

# PHOTOMASK

BACUS—The international technical group of SPIE dedicated to the advancement of photomask technology.

**PHOTOMASK**

N • E • W • S

SEPTEMBER 2016  
VOLUME 32, ISSUE 9

PMJ16 Best Paper Award

## Multi-Beam Mask Writer MBM-1000 and its Application Field

Hiroshi Matsumoto, Hideo Inoue, Hiroshi Yamashita, Hirofumi Morita, Satoru Hirose, Munehiro Ogasawara, Hirokazu Yamada, and Kiyoshi Hattori, NuFlare Technology, Inc. 8-1 Shinsugita-cho, Isogo-ku, Yokohama 235-8522, Japan

### ABSTRACT

NuFlare has started development of multi-beam mask writer MBM-1000 aiming to apply to N5 and to release in Q4 2017. MBM-1000 is based on large area projection optics with shaping aperture array plate, blanking aperture array (BAA) plate, single cathode and inline/realtime data path for vector data rasterization and bitmap dose correction. It is designed to accomplish higher throughput than EBM series (variable shaped beam (VSB) writers) with massive beam array, higher resolution by using 10-nm beam size and 10-bit dose control, and better writing accuracy with more write passes. Configuration of MBM-1000 and flow of data path processing are described. Write time estimation suggests MBM-1000 has advantage over VSB writer with shot count > 200 Gshot/pass and resist sensitivity >75  $\mu\text{C}/\text{cm}^2$ . Printing test of 20 nm hp 1:1 line and space pattern with ZEP-520 resist showed better beam resolution of MBM-1000 alpha tool than EBM series.

### 1. Introduction

ArF immersion lithography has been extended down to hp 16 nm by introduction of multiple patterning and aggressive optical proximity correction (OPC). Lithography techniques for miniaturization has been posing a challenge to mask writers such as increasing number of photomasks and increasing shot counts per mask, and more and more stringent writing accuracy.

EUV lithography will be applied to N5 and beyond, and drastic increase of shot count is expected.<sup>[1]</sup> Even if it will not make it in time for N5, ArF immersion lithography with more aggressive source mask optimization (SMO) and OPC technique leads to increase of shot count. Improvement of critical dimension (CD) uniformity and reduction of line edge roughness (LER) are required, and thus resist sensitivity tends to be lowered in order to reduce the shot noise effect.<sup>[2]</sup>

Single variable shaped beam (S-VSB) writer has been meeting such requirements in photomask making by evolution in increasing beam current density and reducing deflection settling time. EBM series (NuFlare's VSB writers) has been shrinking shot time with increased beam current density 2X per generation, and reduction of deflection settling time by introducing three-stage-deflection for

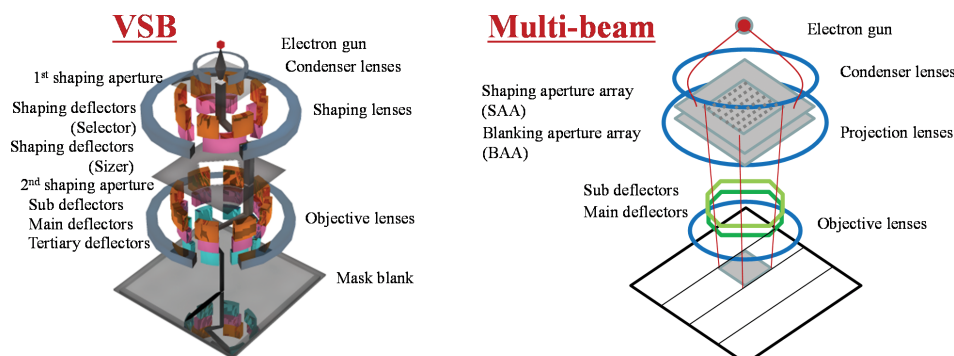


Figure 1. System of VSB writer EBM-9000 and multi-beam mask writer MBM-1000.

TAKE A LOOK  
INSIDE:

INDUSTRY BRIEFS  
— see page 7

CALENDAR  
For a list of meetings  
— see page 8

**SPIE.**

9984-30

# EDITORIAL

## Inverse- versus Forward-Lithography Mask Correction Methods

Shane R. Palmer, Nikon Research Corporation of America

It is clear, at least to me, that when you are pushing the limit of your lithography tool, inverse lithographic correction (ILC) methods provide superior results over the traditional forward-type optical proximity correction (OPC) approach. ILCs just seem to find the best solution, and that solution is often non-intuitive to the OPC expert. For example, the automated generation and placement of multiple “curved” sub-resolution features that improve the exposure and focus latitude from an ILC output would strain the seeding routines of any forward-OPC recipe. Inverse methods also have a large advantage over forward methods when selective weighting is required to improve the correction of critical features, e.g., setting a focus latitude value for line-to-line abutments, since they employ “assisted” correction features that uses the full influence range (of the model) to achieve the desired result. Inter-target assist features often appear in ILC that would unlikely be conceived by a forward method. ILC methods with source optimization have also opened the door to perform corrections to both “bright” and “dark” field patterns on the same mask. This would have been considered “taboo” in the past.

