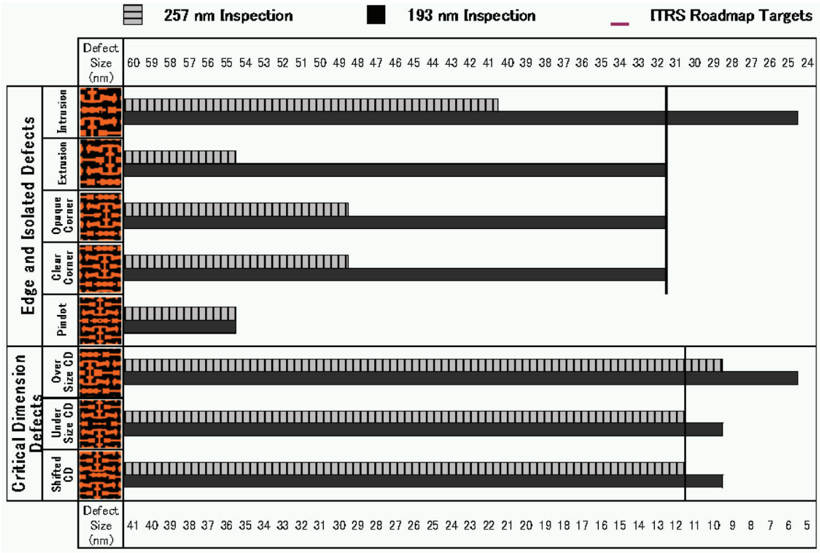

*Figure 21. Comparison of 257 nm vs. 193 nm inspection wavelength sensitivity for a programmed defect test mask built on the Thin-OMOG attenuator.*

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# Industry Briefs

## Zero growth seen for mask business

“2010 will go down in history as a year when a 25 percent growth in the semiconductor photomask business in the first half of the year will be followed by minus 25 perent growth in the second half of the year,” said Robert Castellano, President of The Information Network, in a statement. “We anticipate 0 percent growth for the global market for all of 2010.” Merchant photomask sales for 2010 will exhibit revenues of $1.6 billion and $900 million for captive photomask sales, according to the firm. “Most designs for state-of-the-art semiconductors were done in 2009 and mask sets were made in the first half of 2010. Without a bright macroeconomic outlook, we won’t see much capacity expansion in 2011. We’ve already reported that our leading indicators, which correlate with semiconductor revenues, have moderated,” added Castellano. “The bright spot is that designs for the next technology node, 28-nm, is underway, which will lead to growth in 2011 for the semiconductor photomask industry. A 65-nm mask set is comprised of 40 photomask layers, five of which are critical (45-nm design rule) and 15 subcritical (90-nm design rule). A 65-nnm mask set can cost 1.8 times that of a 90-nm set, while a 45-nm mask set can cost 2.2 times that of a 65-nm set. Hence, there was rampant revenue growth in the first half of 2010 on high demand for high-priced photomasks.

## The horror of 80-hour photomask write times

If you think photomask write times are excessive now, just wait until the 20/22-nm node. At that point, the complexity of reticle enhancement techniques needed to make 193-nm wavelength lithography scanners write 22- or 20-nm features will require something like an 8X increase in write times from the 32-nm node for complex masks, according to Aki Fujimura, CEO of D2S Inc. Fujimura’s company, D2S, is the managing sponsor of the eBeam Initiative, a multi-company effort pushing a design-to-manufacturing approach known as design for e-beam (DFEB). D2S (San Jose, Calif.) offers a computational design platform that maximizes e-beam technology to reduce mask costs for low- and high-volume applications. According to Fujimura, DFEB technology can help to solve the “80 hour mask” problem by using overlapping variable shaped beam (VSB) and circular shots to cut the number of ebeam shots needed to image a mask dramatically. At the BACUS photomask symposium last week in Monterey, Calif., members of the initiative presented data that validates DFEB’s concepts for overlapping VSB shots and model-based mask design preparation, according to Fujimura. With EUV delayed, leading-edge chip makers are hoping to extend 193-nm immersion as far as possible through double patterning and other techniques. Meanwhile, several private companies and consortium are pursing various e-beam direct-write technologies for prototyping and low-volume production, but tools appear to be several years away. E-beam direct-write lithography tools will be available no sooner than 2015, according to Kurt Ronse, lithography department director at nanoelectronics research center IMEC. Fujimura said the eBeam Initiative continues to make progress toward making DFEB technology commercially viable. The group now boasts 34 members with the additions last week of Synopsys Inc., Abeam Technologies Inc., EQUIcon Software GmbH Jena and Tool Corp. During a panel discussion at BACUS last week, now available online, Fujimura and others stressed that EUV and direct-write are complimentary, not competing, technologies. Fujimura declined to say which of the competing direct-write technologies had the best chance of making an impact. But he said funding would be the key.

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## About the BACUS Group

Founded in 1980 by a group of chrome blank users wanting a single voice to interact with suppliers, BACUS has grown to become the largest and most widely known forum for the exchange of technical information of interest to photomask and reticle makers. BACUS joined SPIE in January of 1991 to expand the exchange of information with mask makers around the world.

The group sponsors an informative monthly meeting and newsletter, BACUS News. The BACUS annual Photomask Technology Symposium covers photomask technology, photomask processes, lithography, materials and resists, phase shift masks, inspection and repair, metrology, and quality and manufacturing management.

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*Late submissions will be considered by conference chairs.*

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Monterey Marriott
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