PHOTOMASK

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Third Place Best Poster Award

A new CDSEM metrology method for thin film hardmasks patterns using multiple detectors

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ABSTRACT

Thin film hardmasks with 10nm or less are used in double patterning techniques to generate fine patterns for 32nm-node and beyond. Using a conventional Mask CDSEM for ultra accurate measurement of patterns on these thin film hardmasks is difficult due to weakness of the edge profiles generated by a scanning electron beam. Additionally, the tones of a SEM image can be reversed due to a charging phenomenon, which causes false recognition of lines and spaces. This paper addresses ultra accurate measurement of thin film hardmasks using a new measurement algorithm that is applied to profiles obtained from multiple detectors.

1. Introduction

The Mask CDSEM measures critical dimensions (CDs) on photomasks by characterizing the sample's surface topography with contrast. The pattern edge areas have higher contrast than the other areas. (Figure 1)

This principle is effective when traditional masks, whose pattern layer is sufficiently thick, are measured. However, when conventional Mask CDSEMs measure thin film hardmasks with 10nm or less, the contrast of pattern edge areas is very small due to the thinness of these hardmasks (Table 1). This causes measurement failure or deterioration of measurement precision.

In addition, there is another difficulty in detecting pattern edges of thin film hardmasks due to a charging phenomenon that often causes higher contrast in flat areas than that in pattern edge

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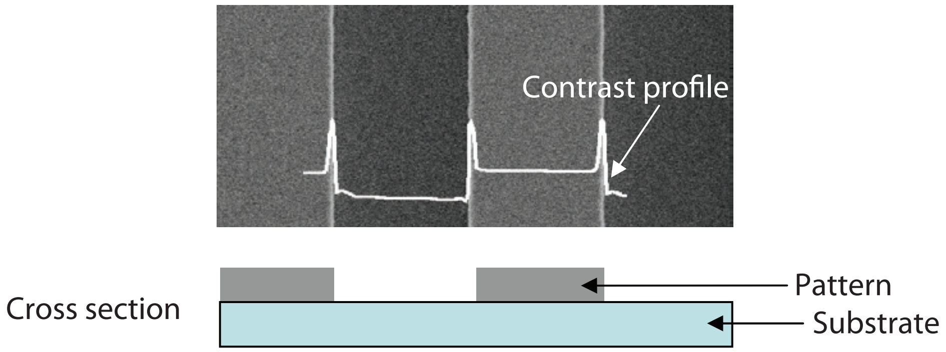

Figure 1. Contrast profile of a Chrome binary mask.

TAKE A LOOK INSIDE:

EDITORIAL

To Share and To Learn

Wilhelm Maurer, Infineon Technologies AG (Germany)

Preparing to go to a conference—e.g. SPIE's Advanced Lithography Symposium in San Jose—you had to find a reasonable and justifiable answer to the questions "Why should I participate? What will I, what will my company get out of it?" You may have filled in your topics into your company's travel sheet as every year, you may even have had to identify a special argument for some skeptical manager why this year it had to be, or you may have just said to yourself "same procedure as every year," and then continued without further concern.

As the chairperson of this year's Photomask Symposium, I see as my number one job to motivate as many people as possible to join our conference. So I have wholeheartedly and honestly asked myself about my personal motivation, and also discussed the topic with some of my colleagues. After sorting out semi-relevant reasons like networking or vendor/customer meetings, for which conferences are good places, but neither the only nor the best ones, this is what I found out:

Engineers join a conference for two primary reasons: to share information, and to learn new things. Interestingly, these two prime motivations are not allotted within one individual like water in communicating vessels, where more water in one vessel results in less in the other, resp., if somebody participates with the main intention to share information, then (s)he is less interested in learning, and vice versa. There are rare exceptions of people who attend just for one single reason, e.g. the pushy marketer of a new tool, or the student fresh out of college. Unfortunately (concerning the latter) and fortunately (concerning the former) we meet both specimens quite rarely at one of our conferences. Usually, most participants are motivated by a mixture of both, and for most of them, the proportions of the mixture are the same. However, one of my very positive experiences at my first lithography and mask conferences was that there has been a substantial group of individuals who are extremely motivated to both share and to learn, who like lighthouses have provided content and direction by asking questions, by providing comments in the official sessions, by initiating discussions in informal groups, or even at social events. To meet these people and to follow their example is my primary reason to go to a conference.

