PHOTOMASK

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Third Place Best Poster Award (PM11)

Layout Decomposition and Mask Synthesis for Double and Triple Exposure With Image Reversal in a Single Photoresist Layer

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ABSTRACT

Double Patterning is the most promising lithography solution for 22 nm technology node and beyond. It can both increase the pitch density and print intricate 2D patterns reliably, far beyond the capabilities of the conventional Double Exposure methods. Recently, a double exposure method in a single photoresist layer using image reversal DESIR has been proposed which matches the printing capabilities of the double patterning technology while using only one photoresist layer, resulting in a significant process simplification. In general, layout decomposition poses a major obstacle in terms of layout complexity, layout verification overhead, and mask decomposability design related issues. Here, a layout decomposition method and mask selection algorithms for the DESIR approach that can be easily implemented in any mask design tool are proposed. The method is distinctly different from extant layout decomposition techniques because of the intricate photoresist properties subject to several exposures and an intervening critical image reversal baking step. The challenge in the layout decomposition is that the exposure seen by each area before and after the reversal

Continues on page 3.

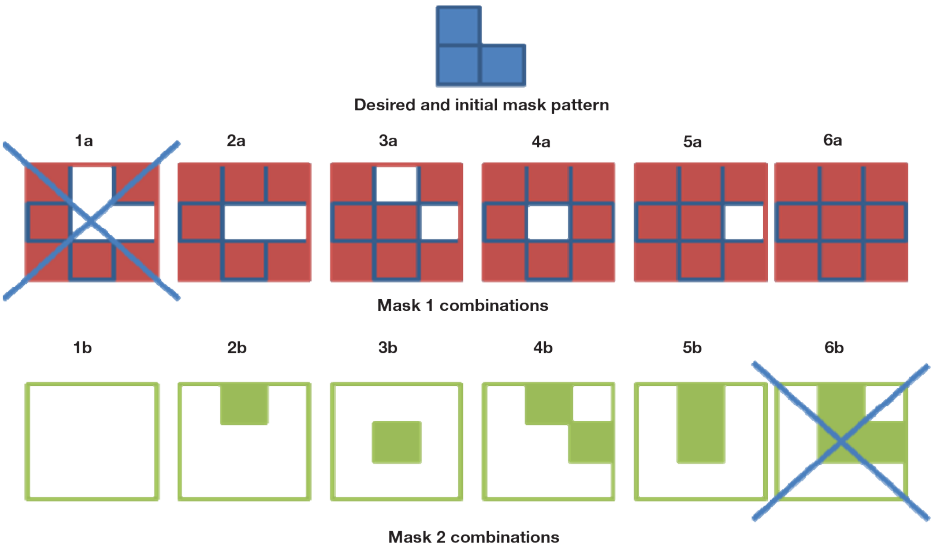

Figure 1. Example showing selection of mask combinations.

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SPIE

EDITORIAL

28th EMLC 2012 or Small is Beautiful

Uwe Behringer, UBC Microelectronics

In 1984, a one-day conference on photomasks was organized in Munich by the Siemens Mask Shop and Fraunhofer-Gesellschaft. Forty attendees discussed their latest results, their failures and their achievements. Hot topics in those years were pellicles, cleaning, e-beam mask writers, exotic masks (for X-rays, e-beam proximity printing, and ion beam projection) and how to optimize mask inspection & metrology to better support their photolithography. Over the years, the conference grew, instituted Uwe Behringer as conference chair (1996), changed the language to English, and included "Lithography" in the conference name to EMLC to provide more emphasis on lithography. The conference moved to Dresden in 2004 with two stints at Grenoble. We also established a connection to SPIE which publishes the conference proceedings. Attendance and the number of papers followed the ups and downs of the industry.

At the 28th EMLC this last January a total of 38 authors, 17 of them from outside Europe, presented their papers to an audience of more than 160 people from 14 countries for two full days. The biggest contributions came from Germany(11), USA(11) and the Netherlands(5). There was a strong showing of smaller companies and universities from Europe. The topics covered a whole range of photomask making and photomask applications from defect printability of EUV masks to lithography process optimization for MEMS fabrication.

