PHOTOMASK

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Third Place Best Poster Award

New analysis tools and processes for mask repair verification and defect disposition based on AIMS™ images

Rigo Richter, Eric Poortinga, Thomas Scherübl, Carl Zeiss SMS GmbH (Germany), Carl Zeiss Promenade 10, 07745 Jena, Germany.

ABSTRACT

Using AIMS™ to qualify repairs of defects on photomasks is an industry standard. AIMS™ images match the lithographic imaging performance without the need for wafer prints. Utilization of this capability by photomask manufacturers has risen due to the increased complexity of layouts incorporating RET and phase shift technologies. Tighter specifications by end-users have pushed AIMS™ analysis to now include CD performance results in addition to the traditional intensity performance results.

Discussed is a new Repair Verification system for automated analysis of AIMS™ images. Newly designed user interfaces and algorithms guide users through predefined analysis routines as to minimize errors. There are two main routines discussed, one allowing multiple reference sites along with a test/defect site within a single image of repeating features. The second routine compares a test/defect measurement image with a reference measurement image. Three evaluation methods possible with the compared images are discussed in the context of providing thorough analysis capability.

This paper highlights new functionality for AIMS™ analysis. Using structured analysis processes

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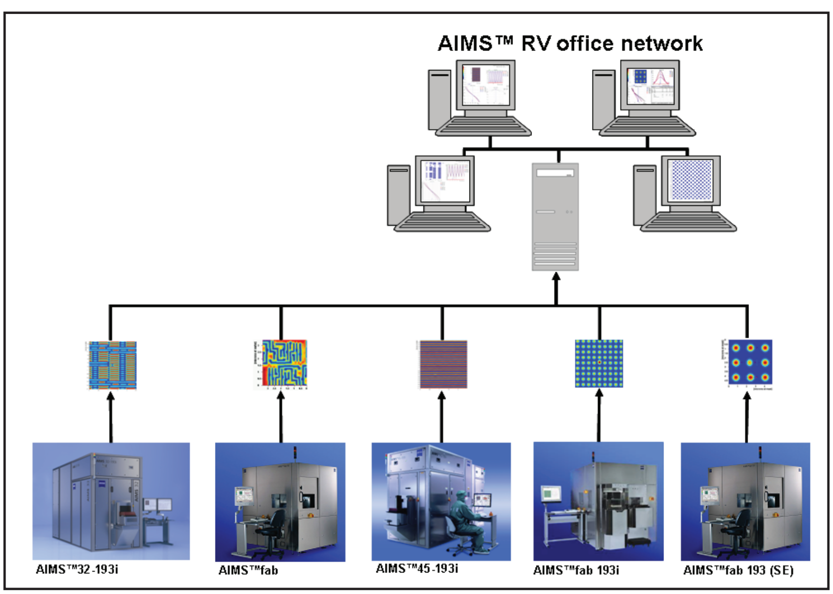


Figure 1. AIMS™ RV Office network The architecture of a possible application discussed here should be divided into three main components: Multi-Slice Analysis (MSA), Image Compare (IC), and Contact Hole analysis.

Take A Look Inside:

SPIE

Editorial

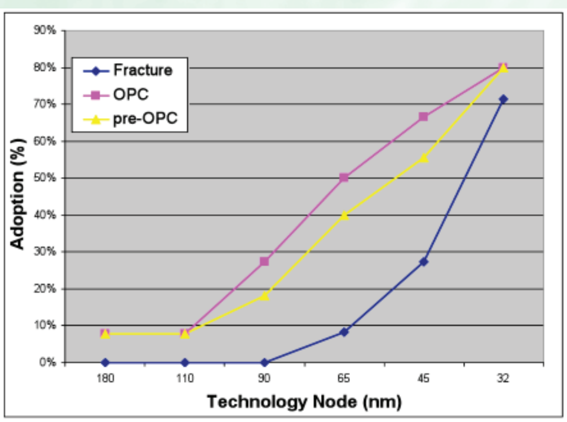
Is the Data Volume Explosion Under Control?