An example of a contact output using an ILC method is shown in Figure 1. This pattern was optimized with weighting to provide good printability over a fixed focus and dose range with a post-Manhattanization correction. The common process window using the OPC method could not compete with this ILC result unless extensive “hand-crafted” intervention by an expert was employed.

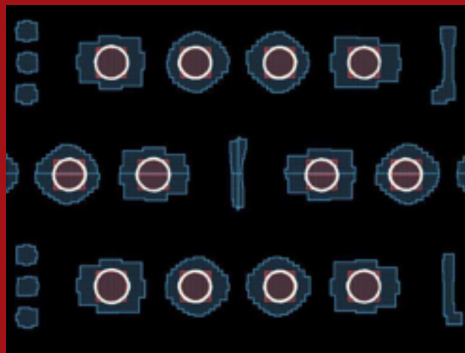


Figure 1. Correction of a 7 nm node contact pattern showing process variation bands for  $\pm 2.5\%$  dose and  $\pm 30$  nm defocus values (white contours). The red boxes represent the 36 nm target features (minimum pitch is 84 nm) and the blue features the ILC output.

On the flip side, ILC methods can create nightmarish scenarios for both lithographer and mask maker. The lithographer must now take additional care with creating ILC models that account for a wider variety (and range) of sub-threshold printing features. This entails additional time to measure patterns (on a representative imaging stack), build and verify the model. The ILC (software) is understandably more complex. Making sure that the ILC method avoids “local minima” traps in its search for the best (global?) solution, creates added complications in writing the recipes and scripts. ILC generally needs a sophisticated Manhattanization routine to treat the “curved” output features that oft requires a final OPC-like correction and verification to that post-Manhattanization pattern. There are other complications too, but that can be left for another discussion.

For the mask manufacturer, the unsung heroes of our industry, the ILC output file is generally larger and requires refinement to the “mask process” to produce the highly complex patterns. Creating and measuring inter-feature assist patterns add a new challenge. All of this leads to longer write, process and inspection/repair times. Die-to-die and die-to-database inspection methods are equally stressed by the measurement of the Fresnel-like focusing patterns that occur at the boundaries of arrays.

So where is all of this going? Should you use ILC or OPC? I believe the merits and drawbacks need to be weighed for each method. Then based on what “works” to achieve your given patterning/tolerance requirement hopefully will provide the answer. Cost and time must be considered. Use OPC if the yield difference between the two is acceptable and your profits are not decreased. Apply ILC if OPC doesn’t provide sufficient process latitude (generally yield). Yes, it is all about yield and profit.

# BACUS

## N • E • W • S

BACUS News is published monthly by SPIE for BACUS, the international technical group of SPIE dedicated to the advancement of photomask technology.

Managing Editor/Graphics Linda DeLano  
Advertising Melissa Farlow  
BACUS Technical Group Manager Pat Wight

### ■ 2016 BACUS Steering Committee ■

#### President

Paul W. Ackmann, GLOBALFOUNDRIES Inc.

#### Vice-President

Jim N. Wiley, ASML US, Inc.

#### Secretary

Larry S. Zurbrick, Keysight Technologies, Inc.

#### Newsletter Editor

Artur Balasinski, Cypress Semiconductor Corp.

#### 2016 Annual Photomask Conference Chairs

Bryan S. Kasprovicz, Photronics, Inc.

Peter D. Buck, Mentor Graphics Corp.

#### International Chair

Uwe F. W. Behringer, UBC Microelectronics

#### Education Chair

Frank E. Abboud, Intel Corp.

#### Members at Large

Paul C. Allen, Toppan Photomasks, Inc.

Michael D. Archuletta, RAVE LLC

Brian Cha, Samsung Electronics Co., Ltd.

Jerry Cullins, HOYA Corp. USA

Derren Dunn, IBM Corp.

Thomas B. Faure, GLOBALFOUNDRIES Inc.

Emily Gallagher, IMEC

Brian J. Grenon, Grenon Consulting

Jon Haines, Micron Technology Inc.

Naoya Hayashi, Dai Nippon Printing Co., Ltd.

Patrick M. Martin, Applied Materials, Inc.

Shane Palmer, Nikon Research Corp. of America

Jan Hendrik Peters, Carl Zeiss SMT GmbH

Moshe Preil, KLA-Tencor Corp.

Douglas J. Resnick, Canon Nanotechnologies, Inc.