Burn Lin from TSMC provided the 1st key note topic on "Nanometer-Level Semiconductor Imaging for Micrometer MEMS", and Paul Chipman from Toppan Photomasks presented the second key note address on "Adapting Mask Fabrication and Service to New Customer Models".

Despite almost annual remarks of doom by some pessimists EMLC continues to do well. Its European source and international acceptance was demonstrated by 21 presentation from Europe and 17 presentations from outside Europe.

Can the EMLC conference be a 100% substitute for the large symposia like SPIE's Advanced Lithography or the SPIE/BACUS Photomask?

YES and NO.

Probably not if you have the need to disseminate your results to everybody in the world potentially interested, or if you look for an overview of all what is going on in mask and lithography. Accepting parallel sessions, the large conferences like SPIE's Advanced Lithography or SPIE/BACUS Photomask are your conferences to go.

YES: However, if you prefer that unique "small conference feeling", where everybody still gets a chance to discuss with everybody else her/his special topics without the hassle of missing that one presentation (no parallel sessions). Almost all attendees of this year's EMLC confirmed a positive experience and expressed their intention to return again and to recommend to their colleagues to also attend.

The EMLC2012 program committee is very proud that we were able obtain manuscripts for 37 out of 38 of the presentations which were submitted to the conference.

With of more than 50% of the conference participants providing inputs from the evaluation sheets it was very easy to determine the Best Paper of the conference.

The attendees selected the presentation "Correcting Image Placement Errors Using Registration Control (RegC) Technology over the Photomask Periphery" by Avi Cohen from Carl Zeiss Israel as best paper. Mr. Cohen will receive the "EMLC2012 Best Paper Award" during the PMJ conference in April Yokohama.

The EMLC has an accepted place as a Mask and Lithography conference in Europe and outside Europe. Therefore we have already started work to organize EMLC 2013. Following suggestions to avoid (at least in some years) the bitter cold of Central Europe in January, the conference date had been changed to June 25 to June 27 2013. The well-acclaimed environment provided at the Hilton Dresden and the cruise boat for the banquet dinner will again welcome you to enjoy not only stimulating scientific exchange, but also to experience the personal touch a small conference can provide. If you have any idea for further improvements I look forward to your comments, and definitely want to welcome you at EMLC 2013, June 25 to 27 2013 at the Hilton Hotel in Dresden, Germany.

BACUS

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Table 1. Selection of mask 1 and mask 2 combination.

Mask 1 & 2 combination	1b	2b	3b	4b	5b
2a					
3a					
4a					
5a					
6a					

Combination that work

Combination that result in different pattern other than that of the initial pattern and have to be discarded

bake determines the solubility of the resist. This circumstance constitutes a welcomed benefit of optimum pattern printability by using an internal corner counting algorithm.

1. Introduction

The scaling of IC devices for future technology nodes is mainly limited by current existing lithographic techniques.[1,2] Ongoing research is targeting the double patterning method considered one of the most promising lithography solutions for 22 nm node and beyond. The double patterning method allows the increase of line density and printability by using multiple resist layer such as in the case of litho-etch-litho-etch (LELE) method and the litho-freeze-litho-etch (LFLE) process.[3] Recently, a new double exposure using image reversal photoresist (DESIR) has been proposed.[4] This method offers printability benefits of the conventional double patterning methods while using one photoresist layer instead of two photoresist layers as in LFLE or an additional hard mask etched twice as in LELE method. In DESIR, the key idea is to break up the desired layout into two masks such that sub-resolution configurations are separated between the masks into simpler, printable patterns that reduce the pattern distortion and improve printability.

In this paper, a layout decomposition and mask synthesis method for the DESIR lithography approach is presented. This method is distinctly different from existing layout decomposition techniques[5,6] because of the image reversal photoresist (PR) properties combined with the double exposure method requiring multiple exposures and an intervening reversal bake.