Steffen Schulze, Mentor Graphics

When the ITRS roadmap in 2001 predicted an exponential data volume explosion for design data entering the mask houses the industry joined forces under the SEMI umbrella and initated a task force to find solutions to contain the growing data volumes. Representatives from IDMs, EDA companies, mask manufacturers and mask equipment manufacturers got together and developed a new standard for data exchange – named OASIS or also known as SEMI Standard P39 and published in 2004. As a follow-on activity and as a subset of the P39 standard a mask manufacturing machine compatible standard was defined under the stewardship of Selete in Japan. It is called OASIS.MASK, listed as SEMI standard P44 and published in 2005. The new OASIS standard (P39) achieved its goal to reduce the data volume on average an order of magnitude compared to the then dominating standard format – GDSII. The OASIS adoption was enabled by the rapid support of the new formats by the EDA companies. All of the major EDA companies who provide software for physical verification, OPC, and fracture for leading technologies supported the new format by the end of 2005. File size is an important metric of data preparation efficiency so the extension to support OASIS was a logical part of the continuous software tool improvement. Over five years after the release of these new standards it is worthwhile checking where the industry stands today and if the data volume challenges persist or how they were resolved.

The 2009 annual mask industry survey reported that the largest file size to be processed at the fracture step was over 1.3TB – the average on maximum file sizes reported by the participating mask houses was at 419GB – somewhat below the 2007 ITRS prediction of approximately 700GB for 2009. According to the same survey though the majority of the data is received in MEBES and GDSII format - on average 40% and 54% respectively. In light of the data volumes this result is somewhat surprising.

Since the annual mask industry survey does not distinguish by technology node we conducted an informal survey among our customers to check on the status of adoption of the new OASIS standards. We asked the participants to distinguish by node and by data preparation step. The results from 19 respondents are shown in the graph below.



This survey certainly does not cover the whole industry yet it identifies some interesting trends. The adoption of OASIS is driven by the OPC data processing step – where the data volume increase is most felt. The adoption happened gradually and a significant level (>50%) was achieved at the 65nm node. The pre-opc space is less affected by data volume concerns – here design hierarchy is still

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Managing Editor/Graphics Linda DeLano
Advertising Teresa Roles-Meier
BACUS Technical Group Manager Pat Wight

SPIE

P.O. Box 10, Bellingham, WA 98227-0010 USA
Tel: +1 360 676 3290 or +1 888 504 8171
Fax: +1 360 647 1445
SPIE.org
customerservice@spie.org

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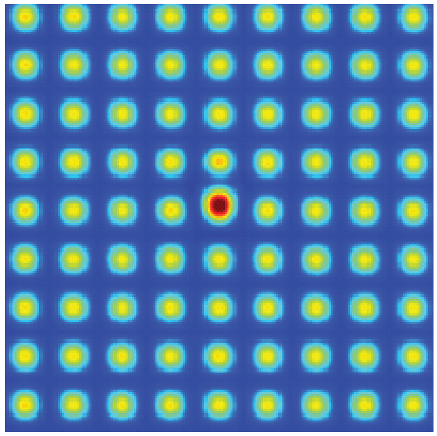


Figure 2. Repeating array of identical contact-holes, suitable for MSA analysis.

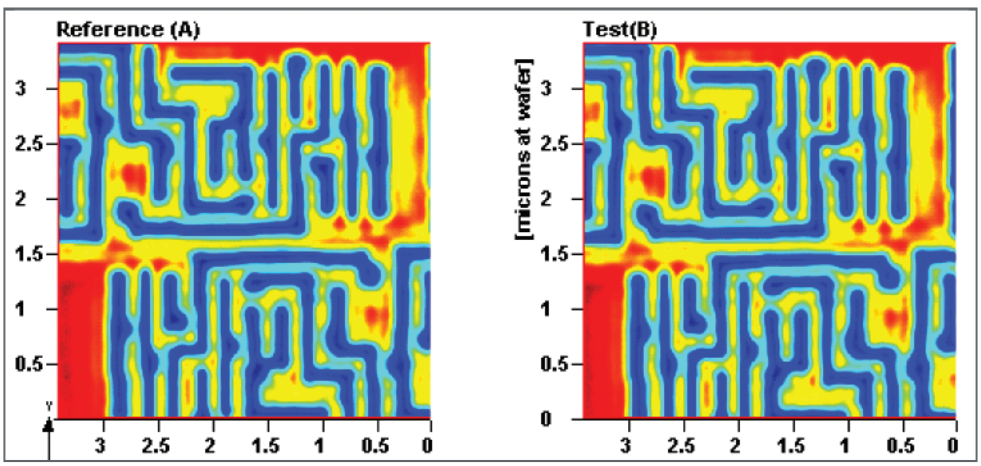


Figure 3. Test and Reference image pair, suitable for Image Compare analysis.