I am convinced that the deeply ingrained tradition of sharing and learning in our industry has been one of the cornerstones for its unique development over the last 50 years. So I cordially invite you to join BACUS 2011 in Monterey this September. You will find plenty of colleagues to discuss the latest and greatest on masks and mask-related topics in EUV, optical double-/multi-exposure, NIL, and Patterned Media, and recent developments in mask making, mask inspection and mask management. What about 20nm? EUV? Tell us, if you are excited about SMO! How about the alternative between buying a new generation of tools vs. farming out the technology to a foundry which can afford it? Which EDA-tooling options will be needed, which strategies in DfM and mask data prep will be essential for sub-20 nm? Let's jointly foster our culture to share and to learn, and bring home a lot of new ideas for our personal benefit, for the benefit of our companies, and for the benefit of our industry!

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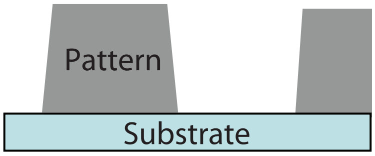
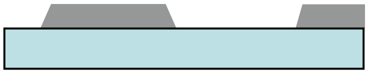
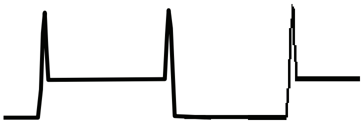
Table 1. Contrast profile comparison between thick pattern layer and thin pattern layer.

Thickness of pattern layer	Thick	Thin
Cross section		
Contrast profile		

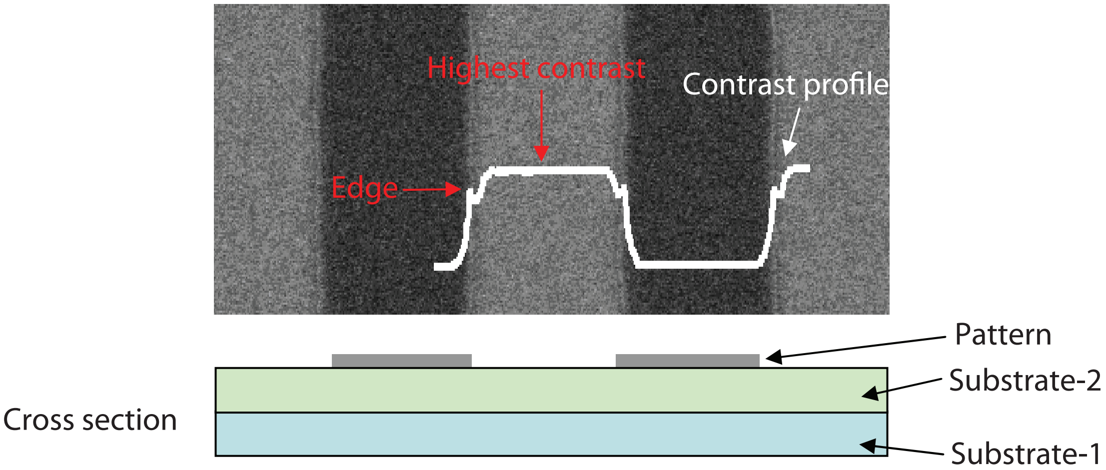


Figure 2. Contrast profile of a thin film hardmask measured by a conventional Mask CDSEM.

areas. (Figure 2) This phenomenon also causes failure to distinguish whether the feature is a pattern area or a non-pattern area.

Due to the technical difficulties mentioned above, the automated measurement of thin film hardmasks is extremely difficult. During its measurement, the following errors happen:

- Inability to measure due to the insufficient edge contrast.
- Incorrect detection of a position different from an edge position due to inclusion of fliers.
- Measurement of an incorrect feature whose position is next to the correct one.

As a result, many positions require remeasurement using a manual measurement method. However, the manual measurement of thin film hardmasks has many difficulties as follows:

- To measure only edge areas, not to incorrectly measure flat areas which have higher contrast than edge areas, the range of the edge search should be extremely narrowed to such as 30 nm.
- The width of the regions of interest (ROI) box should be accurately matched as well as the width of pattern due to the narrow range of the edge search.
- The operator needs to check visibly whether there is incorrect detection of a position different from the edge at each segment inside the ROI box.