The method for choosing mask 1 for the first exposure and mask 2 for the second exposure comprises two phases: 1) decomposition of the desired final pattern into combinations of mask 1 and mask 2, 2) selection of the combination of masks that will result in best printability. The challenge in the layout decomposition and mask synthesis for DESIR is that many combinations of mask 1 and mask 2 layout patterns lead to the same final resist solubility property. The basic rules for decomposition are derived from the four possible exposure states and the response of the resist to these exposure states. Specifically, respective areas of the image reversal resist will be insoluble if never exposed, exposed twice or only exposed during the first exposure and soluble if exposed only during

Table 2. Mask algorithm definition.

Mask		Photoresist (PR)	
Opaque	Transparent	Insoluble	soluble
0	1	0	1

Mask 1 (A)	Mask 2 (B)	Initial mask and final PR (C)
0	0	0
0	1	1
1	0	0
1	1	0

the second exposure. Therefore, for resist areas that should be soluble, the corresponding areas should be opaque on the first mask and transparent on the masks (e.g. never exposed), transparent on both masks (exposed twice) or transparent on the first mask and opaque on the second mask (exposed only by the first exposure). As a corollary, it is noted that the order in which masks 1 and 2 are overlaid is crucial in determining the final pattern, i.e. the mask 1 and mask 2 are not commutable. Thus, to implement the mask decomposition technique for DESIR, first, the desired pattern is broken down into blocks. For blocks of a pattern that are opaque in a block of the desired pattern initially designed, there are three different combinations of masks available for each block or area of a single mask. These exposure options in regard to areas that should be insoluble provides substantial flexibility for mask selection for the decomposed mask and which will result in the desired pattern for a block of the desired overall resist pattern.

Next, the combinations of mask layer 1 and mask layer 2 which would generate an undesired final pattern need to be eliminated. Subsequently, the mask layout combination that results in optimum pattern printability is selected by using an internal corner counting algorithm. Aside from the proximity between patterns, the corners (mostly inside corners) in the

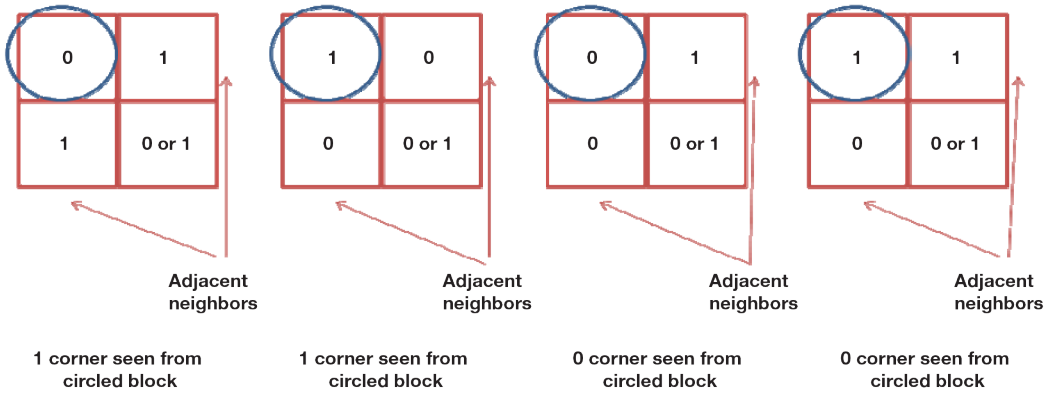

Figure 2. Counting of corners that would cause distortion of resist patterns.

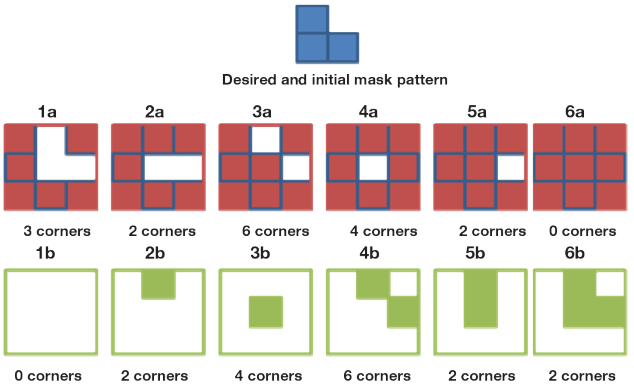

Figure 3. Ultimate criteria for selection of mask combination.

patterns generate a great challenge in resolving pattern with great fidelity. The best combinations of mask 1 and mask 2 are generated using a defined figure of merit based on the corner counting algorithm such as to minimize corners on the mask 1 and 2 liable for rounding errors. Finally, the optimum mask layout combination is selected by choosing the layout with the largest area of blocks forming a contiguous rectangular or square shape.