Thomas Struck, Infineon Technologies AG

Bala Thumma, Synopsys, Inc.

Michael Watt, Shin-Etsu MicroSi Inc.

## SPIE.

P.O. Box 10, Bellingham, WA 98227-0010 USA

Tel: +1 360 676 3290

Fax: +1 360 647 1445

www.SPIE.org

help@spie.org

©2016

All rights reserved.

Table 1. Key parameters in EBM-9500 and MBM-1000.

Item	EBM-9500	MBM-1000
Accel. Voltage	50 kV	50 kV
Cathode	1200 A/cm <sup>2</sup>	2 A/cm <sup>2</sup>
Beam blur	r	< r
Beam size	VSB ( $\leq 250$ nm)	10 nm
Field size	~80 $\mu$ m (deflection field size)	~80 $\mu$ m (beam array size)
Beam current	500 nA @ max shot size	500 nA with all beam on
Stage	Frictional drive with variable speed	Air bearing stage with constant speed
Data format	VSB12i, OASIS.MASK	MBF, VSB12i, OASIS.MASK
Corrections for writing accuracy	PEC/FEC/LEC, GMC, CEC, GMC-TV, TEC	PEC/FEC/LEC, GMC, CEC, GMC-TV, TEC, EV-PEC

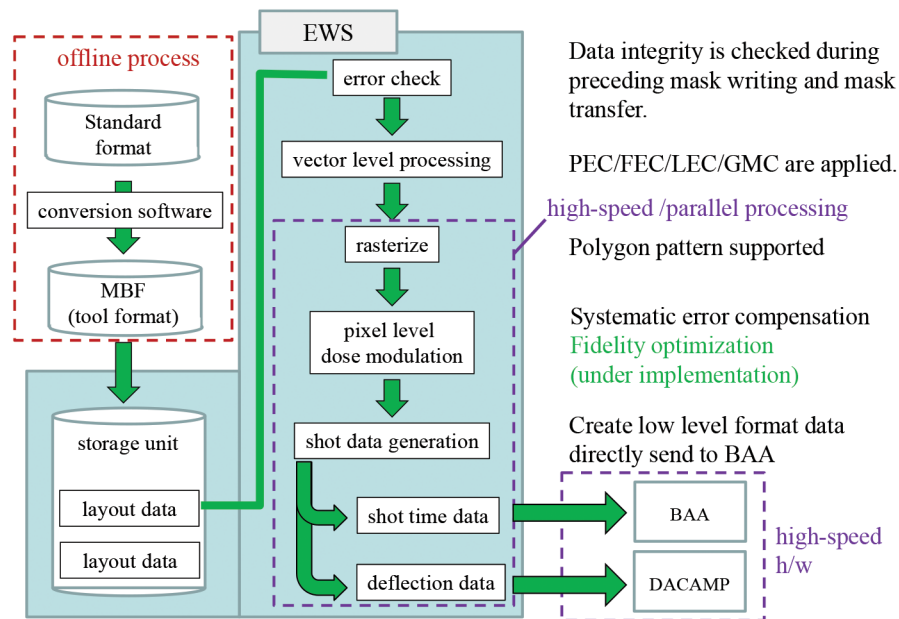


Figure 2. Flow of data processing in MBM-1000.

EBM-9000.<sup>[3]</sup> To support increase of beam current density, thermal effect correction has been introduced to EBM-9500.<sup>[4]</sup>

However, it is becoming unrealistic to keep such extension during next decade since technical barriers in deflection amplifier, cathode and durability of resist against heating. Switch to multi-beam (MB) mask writer in near future seems to be inevitable. NuFlare has started development of MB mask writer MBM-1000 in 2012, and has built an alpha tool to integrate key technologies and to verify its performance.

## 2. System Configuration

### 2.1 Basic design

The target of MBM-1000 is to adapt to higher pattern density and slower resist trend than what VSB writer can handle today. Multi-beam mask writer can perform at larger shot count and lower resist sensitivity better than VSB writer, by using massive number of

beams. Full size array of beamlets can be used to expose patterns regardless of pattern size, making write time independent of pattern density. Although size of individual beamlet is very small, sum of area of beamlets is larger than VSB writer's shot size shaped for small features, and thus number of exposure times of MB writer is smaller than that of VSB writer. This allows MB writer to use longer exposure time and lower current density to handle resist with lower sensitivity. It also allows to relax deflection settling time for better beam positioning accuracy.