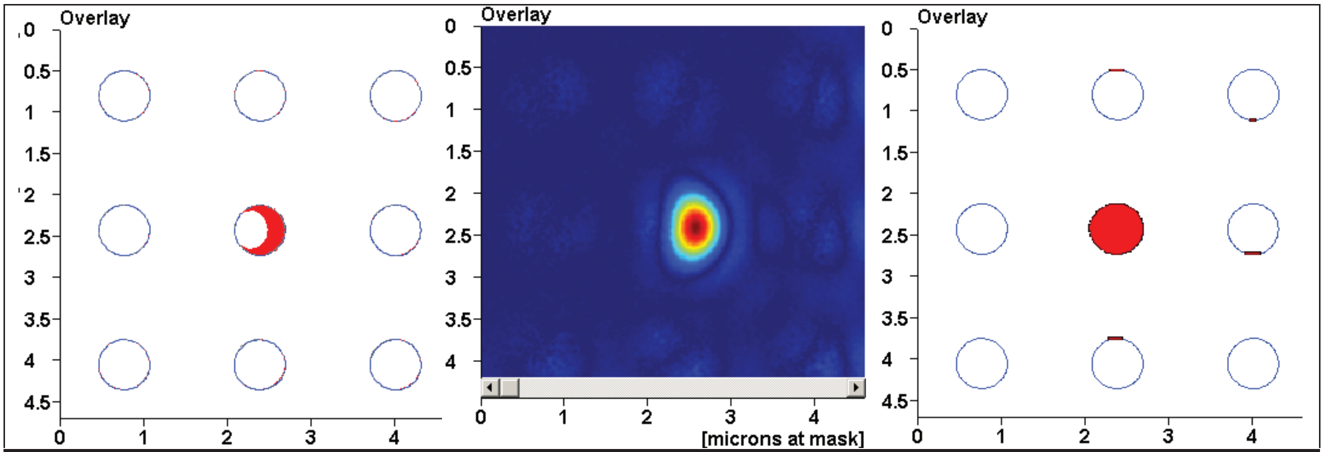
and innovative analysis tools leads to a highly efficient and more reliable result reporting of repair verification analysis.

1. Introduction

The aerial image measurement system (AIMS™) developed by Carl Zeiss more than a decade ago is the industry standard for the verification of defect repairs on photomasks. This was born out of the importance of defect free photomasks in the lithographic process of semiconductor manufacturing. Nearly all repair techniques leave physical evidence of the repair in the defective area of the photomask. Under high magnification, such as when using scanning electron microscopy (SEM), it is evident that a defect has been fixed through the removal or adding of material. A methodology to verify that the defect was fixed and ensure the repair process itself did not create additional defects was needed. In the 1990's, a method of using an emulated aerial image, based on the same lithographic parameters as used in the wafer fab, for repair verification, the AIMS™ (Aerial Imaging Measurement System) was developed.[1]

The AIMS™ methodology provides user adjustable illumination setting as to match the conditions used at the wafer fab. The wavelength of light is the same (248nm or 193nm depending on technology), coherence type is similar, and the incidence to the photomask is the same. On the imaging side, a user adjustable numerical aperture (NA) matches that of the wafer scanner. The main difference is that the photomask pattern is projected on to a CCD instead of a photoresist-coated wafer. This difference requires AIMS™ tools to post-magnify the projected image in order to accommodate resolution requirements with respect to CCD pixel size. On the MSM and AIMS™ fab platforms, this technique provides suitable matching to wafer scanner results. When using high NA, industry consensus is >0.8NA, the polarized components of the diffracted light that form the projected image must be taken into account to ensure correct contrast. With the introduction of the AIMS™45-193i system in 2006 a solution was developed to compensate for the inability of the magnified image to inherently capture so-called vector effects.[2]

As improvements to the hardware of the AIMS™ platform have kept pace with technological improvements to wafer scanners, so have software applications progressed. The MSM platform was more or less a research tool with manual controls and rudimentary operating software. The analysis software provided very basic and manually driven image analysis that reported simple intensity and CD through-focus data. The AIMS™fab platform moved aerial image measurements into the manufacturing realm. The operating software allowed automated acquisition of images and the analysis



Figures 4a-c. left: contour edge difference, center: intensity difference, right: highlighting %CD difference.