In the industry, there is no Mask CDSEM capable of measuring thin film hardmasks reliably. In this paper, we introduce a new measurement algorithm which enables automatic ultra accurate measurement of thin film hardmasks.

2. The Multiple Detectors System and New Measurement Algorithm

The new column configuration with four channel detectors is illustrated in Figure 3. The four detectors (Detector A, B, C and D) are independently set up in symmetry for the axis of the electron beam.

The secondary electrons emitted from the photomask surface tend to enter one specific detector among the four detectors depending on the properties of the emission area. As a result, secondary electrons detected by each detector are distributed as shown in Figure 4, where pattern edges are emphasized in accordance with the direction factor of each detector. Four images are obtained simultaneously by the scanning of one electron beam.

The image A is the image taken by the detector A. Also, the image B, C and D are the images taken by the detector B, C and D.

As we describes in chapter 2, thin film hardmasks have the technical difficulties in measurement. The new algorithm, which we introduce in this paper, can solve these difficulties with the combination of the four channel detector system.

In case of vertical dense line and space arrays on a thin film hardmask, the two left-side detectors (Detector B and C) empha-

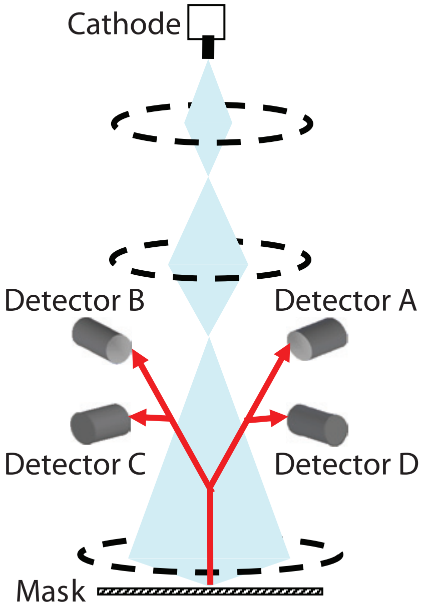


Figure 3. Column configuration of four channel detectors.

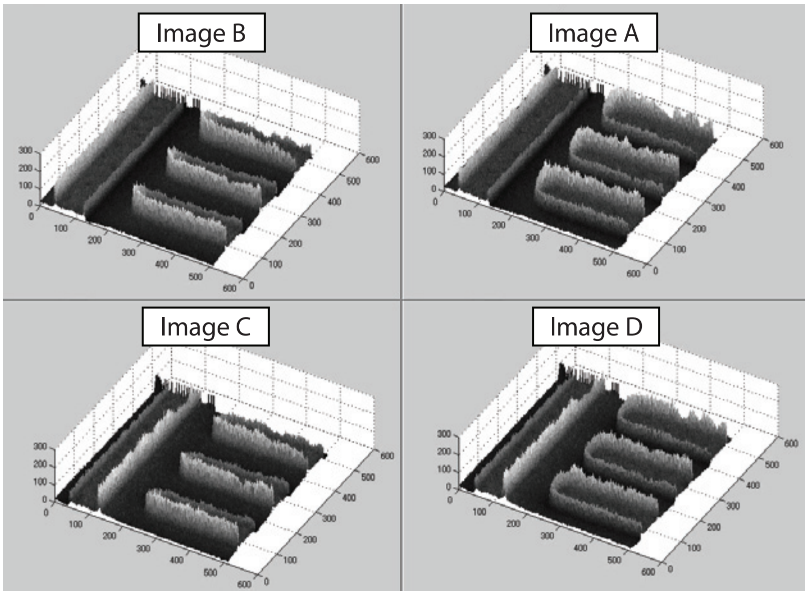


Figure 4. Secondary electron intensity map of each detector.