2. Mask Decomposition Process

2.1 Determing potential mask patterns

Initially, the desired initial mask pattern (final resist pattern) is broken up into blocks or tiles. The purpose for this step is to be able to independently determine the adequate mask 1 and mask 2 layers that would generate the same block pattern when using the DESIR lithography method. During the DESIR lithography process, each block will either be soluble or insoluble based on the properties of the mask block transparency or opacity. In DESIR, the areas never exposed, exposed the first time only, and exposed twice are insoluble when developed. Only areas exposed the second time after the reversal bake will be soluble. Thus, by breaking the initial mask pattern into blocks, the optimum mask pattern can be designed in order to improve pattern printing fidelity. The final mask pattern is obtained by selecting the best combination of individual block patterns. The various combinations of final mask pattern must also meet the requirement of generating the desired final resist pattern. This selection method is optimized by application of a selection algorithm. An example is provided below in Figure 1 to aid the understanding of this process.

In the example below, the "L-shaped" desired initial mask pattern is shown. The various mask 1 patterns are generated by combining different opaque and transparent blocks; the same function is performed for mask 2 patterns. In Figure 1, only selected mask 1 and mask 2 patterns are shown, although the patterns which are symmetric to the ones shown should be considered in the actual design. Next, the mask patterns which are replicate or inverse of the initial mask patterns are eliminated since using these masks would not require the use of DESIR and thus would not improve printability. Since only areas exposed the second time are soluble, the first elimination process can be performed. The areas of the desired initial mask which are transparent would need to be opaque in mask 1 and transparent in mask 2.

2.2 Selecting potential masks' combinations

In the second stage, the combinations of mask 1 and mask 2 patterns that generate the desired resist pattern are selected. In the final resist pattern, the insoluble resist blocks would result from all previously selected masks combinations except the ones where the first mask is opaque and the second is transparent. These mask combinations include masks 1 & 2 opaque, mask 1 transparent and mask 2 opaque, and masks 1 & 2 transparent. Table 1 below shows the combination of masks 1 & 2 which would generate the desired resist pattern. It must be noted that mask patterns 1a and 6b were previously eliminated since they represent the replicate and inverse of the final resist pattern.

Valid combinations of first and second tile patterns can be easily and rapidly detected by assigning a first logic value (e.g. "0") to block areas that are opaque in respective mask patterns and areas that are to be insoluble in the image reversal resist and assigning another logic value (e.g. "1") to areas that are transparent in the respective tile mask patterns and areas that are to be soluble in the image reversal resist and then iteratively

Table 3. Corners counted in selected masks combinations.