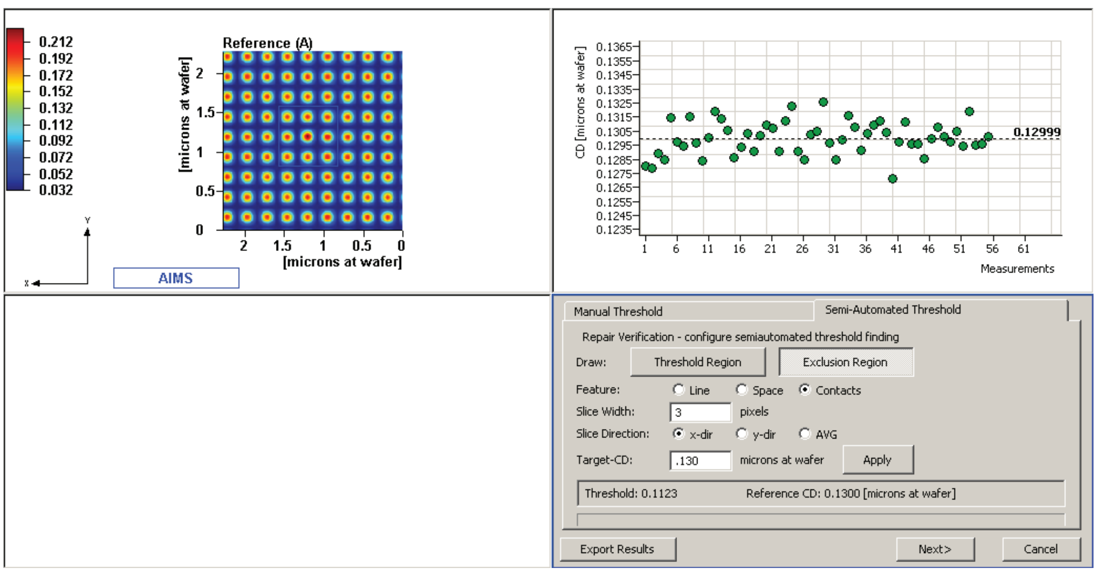


Figure 5. Semi-Automated Threshold Analysis.

software provided dynamic options for interpreting the results.

The AIMS™45-193i takes those improvements to the next level by providing aerial image measurement capability to high volume photomask manufacturers.[3,4] Options such as global alignment using pattern-recognition, improved autofocus algorithms, batching of recipes, and SECS\GEM integration have increased the throughput and utilization rates. The timing of these improvements corresponds to an industry need to qualify more photomasks with an increasing number of sites using aerial image measurements. This is due to advances in reticle enhancement techniques (RET) and the use of phase shift materials[5] that have led to highly complex layouts on the photomask. Furthermore, recent approaches like Computational Lithography and Source Mask Optimization lead to highly complex patterns on the reticle.[6] The ability to easily identify critical features in these types of layouts has been lost. Aerial image measurements are the most effective method to predict the final printed image quality on advanced photomasks of today.

Larger volumes of acquired aerial images leads to a larger amount of time spent analyzing those images. This coupled with an improvement in defect repair technologies, which has made it harder to identify the previous position of a defect, has created the necessity to discuss possible improvements of the AIMS™ analysis capability.

2. Methodology

Users provided feedback that the standard process flow for analyzing a typical defect repair was too manual in nature. This situation gave rise to user errors and inconsistent analysis procedures between users, generating additional monetary and throughput costs. The amount of time analysis took was also an issue because it leads to an extended period before the photomask could be moved onto the next manufacturing step. More advanced analysis techniques became mandatory to engineers that want to garner more information about a specific repair or defect.

From these requirements, a framework was created that serves as the basis of possible functions of new software applications.