Multi-beam mask writer has advantages over VSB writer, but not for all aspects. Its fundamental limitation is that it has to use gray-beam writing to print pattern at arbitrary positions and with arbitrary CD. In another word, gray beam wiring is required to have pattern edge off-grid to discrete beam exposure grids. Use of gray-beam writing brings limitation that beam size should be smaller than half of the beam blur as measured as 1/e half width

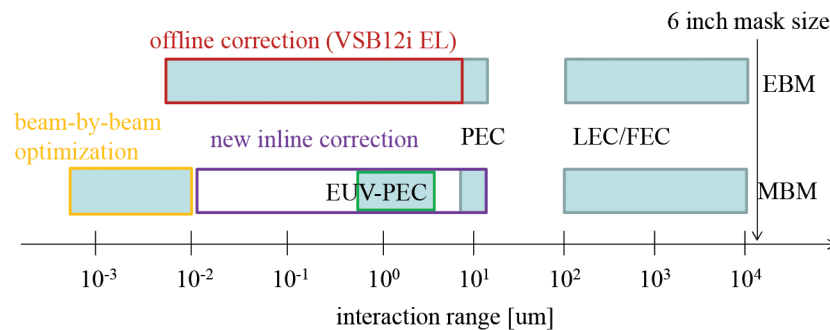


Figure 3. CD correction functions and supported interaction range in EBM series and MBM-1000.

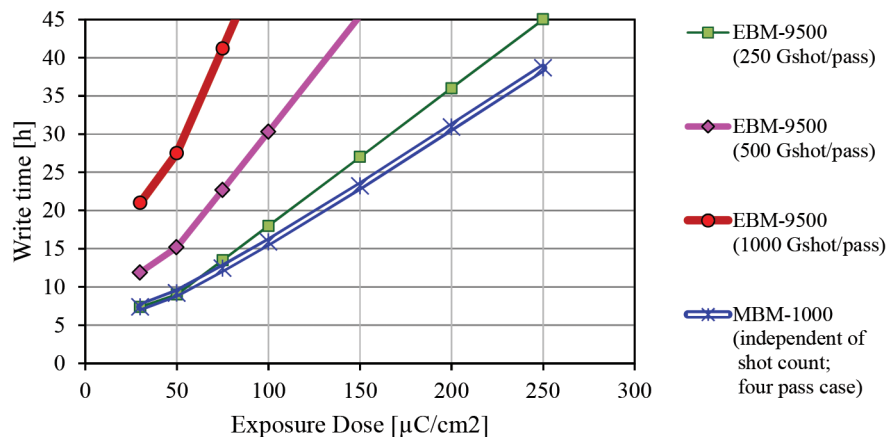


Figure 4. Write time of 100\*130 mm main chip with MBM-1000 and EBM-9500.

of Gaussian.<sup>[5]</sup> Smaller blur in mask process is favorable to small features, but does demand smaller beamlet size that requires longer writer time. Thus mask process should be designed taking account of both of minimum feature size and write time. For N5, we propose 10-nm beam size and 20-nm total blur.

Multi-beam mask writer is required to accomplish higher writing accuracy than VSB writer. Our primary idea is to use higher number of write pass than those VSB writer can use in order to reduce systematic error in beamlet position. Second is to use resist of sensitivity  $>50 \mu\text{C}/\text{cm}^2$  in order to improve LER and to have smaller resist blur for better resolution and more process margin for small features. Relaxed deflection settling time also contributes to obtaining better performance.

## 2.2 Configuration

Figure 1 schematically explains basic design of MBM-1000 in comparison with EBM-9000. MBM-1000 uses traditional MB system with single cathode illuminating shaping aperture array (SAA), and blanking aperture plate (BAA).<sup>[6,7]</sup> Beamlets are formed by SAA, blanked individually by BAA, and collectively deflected by objective deflectors. MBM-1000 uses two-stage deflectors for stage tracking deflection and beam positioning.

Key parameters of MBM-1000 and EBM-9500 is shown in Table 1. Pattern on a blank is exposed stripe by stripe.

Stripe size is a key parameter for stage speed and number of stage turn, and is defined by beam deflection field size in the case of VSB writer. In MBM-1000, stripe size is defined by beam array size, and is set to approx.  $80 \mu\text{m}$  which is comparable to stripe width of EBM-9000, to allow increase of write pass with acceptable stage speed.

## 2.3 Optics and Blanking aperture array

Blanking aperture array is fabricated based on LSI and MEMS technology and thus its size is limited by scanner field size in LSI fabrication process. To realize  $80 \mu\text{m}$  field size, demagnification ratio of 200 and aperture array size of 16 mm are determined. Beam pitch is set to  $32 \mu\text{m}$  to accommodate LSI circuit for individual blanking control, leading to  $512 \times 512$  beam array size.

Single-stage acceleration system at 50 kV is selected not to elongate effective beam path and to minimize the effect of electromagnetic noise on beam. Total beam current is set to 500 nA, which is comparable to beam current of EBM series at maximum shot size. This is to keep write time of MBM-1000 with middle grade product, peripheral patterns or soild background in negative resist at comparable level with EBM series. It leads current density of  $2 \text{ A}/\text{cm}^2$  with  $512 \times 512$  array of 10-nm beamlets. Cathode and 50-kV power supply are designed to be capable of  $4 \text{ A}/\text{cm}^2$ , allowing 7-nm beam size for MBM-2000 (NuFlare's next generation tool). Optics is designed to have smaller beam blur than EBM-9000, with compromise in longer column length.