Mask 1 & Mask 2 FoM	2b	3b	4b	5b
2a	9		21	9
3a		35		21
4a			35	
5a				9

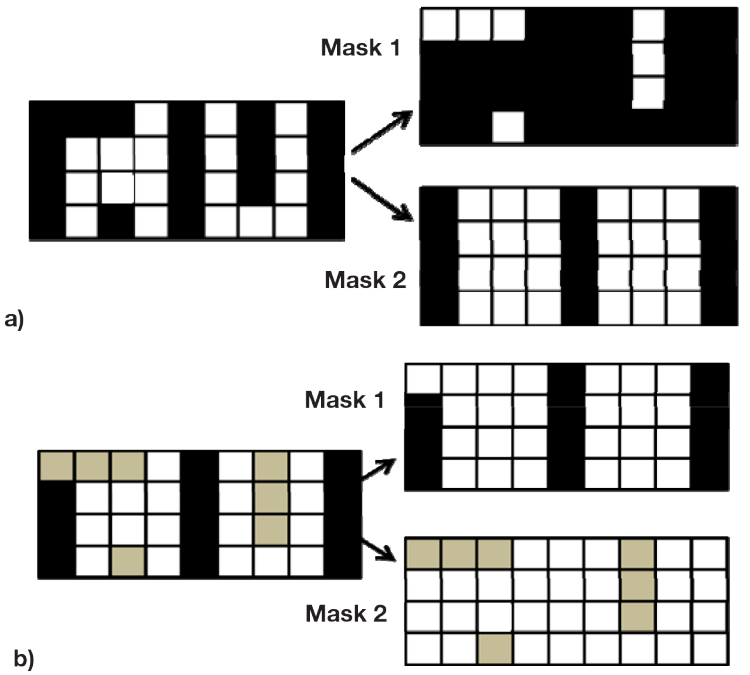

Figure 4. Comparison of the mask layout decomposition for DESIR and DP a) In DESIR, one single layer layout is decomposed into two masks (one possible combination). b) Layer layout decomposition in conventional DP method into two masks using LELE or LFLE process.

(or in parallel) testing respective blocks of a given mask pattern combination against corresponding blocks of the desired resist structure pattern in accordance with the truth table shown in Table 2. The opaque mask block and transparent mask block are respectively given a 0 and 1 value. Similarly, the insoluble and soluble resist blocks are respectively given a 0 and 1 value. The translation of this truth table is that blocks of mask 1 & 2 which are opaque (0), mask 1 transparent (1) and mask 2 opaque (0), and mask 1 & 2 are transparent (1) would result in resist insolubility; however blocks of mask 1 that are opaque and mask 2 that are transparent would result in resist solubility.

It is recognized that the logical test shown in Table 2 is simply that of an exclusive OR gate with additional inversion of the output to reflect whether a single exposure is produced by a respective block of the first mask or a corresponding block of the second mask. The logic of this test can be even more simply embodied in an AND gate with an inverting input such that if a block of the first mask is logic variable A, a corresponding block of the second mask is logic variable B and C is the value of the block of the desired resist structure shape, the logic test can be expressed as:

$$\overline{A} \cdot B = C \qquad (1)$$

where "·" denotes the logical AND operation and the bar denotes the logical complement of the variable "A". If this test is true for all blocks of a tile, the combination of tile mask patterns is valid. Accordingly, while many combinations of tile mask patterns may be presented, valid combinations can be detected very rapidly by a very simple logic operation. The results of detected valid combinations are visulaized in Table 1.

2.3 Printability optimization

Valid combinations of masks which have been detected as discussed above can then be compared for printability with the goal of further refinement in order to improve pattern resolution. A major advantage of DESIR is the avoidance of diffraction distortions present in the inclusion of corners, in particular inside corners. Therefore, the selection phase of the algorithm continues next with the detection and counting of corners presented by the respective first and second block patterns of the valid combinations.

The best combinations are the ones that contain the least number of inside and outside corners together to avoid pattern distortion during exposure and reduce the need for optical proximity corrections (OPC). The inside corners are counted in a specific manner using the truth table values defined in the previous section. From each block of each group the which the inspection is performed (and thus the adjacent blocks must be of a logic value equal to each other). If so, a corner is "seen" by the block from which inspection is done. If not (e.g. the adjacent blocks are of different logic values) no corner is seen. This test is performed for each of the blocks of each group. The number of corners detected is counted for each pattern mask as depicted in Figure 2. A figure of merit (FoM) is derived by adding 1 to the number of corners counted in each tile pattern mask of a valid combination and the resulting numbers are multiplied according to:

$$\text{FoM} = (\text{corners from mask 1} + 1)\cdot(\text{corners from mask 2} + 1) \qquad (2)$$

The best (most printable) combination will exhibit the minimum figure of merit. It should be noted that the "+1" which is added to the counted number of corners in each mask is to prevent a large number of corners in one mask with zero corners in the other mask from producing a FoM = 0 notwithstanding a substantial number of corners in one mask. Other algorithms for computing a FoM, such as summing the counted number of corners can also produce useful results in most or all cases. It is thus seen that the algorithms may be adjusted

to a particular application and technology requirement.