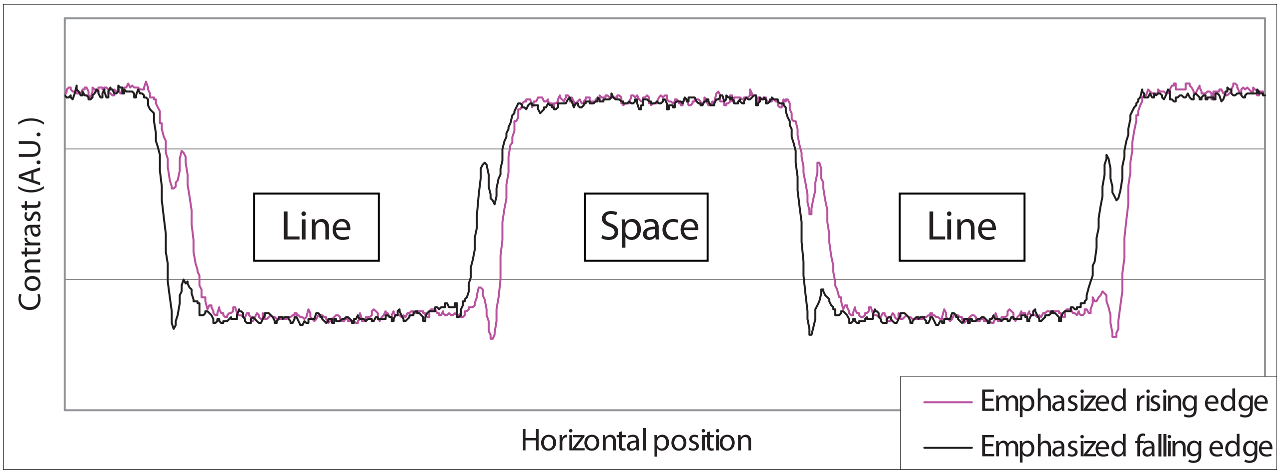


Figure 5. Contrast profiles of vertical dense line and space arrays on a thin film hardmask obtained using the new algorithm and four channel detectors.

size the left edges of lines (the rising edges), and weaken the right edges of lines (the falling edges). On the other hand, the two right-side detectors (Detector A and D) emphasize the falling edges, and weaken the rising edges. The following formulas show how to obtain images separately with the rising edges emphasized or with the falling edges emphasized.

(Image emphasizing rising edges) = sum of (Image B and C)

(Image emphasizing falling edges) = sum of (Image A and D)

By the operation above, the contrast profiles shown in Figure 5 have been acquired. Only the edge areas have the obvious difference in these two profiles. Higher contrast on flat areas still remains.

Then, to compose one image with only edge information extracted, the image with the rising edges emphasized is subtracted from the image with the falling edges emphasized, as the following formula. Consequently, the image show in Figure 6 is composed. We call this image as “Subtract Image”.

(Image extracting only edges) = sum of (Image B and C) – sum of (Image A and D)

Figure 7 shows the contrast profile of the Subtract Image in Figure 6.

In Figure 7, the technical difficulties of thin film hardmasks, such as the weakness of the edge profiles and the higher contrast on the flat areas, have been solved. Furthermore, the amplitude of the edge contrast is much larger than that of the noise.

We have succeeded to extract edge information which has sufficient contrast on a thin film hardmask utilizing the new measurement algorithm with multiple detectors.

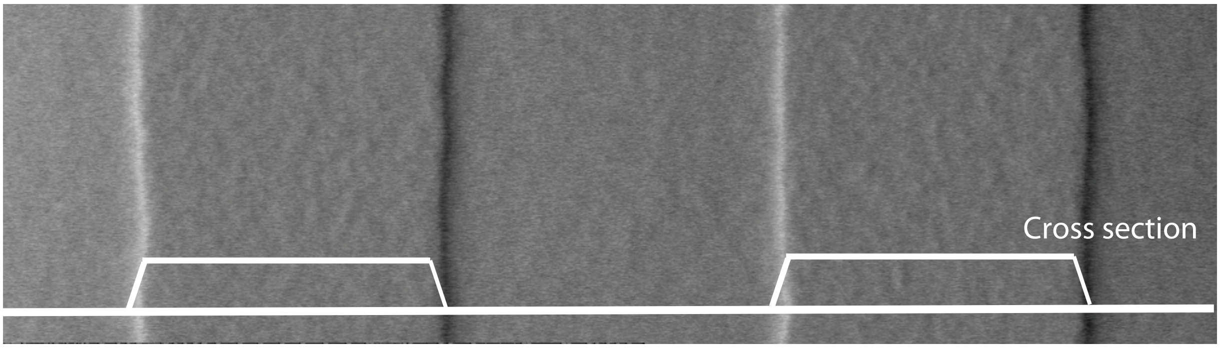


Figure 6. "Subtract Image" of a thin film hardmask.