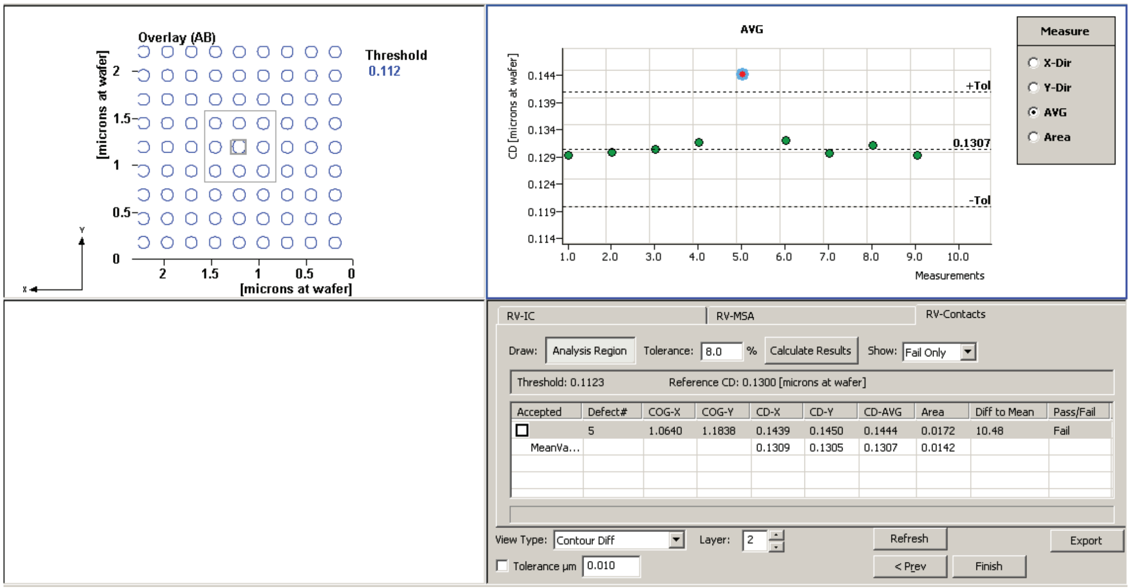


Figure 6. Contact-Hole Analysis.

The application would need to follow a structured analysis process as to limit user errors. The software application should be integrated into the operational software so time is not wasted moving between interfaces when analysis on the AIMS™ tool is required. Also, new and innovated analysis tools should be developed that allow thorough result reporting on advanced photomasks. The way results are reported should also be customizable by the user to fit manufacturing process needs. All of these tasks should be automated as much as possible to further reduce user errors and increase throughput and reliability of the data.

Another important feature of the software is its capability to work as off-line analysis software. This has the advantage that the images from several AIMS™ tools at different sites can be analyzed by using an off-line or network license of the analysis software. Additionally, images from different tool generations can be analyzed with one analysis software (see Figure-1).

The architecture of a possible application discussed here should be divided into three main compnents: Multi-Slice Analysis (MSA), Image Compare (IC), and Contact Hole analysis.

2.1 Multi-Slice Analysis

The MSA component is intended for aerial images that consist of a repeating pattern within the acquisition field (see Figure-2). When this component is initialized, the user has the ability to define measurement slices over multiple reference features. The user also defines a measurement slice over a feature in the area that the defect resides or the area fixed by repair. The setup of the slices is automatically recorded in a table within the plug-in interface. The table lists the position within the image, the length, the width, and angle of the measurement slice. There is also an option to automatically copy the length, width, and angle to remaining slices.

After the measurement slices are defined, the user switches the table type from the setup style to an analysis style. The user then defines a common reference intensity threshold or an associated target reference CD. If a target reference CD is used, the software automatically calculates the intensity threshold that correlates to that CD. The result values from each measurement slice are updated in real-time. The setup of the analysis table style is user-configurable and can output a number of values including CD, Intensity, Normalized Image Log Slope (NILS), and Depth of Focus (DOF) for all the measurement slices. Analytics can also be defined to automatically calculate the absolute delta or percent difference between the test slice and an average of the reference slices.