However, such a unique and optimal value for FoM does not always result from the above analysis for other geometrical patterns. For example, for an "L" shaped resist structure pattern it can be shown that three tile pattern mask combinations will result in a minimum FoM = 9, as shown in Figure 3. In such a case, the optimal (e.g. most printable) combination pattern masks will be the number of blocks in respective opaque or transparent regions in the first or second mask which will form the largest contiguous rectangle or square, as illustrated in Figure 3 (mask 2a and mask 5b). Again, as discussed above, rectangular mask shapes are most effective in avoiding diffraction distortions in the final resist structure shape.

Table 3 shows the FoM calculated for the combination of mask 1 & 2 that were previously selected. The combination of masks with larger FOM values are eliminated leaving the ones with the minimum FOM is 9. Thus, the largest number of consecutive blocks which together form a rectangle or a square will determine the ultimate the mask layout for double exposure using IR photoresist. If the condition FoM=min gives a unique optimum mask decomposition, the rule of largest contiguous rectangles does not have to be invoked.

3. Discussion and Example

A more realistic example of a mask decomposition is shown for the DESIR method and the conventional DP method in Fig. 4. In the DESIR method, a reversal bake is required between the two exposures leading to various resist solubility properties: areas exposed only the second time are soluble, while never exposed areas, areas exposed the first time only and areas exposed twice are insoluble. However in the DP method, in the case of LELE, a hard mask is required to transfer the first resist pattern before the second resist layer is patterned and in the case of LFLE, the first resist layer is cured so it becomes insensitive to light and a second layer of resist is then patterned on top of the first using the second mask. In both DP methods, the lithography process is complex in either case because of the additional hard mask and photoresist layer and the required processing involved. In DESIR, only one single resist layer is used with a reversal bake step.

The mask decomposition algorithms described here can be optimized to meet memory requirements and processing time management. These factors will be influenced by the size of area of the decomposed blocks initially picked (block granularity of the pattern) and the procedure in which the elimination is performed. The combination of blocks can be checked against all mask algorithms before being stored and then checked against each mask algorithm while being selected or eliminated. Some possible algorithms of the mask decomposition and synthesis have been described to enhance pattern resolution by improving corner roundings and reducing the need for OPC. However, a similar technique could be developed to utilize other advantages of DESIR such as reducing the number of photolithography-related process steps.

4. Conclusion

Double patterning lithography represents one of the best potential replacement to conventional lithography in order to extend 193 nm UV exposure past 22 nm and beyond. DESIR is a promising double exposure technique with the same advantages as double patterning lithography but without the additional masking and patterning steps. The method can be retrofitted into any existing CMOS process flow, requires however, a state-of-the-art image reversal photoresist. In this paper, a method of mask decomposition for DESIR application has been presented in which the conventional initial mask is decomposed into two masks for two exposures with an image reversal bake in between. All possible patterns for mask 1 and all possible patterns for mask 2 have to be generated first by breaking the initial mask pattern into blocks. Each block can be opaque or transparent from which combinations of blocks for mask 1 and mask 2 can be defined. Any mask that replicates the exact pattern or the exact opposite pattern as the initial mask is discarded. The next selection rule is that the transparent blocks in the initial mask must be opaque and transparent respectively in mask 1 and mask 2 of the decomposition. Thus, all combination of mask that do not meet this requirement can be eliminated. Additionally, the rest of the combinations of mask 1 and mask 2 that will not generate the same pattern as the initial mask pattern are eliminated using the following AND logic operation: $(\overline{mask1})\text{-}(mask\,2) = (initial\ \ mask)$.

A further selection rule of counting corners has been proposed. Mask combination(s) that have the least number of total corners according to the FoM = (mask 1 corners + 1)·(mask 2 corners + 1) are selected. In many cases, this rule leads to a unique mask combination. If this is not the case, then the rule of the largest continuous opaque (transparent) rectangles or squares is applied to determine the optimum mask combination. The selection algorithms lend themselves for easy software implementation and automatization. It should be noted that the described algorithms are applicable in two situations: 1) one in which DESIR supplants competing double exposure methods offering drastically reduced cost of ownership of the photolithography module, and 2) one in which conventional single exposure lithography is replaced by DESIR offering a drastic reduction of the mask count for the required resist patterns [4].