## 2.4 Dose level

Blanking aperture array is designed to be capable of 10 bit resolution ( $=1023$  levels) in shot time control per write pass. This is to accomplish 0.1 nm CD/position control accuracy with dose latitude around 1 nm/% without using complicated dose calculation method to mitigate dose level quantization error. It allows dose correction method such as proximity effect correction (PEC)/fogging effect correction (FEC)/loading effect correction (LEC) developed for VSB writer to be compatible with MBM-1000. Single exposure with 10 bit resolution minimizes data sent to BAA chip; with 6 bit



Table 2. Specification of EBM-9000, EBM-9500, and MBM-1000

Specification		EBM-8000	EBM-9000	EBM-9500	MBM-1000
Image placement accuracy [nm 3 $\sigma$ ]	Global	4.3	3.0	2.1	1.5
	Local	1.3	1.3	1.3	1.0
CD uniformity [nm 3 $\sigma$ ]	Global	3.8	3.0	2.1	1.5
	Local	1.3	1.3	1.3	1.0
Main chip (130mm $\times$ 100 mm) write time [hours]		-	-	-	12 @ 75 uC/cm <sup>2</sup>
Beam size [nm]		0.1 to 350	0.1 to 250	0.1 to 250	10
Current density [A/cm <sup>2</sup> ]		400	800	1200	2

BAA, 16 times of exposure and 96 bit of data transfer to BAA is required to accomplish approx.1000 dose levels.

### 3. Data Path

Data path is also challenging part for MB writer. In the case of VSB data path, patterns are divided into shots and arranged into deflection fields and stripes, and assigned exposure dose for PEC/FEC/LEC. Multi-beam data path should do further rasterization and dose correction to generate array data of exposure time sent to BAA. Pattern data is no more limited to rectangles and right triangles, but includes quadrilateral, triangle and polygons. Integrity in processing and transfer of huge volume data should be confirmed.

Data path of MBM-1000 is designed as real-time/inline processing as shown in Fig. 2. This is to allocate write time to processing for fracturing and dose correction calculation and to minimize processing time required in prior to writing to reduce mask turnaround time. It is designed to do short-range correction for extreme ultraviolet (EUV)-PEC and pattern fidelity optimization and beam-by-beam correction inline/real-time as summarized in Fig. 3. In the case of EBM series, collection dose for short range correction was calculated offline by user, and supplied to writer along with layout data. As EUV-PEC will be no longer optional for N5, we decided to implement as standard function of writer.

Mask design data is converted offline to tool-specific format by user, registered as layout data and then transferred to data storage unit in MBM-1000. Minimum check of data format error is done at this stage. This process is done in prior to writing and in parallel to preceding mask writing, and has no impact on mask write time.

When writing process is invoked, writing preparation processing is carried out. Whole part of layout data is transferred from data storage unit to high-speed disk unit in shot data generation system. During this step, whole part of data is verified. Pre-processing for correction calculation and write control are also done by using global distribution of pattern and shot density. Corrections of FEC/LEC/charge-effect correction(CEC) are done at this stage. These processes are done in computers separated from writing control computers during preceding mask writing, and thus doesn't affect preceding writing.

Data processing during writing comprises three parts. First, vector level processing is done to place patterns into stripes with coordinate modification for GMC, and to calculate correction dose for PEC on 1- $\mu$ m mesh. This part is similar to processing in EBM series. Secondly, rasterization and dose calculation are carried out to define exposure time of each pixels on the target. Idea of

gray-beam writing is to expose pixel with dose proportional to pattern coverage with the pixel arranged on orthogonal uniform grid so that dose profile obtained by uniform dose exposure inside pattern area is reproduced. In order to do it with beam array having distorted position by lens distortion, beam-by-beam dose modulation is applied to compensate systematic error in beam position. Dose modulation to improve pattern fidelity can be further applied. Final part is to convert pixel-by-pixel exposure time data into array of exposure time in BAA specific format along with beam array deflection data. Then data is sent to BAA and deflection amplifier, simultaneously.

Data integrity is checked at several steps. Data transfer error to DACAMP and BAA is prevented by using checksum function as it has been done in EBM series.