2.2 Image Compare Analysis

Another component of the application is Image Compare. The IC process is intended for aerial images that are in defect/reference or repair/reference pairs (see Figure-3). Typically, this is possible with multiple-die photomask layouts where each die is identical. The IC interface steps the user through the process of defining an intensity threshold using the reference image (with the ability to use a target CD instead), correlates the images so that they are perfectly overlaid, and provides various option to identify out-of-spec areas of the defect or repair image.

The IC interface introduces new techniques to correlate and overlay the image pairs. Users have the ability to define a correlation region of interest. Only the section of image inside the region of interest is used to determine the correlation offset. This allows the user to exclude the defect area which would lower the accuracy of the correlation algorithm. An error value for the correlation result is displayed to aid the user's determination of the effectiveness of the correlation setup.

The user has four options to determine out-of-spec areas of the defect or repair image inside the IC interface. The first option is the ability to display a plot of the overlaid contours with edge differences highlighted (see Figure-4a). If the defect or repair image contour is bigger then the reference image contour, the area between the contour edges is highlighted gray. If the difference is defect or repair image contour is smaller, the difference is highlighted red. To assist the user in finding only differences that are significant, a tolerance value is available. The user can input a tolerance that turns-off the highlighting if the difference between the contour edges is below the defined tolerance.

Another option is the ability to display a plot of the intensity differences between the image pairs (see Figure-4b). The reference image is subtracted from the defect/repair image and the result is displayed. If the user's result criterion includes intensity differences, then this would allow the user to easily find those types of

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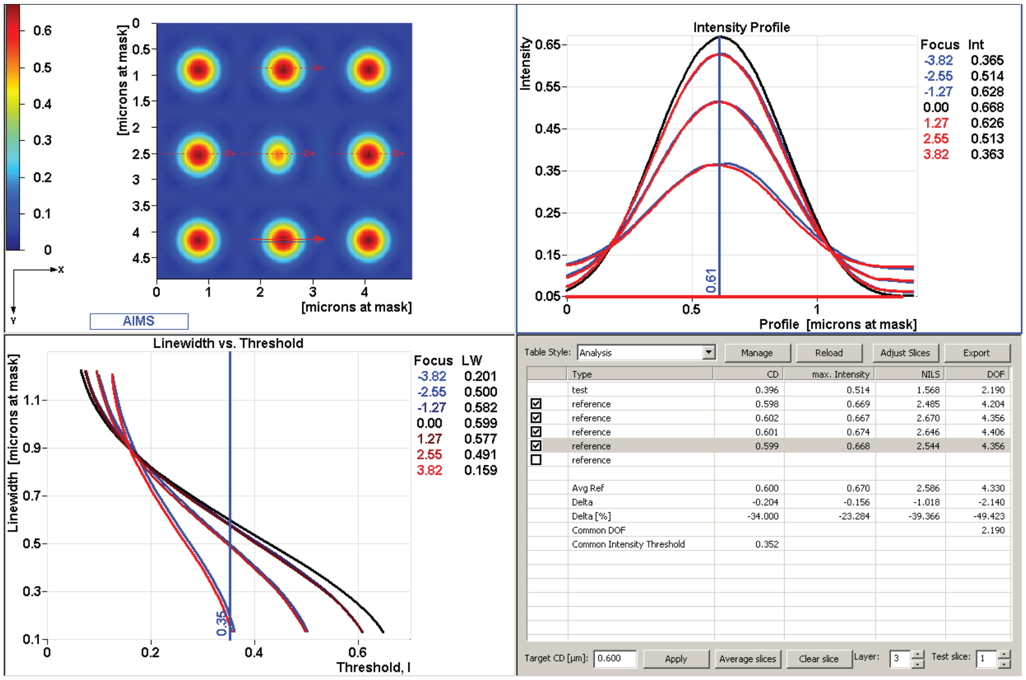

Figure 7. Multi-Slice Analysis result table of undersized contact-hole.

errors in the images.

If the user is interested in finding deviations as a percent difference between the defect/repair CD compared to the reference CD of a feature, the Defect Highlighting option provides this data (see Figure-4c). The CD percent difference is calculated at every position in the image contour. The user chooses which measurement direction and feature type, line or space, should be evaluated. The software automatically highlights all features that do not meet a user defined specification limit.

With these analysis options, the user is still required to manually draw measurement slices over desired highlighted regions of the plots. The slices can be added to the analysis result table, storing the slice positions into memory for easy switching between slices.