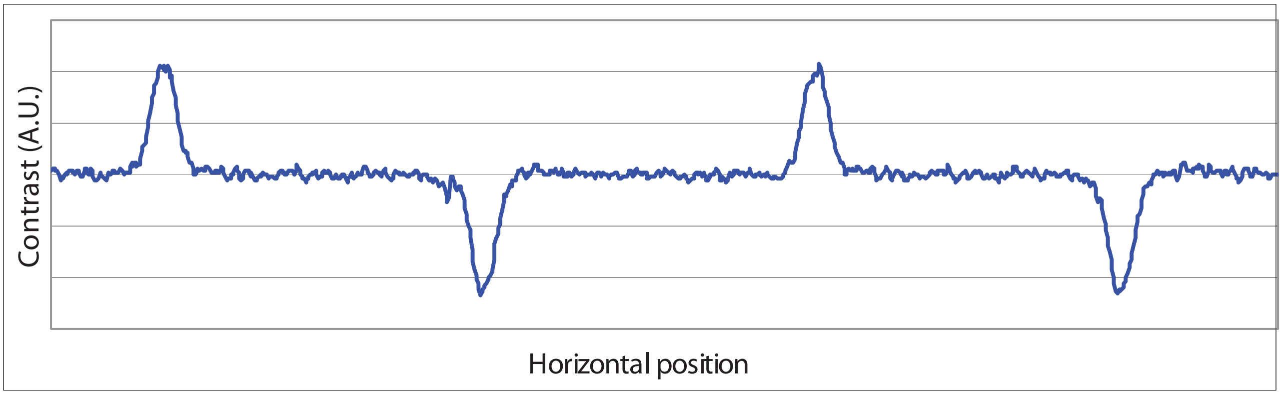


Figure 7. Contrast profile of "Subtract Image" of a thin film hardmask.

3. Improvement in Measurement Accuracy

The improvement in measurement accuracy of thin film hardmasks with the Subtract Image taken by multiple detectors is evaluated, comparing with a conventional algorithm. In this evaluation, 10 dynamic loops with 3 time load and unload were performed (a total of thirty measurements).

In case of dense line and space arrays of thin film hardmasks, figure 8 shows the measurement accuracy comparison between the new and conventional algorithm, based on the measurement accuracy with the conventional algorithm is assumed to be 100. More than 60 % of improvement is confirmed with the new algorithm.

Also, the measurement accuracy of pattern edge roughness is evaluated as the same method as above. The new algorithm has achieved more than 70% of improvement. (Figure 9)

4. Improvement in Automated Measurement Success Rate

Subtract Image brings more information which illuminates the rising edge or the falling edge without the tone. Figure 10 shows the case of vertical dense line and space arrays on a thin film hardmask. Positive peaks of the contrast profile on the Subtract Image show the rising edges.

The new algorithm, which can distinguish the rising edge or the falling edge on Subtract Image, is developed. This new algorithm clearly improves the success rate of automated measurement, especially the pattern recognition before measurement for correct positioning. Also, this new algorithm can automatically move the measurement ROI box to the correct position. Even though small positioning displacement remains after the local alignment, the correct target can be robustly measured. Consequently the new algorithm has achieved 100 percent measurement success rate on thin film hardmasks during our evaluations.

This technique can be also used for a variety of photomask material types such as Chrome binary mask, MoSi binary mask, alternating PSM, attenuated PSM and etc.

Furthermore, this technique is effective for resist masks which have difficulty distinguishing the rising edge or the falling edge. [1]

5. Conclusions

We introduced and described the new algorithm with the combination of four channel detector system. There were the technical difficulties for thin film hardmask measurement such as the weakness of the edge profiles and higher contrast in flat areas. However, this new approach has solved these difficulties, and has brought ultra accurate measurement of thin film hardmasks.