### 4. Throughput and Writing Accuracy

Figure 4 shows comparison of estimated write time between MBM-1000 and EBM-9500. Write time of MBM-1000 is independent of shot count, and dependent on mainly exposure dose, BAA data transfer time and number of write pass. Data transfer is carried out in parallel to writing, and it impacts on write time less at smaller dose. When exposure dose >100  $\mu$ C/cm<sup>2</sup>, exposure time is dominant and thus write time increases almost linearly with respect to exposure dose. Write time of VSB writer mainly comprises exposure time and deflection settling time,<sup>[2]</sup> and increases drastically with larger shot count. It also varies depending on distribution of patterns since it uses variable stage speed mode, and thus write time in Fig. 4 is one example. It is concluded that MBM-1000 excels in write time EBM-9500 for shot count >200 Gshot/pass and exposure dose >75  $\mu$ C/cm<sup>2</sup>. Target of writing accuracy of MBM-1000 is compared with EBM series in Table 2.

Target of writing accuracy of MBM-1000 is compared with EBM series in Table 2. It is aimed to follow recent trend of writing accuracy enhancement and to meet N5 requirement.

### 5. Printing Test

To verify performance of optics, 20-nm-hp resist pattern was printed by MBM-1000 alpha tool. Pattern was resolved in 70  $\mu$ m square area in exposure field as shown in Fig. 4. Although pattern quality was degraded at perimeter of 80  $\mu$ m exposure field, the result was better than EBM-9000 as it did not resolve 20-nm-hp pattern with NuFlare's resist process. Better resolution of MBM-1000 than EBM-9000 is concordant with optics design shown in Table 3.

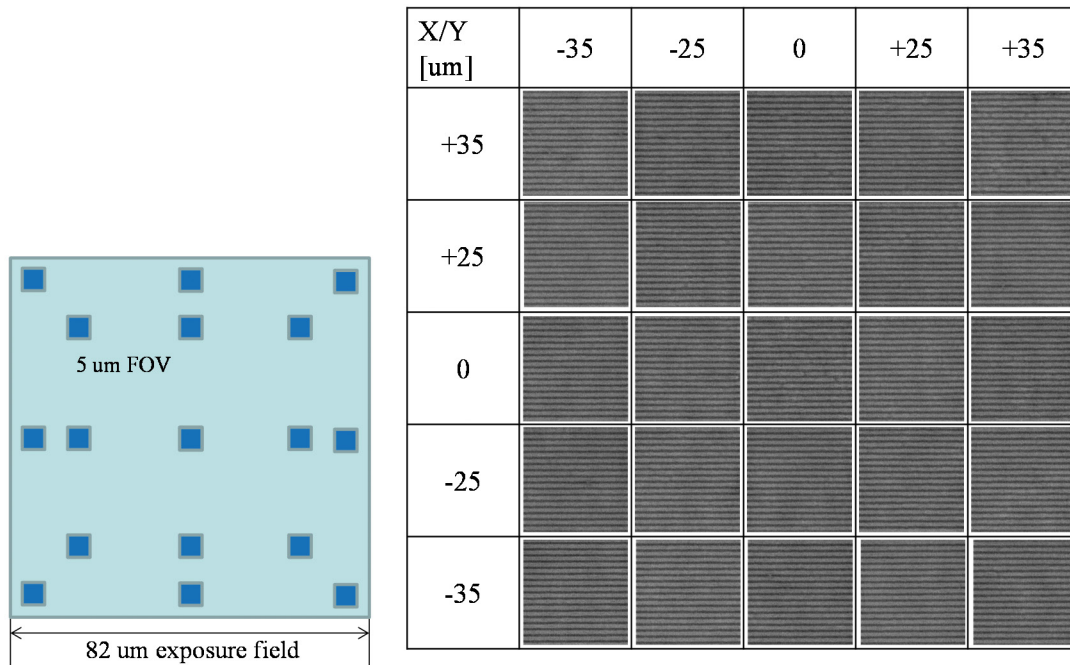


Figure 5. Printing test result of 20 nm hp pattern with ZEP520 resist in 50 nm thickness.

## 6. Summary and Conclusion

NuFlare is developing MBM-1000 as its 1<sup>st</sup> generation multi-beam mask writer, aiming to apply to N5 generation. Its printing resolution performance was verified to be better than EBM-9000. MBM-1000 is designed not only to excel in write time VSB writer with shot count > 200 Gshot/pass and 75  $\mu\text{C}/\text{cm}^2$ , but also writing accuracy and resolution with 10-nm beam, 10-bit dose control and short range dose correction. Multi-beam mask writer is much more complicated system than VSB writer, and it has higher technical barrier to be overcome for MBM-1000 to be a production tool. Continuous effort to integrate MBM-1000 alpha tool is required to accomplish both of target writing performance and writing speed.