The fourth and final analysis option is a fully automatic function that defines a measurement slice over the feature with the maximum contour edge difference. The user only is required to press a single button inside the interface and the measurement slice is automatically defined after a short calculation is executed. This automatic slice can also be added to the analysis result table.

For each measurement slice, the Intensity Profile plot shows the intensity data for each image overlaid and now also shows the absolute difference and calculated percent difference at the position of a user defined vertical marker in the plot. The Linewidth versus Threshold plot shows the through-focus CD values for each image at the pre-defined reference threshold and a chart of the through-focus absolute CD difference and percent difference at the CD threshold defined at the beginning of the analysis process. The result values from any of the windows can be exported by the user in a text file.

2.3 Contact-Hole Analysis

The newest improvement to the software application is an automated process for analyzing contact holes. Contact-hole analysis is difficult when performed manually because of the nature of small squares being imaged lithographically. The contact holes usually form circular shapes in the wafer plane. Round shapes are sensitive to placement of the measurement position across the contour.

The Contact Hole analysis process is applied to two steps within the application. The first step an automated process can be used is the intensity threshold hold determination step. Here the user can chose the Semi-Automated Threshold option and is presented with several options. The first option is the ability to draw an exclusion area on the image plot that will disregard analysis of features inside this area. Normally the user would draw the exclusion area around where the defect or repair is made. The user can also draw a threshold area on the image plot so that any features outside of this area will be disregarded in the analysis. Both the threshold and exclusion areas can be drawn together on a single image. Options for feature type (line, space, or contact-hole), slice width, and slice direction are available to the user. For contact-holes, a user would typically use a value of 1-3 pixels.

The final option the user must make before the automated analysis begins is to enter the target CD value for the features inside the threshold analysis area. Once the user presses 'Apply' for the target CD, the software automatically analyzes every feature in the threshold region, minus any features inside an exclusion area, and calculates the corresponding threshold value that achieves an average value for the target CD (see Figure-5). The results of the analysis can be seen in the Measurement Plot.

Analysis of the defect/repair is the second step of the application that the automated contact-hole analysis process is applied. When the user chooses the Contact-Hole analysis function in the application, the software automatically analyzes all contact-holes in the exclusion area defined in the threshold determination step (Figure-6). If an exclusion area was not defined, all contact-holes in the image are analyzed. In the measurement plot the CD values for each contact-hole are plotted with lines drawn showing the mean CD value and the positive and negative tolerance values. The user can enter a percent tolerance in the analysis window. Any measurement value that falls outside the tolerance range is automatically defined as a defect and highlighted red in the measurement plot. The user can also quickly change the analysis type