Furthermore, the judgment of peak in contrast profile enables big improvement in the automated measurement success rate. The measurement with the high accuracy and high success rate can be achieved on thin film hardmasks with multiple detectors.

6. Reference

[1] J. Matsumoto et al., "A new algorithm for SEM critical dimension measurements for differentiating between lines and spaces in dense line/space patterns without tone dependence," Proc. SPIE 6349-152 (2006).

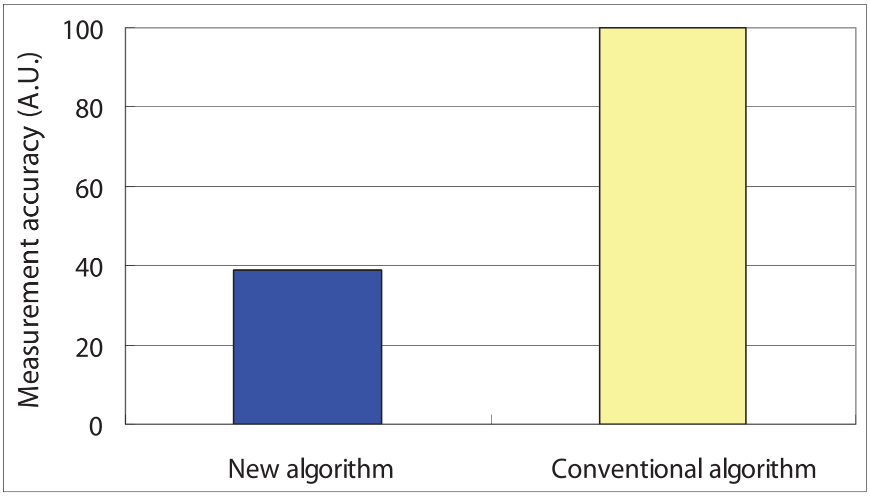


Figure 8. Improvement in measurement accuracy on dense line and space pattern.

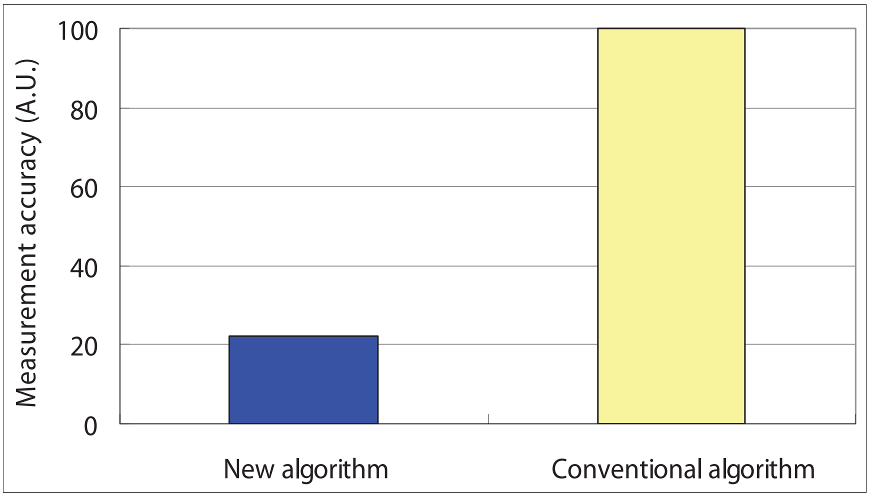


Figure 9. Improvement in measurement accuracy of pattern edge roughness.