5. References

[1] S. Sivakumar, "Lithography Challenges for 32nm Technologies and Beyond," Proc. IEDM, 1-4 (2006).

[2] L. V. D. Hove, K. Ronse, "Lithography options for the 32 nm half pitch node", IMEC (2006).

[3] Chris Mack, "Seeing Double", IEEE Spectrum (11), p.46-51 (2008).

[4] C. Ndoye, M. Orlowski, "Double and triple exposure with image reversal in a single photoresist layer", Proc. SPIE 7970, 79701H (2011).

[5] A. Poonawala, P. Milanfar, J. Micro/Nanolithography, MEMS MOEMS 6 (4), 043001, (2007).

[6] S-K. Kim, H-K Oh, et al., Japanese J. of Applied Physics, 47 (11), 8333-8337 (2008).

Industry Briefs

ASML Brion Rolls Mask Optimization Tool

By EETimes

ASML Brion has introduced the Tachyon Flexible Mask Optimization (Tachyon FMO) tool to enable seamless use of multiple optical proximity correction (OPC) techniques in a single mask tapeout and to allow advanced and computationally intensive OPC in those local areas where they can be most beneficial. The use of different OPC techniques tailored to localized imaging challenges can reduce the tapeout cycle time to just one-third the time of alternative technologies, while maintaining the desired level of imaging performance. Brion has also developed a solution that detects and manipulates hotspots and can cleanly reinsert the corrected hotspots into the full chip design without introducing new defects due to the proximity effects of neighboring patterns. STMicroelectronics (ST) has been evaluating Tachyon FMO for its 2x nm node development, focusing on the hotspot repair application. ST has demonstrated dramatic reductions in defects in the contact layer by using Tachyon MB-SRAF along with Tachyon FMO, while ensuring that no new defects were introduced by the repair method itself.

Gudeng Precision Designs EUVL Pod with VICTREX for Low Contamination

By Solid-State Technology

To maintain a contamination-free environment, Gudeng has designed a new EUV dual-pod with the inner pod made from metal and the outer pod made with VICTREX PEEK-ESD 101. VICTREX PEEK-ESD 101, for all of the photomask contact components and the housings, is a good EUV pod base material because of its high surface hardness, low particle generation, high purity, and tight ESD tolerance. Contamination levels can be effectively reduced and the resistance to wear significantly increased compared to materials currently in use.

EVG620HBL Mask Alignment System

By Photonics

EV Group (EVG) has announced the EVG620HBL Gen II, the second generation fully automated mask alignment system for volume manufacturing of extremely bright light-emitting diodes (HB-LEDs). Introduced one year after the launch of the first-generation EVG620HBL, the Gen II is tailored to address HB-LED customer-specific needs and the ongoing demand to reduce the total cost of ownership. EVG has also signed a joint development and licensing agreement with lithography company Eulitha AG, integrating Eulitha's PHABLE mask-based UV photolithography technology with EVG's automated mask aligner product platform. Combining Eulitha's full-field exposure technology with EVG's mask alignment platform reportedly allows cost-effective, automated fabrication of photonic nanostructures over large areas and supports the production of energy efficient LEDs, as well as solar cells and liquid crystal displays (LCDs).

IBM Technology for 14nm FinFETs

By Semiconductor Manufacturing and Design

IBM and its Common Platform alliance partners, GLOBALFOUNDRIES and Samsung, hope that commercially feasible EUV lithography will be available some time during the 14 nm node, if not at the beginning. The Common Platform companies are hoping many of the challenges in commercializing EUVL will be overcome through its various research links, including those with the EUV Center of Excellence now under construction in Albany, New York.

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.

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Calendar

2012

SPIE Photomask Technology

10-13 September 2012
Monterey Marriott and Monterey Conference Center
Monterey, California, USA
spie.org/pm

2013

Advanced Lithography

24-28 February 2013
San Jose Convention Center and San Jose Marriott
San Jose, California, USA

Watch for the 2013 Call for Paper in Late April!

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