## 7. References

- [1] M. Chandramouli, F. Abboud, N. Wilcox, A. Sowers, and D. Cole, "Future mask writers requirements for the sub-10nm node era", **Proc. SPIE 8522**, 85221K (2012).
- [2] B. G. Kim, et. al., "Improving CD uniformity using MB-MDP for 14nm node and beyond," **Proc. SPIE. 8522**, 852205 (2012)
- [3] H. Takekoshi, T. Nakayama, K. Saito, H. Ando, H. Inoue, N. Nakayamada, T. Kamikubo, R. Nishimura, Y. Kojima, J. Yashima, A. Anpo, S. Nakazawa, T. Iijima, K. Ohtoshi, H. Anze, V. Katsap, S. Golladay, and R. Kendall, "EBM-9000: EB mask writer for product mask fabrication of 16nm half-pitch generation and beyond", **Proc. SPIE 9256**, 925607 (2014).
- [4] H. Nomura, T. Kamikubo, M. Sukanuma, Y. Kato, J. Yashima, N. Nakayamada, H. Anze, and M. Ogasawara, "Study on modeling of resist heating effect correction in EB mask writer EBM-9000", **Proc. SPIE 9658**, 96580R (2015).
- [5] H. Matsumoto, M. Ogasawara, and K. Hattori, "Challenges for future EB mask writers", PMJ 2013 Panel Discussion, April 18, 2013.
- [6] H. Yasuda, S. Arai, J. Kai, Y. Ooae, T. Abe, Y. Takahashi, S. Hueki, S. Maruyama, S. Sago, and K. Betsui, "Fast Electron Beam Lithography System with 1024 Beams Individually Controlled by Blanking Aperture Array ", *Jpn. J. App. Phys.*, 32(12B), 6012 (1993).
- [7] Klein, J. Kliekovic, H. Loeschner, E. Platzgummer, "eMET: 50 keV electron multibeam mask exposure tool", **Proc. SPIE 7970**, 79700C (2011).



N • E • W • S

## Sponsorship Opportunities

Sign up now for the best sponsorship opportunities

### Advanced Lithography 2017 –

Contact: Teresa Roles-Meier,  
Tel: +1 360 685 5445; [teresar@spie.org](mailto:teresar@spie.org)

### Photomask 2016 –

Contact: Melissa Farlow,  
Tel: +1 360 685 5596; [melissaf@spie.org](mailto:melissaf@spie.org)

## Advertise in the BACUS News!

The BACUS Newsletter is the premier publication serving the photomask industry. For information on how to advertise, contact:

Melissa Farlow,  
Tel: +1 360 685 5596  
[melissaf@spie.org](mailto:melissaf@spie.org)

## BACUS Corporate Members

Acuphase Inc.  
American Coating Technologies LLC  
AMETEK Precitech, Inc.  
Berliner Glas KGaA Herbert Kubatz GmbH & Co.  
FUJIFILM Electronic Materials U.S.A., Inc.  
Gudeng Precision Industrial Co., Ltd.  
Halocarbon Products  
HamaTech APE GmbH & Co. KG  
Hitachi High Technologies America, Inc.  
JEOL USA Inc.  
Mentor Graphics Corp.  
Molecular Imprints, Inc.  
Panavision Federal Systems, LLC  
Proficolore Srl  
Raytheon ELCAN Optical Technologies  
XYALIS

# Industry Briefs

## ■ Big Three Chipmakers Likely to Boost Capex

Alan Patterson, *EETimes*

TAIPEI — Intel, Samsung and TSMC are likely to increase capital expenditures during the second half of 2016 while the rest of the semiconductor industry tightens the belt, according to a market research firm. The top-three companies will probably spend \$20 billion, representing a 90 percent increase from the first half of 2016. The companies will need to boost spending later this year to meet full year capex targets.

“In contrast to the ‘Big 3’ spenders, capital outlays by the rest of the semiconductor suppliers are forecast to shrink by 16 percent in the second half of this year as compared to the first half,” the IC Insights report said. “In total, 2016 second-half semiconductor industry capital spending is expected to be up 20 percent over first-half 2016 outlays, setting up a busy period for semiconductor equipment suppliers through the end of this year.”

The boost in spending is likely to widen the technology gap between the big three chipmakers and their smaller competitors. Samsung, Intel and TSMC are so far the only semiconductor companies to have announced plans to ramp up production of geometries in the 10nm range and adopt EUV lithography in the next few years. Combined, they are forecast to account for 45 percent of the total semiconductor industry outlays this year. In total, IC Insights forecasts that semiconductor industry capital spending will increase by only 3% this year after declining by 2% in 2015.

With many chipmakers moving to fab-lite business models and continued growth in fabless companies, wafer foundries have gone from representing just 12% of total industry capex spending in 2008 to what is expected to be 34% of worldwide capital outlays in 2016. Flash memory is the second largest industry segment for capex, projected to account for about 16% (\$15.7 billion) of the total expenditures in 2016.