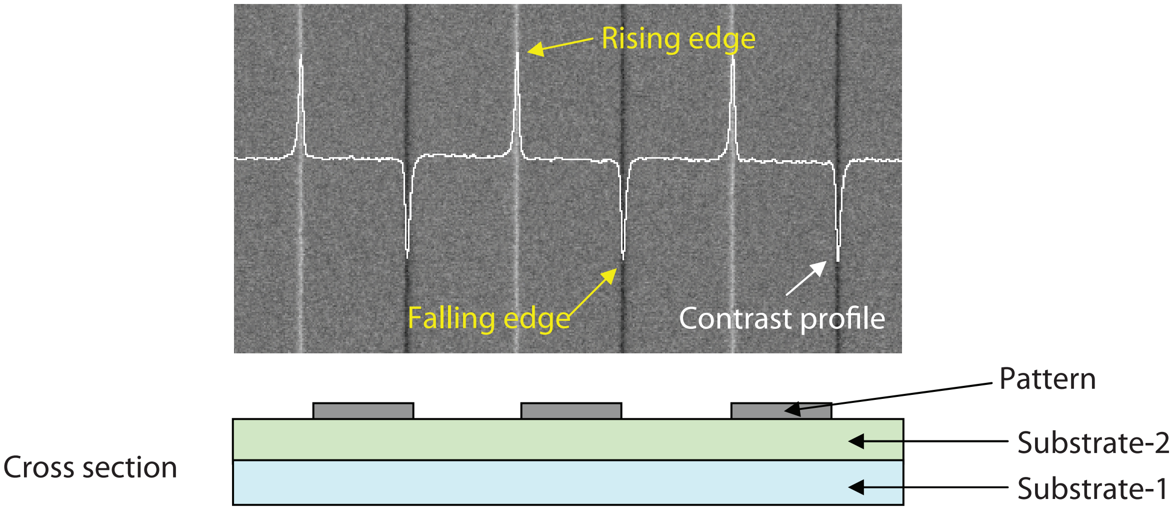


Figure 10. Recognition of the edge type.

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Industry Briefs

Dresden's 'Cool Silicon' Project Preps Phase 2

By **Peter Clarke**, EETimes, London

The Dresden Cool Silicon project, backed by state and federal government funding and launched in 2009, is preparing to enter its second phase. The aim of the project is to reduce the energy consumption of ICs and information technology while stimulating the development of technology and the creation of jobs in the Dresden region. Companies already established in the region, such as GlobalFoundries AG and Plastic Logic Ltd. are participating in individual projects. In the area of micro- and nanotechnologies research projects are looking at the effects of variability and how to mitigate them. Work with GlobalFoundries and the Advanced Mask Technology Center GmbH & Co. are looking at ways to reduce the variations in photomasks. There are also projects to create a 700-V technology in a 0.35-micron process with X-Fab.

IBM, Toppan Extend Litho for 14-nm

By **Mark LaPedus,** EETimes, San Jose

Toppan Printing Co. Ltd. has extended a joint development agreement with IBM for a leading-edge photomask process, covering the 14-nm technology node for logic devices. The firms will extend 193-nm immersion lithography for that node. The development work will take place at IBM's photomask facility in Essex Junction, Vt., and Toppan's Asaka photomask facility in Niiza, Saitama, Japan, from January 2011 through 2012. Toppan and IBM will focus their joint development efforts on ArF immersion lithography for the 14-nm node through the use of IBM's highly regarded resolution enhancement techniques. "The 14-nm logic technology node is likely to be the final node capable of being produced with optical lithography alone, and may prove to be an early transition point into EUV development. Future nodes are expected to deploy EUV lithography in order to print features beyond the diffraction limit associated with 193-nm lithography," according to Toppan. This new agreement represents the continuation of a partnership that began in 2005 with 45-nm photomask process development, and has progressed through the 32-nm, 28-nm, 22-nm, and 20-nm technology nodes. The jointly developed photomask manufacturing processes have been essential contributors to advanced wafer process development by IBM and its partners in East Fishkill and Albany, NY.

Fab Tool Exec Maris Dies

By **Mark LaPedus,** EETimes, San Jose

Photronics Inc. recently announced that a member of its board of directors died on Dec. 13, 2010. Willem D. Maris, 71, served as a director of the company since 2000 and was a member of its board's nominating committee. Before joining the company, he served as the president and CEO of ASML Lithography Holding N.V. from June 1990 until his retirement in January 2000. While serving on the Photronics' board, he also acted as director of FSI International Inc. "Willem's warm presence and contributions at our board meetings will be deeply missed," said Constantine Macricostas, CEO of Photronics, in a statement. "His comprehensive knowledge of technology and the semiconductor industry was a valuable asset to the company."

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

2011

SPIE Advanced Lithography

27 February-4 March
San Jose Marriott and
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Late submissions will be considered by conference chairs.

SPIE Photomask Technology

19-22 September 2011
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