## ■ ASML Boosted by Extreme UV Orders

*Optics.org*

Four orders for production EUV lithography systems placed in latest quarter, as TSMC reveals its plans to deploy the technology.

### Wafer throughput

The semiconductor lithography equipment leader ASML says it has received orders for four more of its extreme ultraviolet (EUV) systems. The announcement comes just a week after TSMC said it planned to be using the laser-driven technology “extensively” in volume production, although that is only likely to be from 2020 onwards. CEO Peter Wennink said in ASML’s financial statement for the latest quarter that the new EUV orders came from foundry and memory chip manufacturers, and were intended for volume production. It increases ASML’s EUV backlog to ten systems, which will ultimately be equivalent to around €1 billion in sales revenues.

With additional orders anticipated in the second half of 2016 it means that the Veldhoven, Netherlands, company should post a record-breaking sales figure for the year - although that depends upon the exact timing of shipments and upgrades to the laser-powered EUV sources to enhance production throughput, which in turn determine the timing of revenue recognition. ASML’s sales of €1.7 billion in the latest quarter included around €100 million relating to EUV systems that were originally shipped in late 2015. “We now expect our full-year 2016 sales to exceed our 2015 record year,” Wennink said. “The ultimate level will depend on the timing of our EUV revenue recognition and the size of the combined 10/7 nanometer node ramp.”

During its own quarterly update last week, TSMC’s president and co-CEO Mark Liu said: “We plan to extensively use EUV lithography in 5 nm to improve density, simplify process complexity and reduce cost. The 5 nm risk production qualification in [the] first half [of] 2019 remains unchanged.” The volume production ramp is scheduled for the following year. The 7 nm node was being used as a development vehicle for EUV. “Currently we are running four state-of-the-art EUV scanners for EUV infrastructure development,” he told investors. “We will move in another two EUV high-volume production tools, that is NXE3400 [ASML’s full production scanner], in [the] first quarter [of] 2017.”

### ASML stock price (past 10 years)

1500 wafers-per-day ASML has set as a target this year. On its own system in Veldhoven, the company’s best effort now stands at 1488 wafers per day – a marginal improvement on the figure of 1350 wafers achieved three months ago, but one that suggests the target is well within reach.

EUV systems now account for 31 per cent of ASML’s overall order backlog, which stands at a grand total of €3.37 billion. The next two quarters should see an acceleration in EUV system output, after only one NXE:3350B unit was shipped in each quarter of 2016 so far. ASML is expecting to ship either six or seven of the €100 million units in total this year.

# Join the premier professional organization for mask makers and mask users!

## 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.

### Individual Membership Benefits include:

- Subscription to BACUS News (monthly)
- Eligibility to hold office on BACUS Steering Committee

[www.spie.org/bacushome](http://www.spie.org/bacushome)

### Corporate Membership Benefits include:

- 3-10 Voting Members in the SPIE General Membership, depending on tier level
- Subscription to BACUS News (monthly)
- One online SPIE Journal Subscription
- Listed as a Corporate Member in the BACUS Monthly Newsletter

[www.spie.org/bacushome](http://www.spie.org/bacushome)

# C a l e n d a r

## 2016

- ✿ **SPIE Photomask Technology**  
12-14 September 2016  
San Jose Convention Center  
San Jose, California, USA  
[www.spie.org/pm](http://www.spie.org/pm)

## 2017

- ✿ **SPIE Advanced Lithography**  
26 February-2 March 2017  
San Jose Marriott and  
San Jose Convention Center  
San Jose, California, USA  
[www.spie.org/al](http://www.spie.org/al)

SPIE is the international society for optics and photonics, an educational not-for-profit organization founded in 1955 to advance light-based science and technology. The Society serves nearly 264,000 constituents from approximately 166 countries, offering conferences and their published proceedings, continuing education, books, journals, and the SPIE Digital Library in support of interdisciplinary information exchange, professional networking, and patent precedent. SPIE provided more than \$5.2 million in support of education and outreach programs in 2015. [www.spie.org](http://www.spie.org)

## **SPIE.**

*International Headquarters*  
P.O. Box 10, Bellingham, WA 98227-0010 USA  
Tel: +1 360 676 3290  
Fax: +1 360 647 1445  
help@spie.org • [www.SPIE.org](http://www.SPIE.org)

*Shipping Address*  
1000 20th St., Bellingham, WA 98225-6705 USA

### **Managed by SPIE Europe**

2 Alexandra Gate, Ffordd Pengam, Cardiff,  
CF24 2SA, UK  
Tel: +44 29 2089 4747  
Fax: +44 29 2089 4750  
spieeurope@spieeurope.org • [www.spieeurope.org](http://www.spieeurope.org)

You are invited to submit events of interest for this calendar. Please send to [lindad@spie.org](mailto:lindad@spie.org); alternatively, email or fax to SPIE.