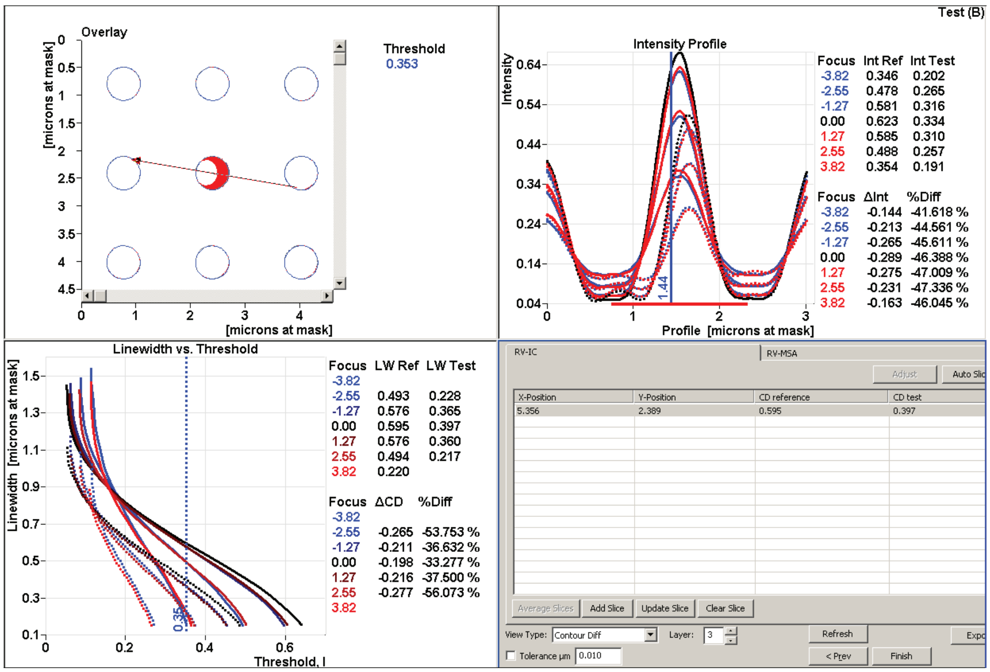

Figure 8. Image Compare analysis window showing automatically placed measurement slice.

between an X-direction, Y-direction, an average of X and Y, and an area measurement using the radio buttons next to the measurement plot. The result table inside the analysis window includes all of the measurement data as wells as simple statistics. Making it easier for the user to identify the feature being analyzed, if any data point is clicked-on, either in the measurement plot, result table, or the image plot, the corresponding data in each those plots is highlighted. The results from the analysis can be exported into a text file for further user analysis. As with the other analysis tools in this application, the user can also analyze the through-focus behavior of the contactholes by changing the focus layer value in the analysis window. The measurement results are updated in real-time.

3. Examples

3.1 MSA Contact-hole example

The first example is using a contact-hole array with an undersized contact-hole. This type of pattern lends itself to be analyzed using the MSA component. After opening the AIMS™ image and the MSA component is initialized from a toolbar icon, the user is presented with a four-pane window. The upper-left pane displays the image plot, the upperright pane displays the Intensity Profile plot, the lower-left pane displays the Linewidth vs. Threshold plot, and the lower-right pane is the MSA working window. Initially the measurement setup styled table is displayed. The user can then draw a measurement slice over the test region of the image, in this case the undersized contact-hole. This example will use horizontal slices, but the user is free to choose any orientation. The first reference slice row in the table is selected and then the corresponding slice can be drawn in the image plot. Additional reference slices can be added by repeating this process. In this example, four reference slices are added, one to the left, to the top, to the right, and to the bottom of the test region.

The user then switches the table of the MSA working window to the analysis styled table (see Figure-7). Using the table as a reference, the slice positions can be moved to the center of the contact-holes by looking for the maximum intensity value for that slice. Once this is completed, a target CD value can be entered into the entry box, and the software automatically calculates the threshold. In this example, a target CD value of 0.600um was entered and a threshold of 0.352 was found. The analysis table shows an absolute CD difference of -0.204um that corresponds to a - 34.0% difference.

2.1. IC Contact-hole example

The same contact-hole array can be analyzed using the Image Compare functionality if a reference image should also be available. There are two ways to initiate the IC interface; the easiest by selecting both the defect and reference image simultaneously in the MSM Browser window, right clicking the mouse on the screen, and selecting "Compare both selected images" from the option list that appears. When references are acquired in the AIMS™ measurement wizard, the images are tagged as being a reference in the save file, allowing the IC interface to distinguish the pair automatically.

The user is presented with a four-pane window. Different to the MSA component, the upper-left pane is now the reference image plot. The lower-right pane is a table to define reference measurement slices. A slice over a reference feature is drawn in the image plot, then the target CD is entered or a known intensity threshold can be input, after which this slice is added to the table. At least one reference measurement must be made, and if multiple references are used, the average intensity threshold is calculation. This value is used throughout the rest of the analysis. The user can then press the "Next" button.

The window changes by showing a new interface used to setup the correlation of the image pair. Both the reference image and defect image is shown at the top of the window and the user options are listed at the bottom. Once the correlation is setup, the "Execute" button starts the calculation to determine the image offsets, which are then applied. Pressing the "Next" button again changes the window one final time.

A four-pane analysis window is displayed to the user as shown in Figure-8. The upper-left pane content is determined by the option the user selects in the lower-right pane. Choosing the Contour-Diff view type highlights the under-sized contact-hole quite prominently. Pressing the "Auto Slice" button in the lower-right pane automatically draws a slice across the largest difference between the reference and defect contour edges. Pressing the "Add Slice" button saves this slice position to the result table. An intensity difference of nearly -90% and a CD difference of over 33% is found. The results could then be exported to finish a basic analysis process. Not only does this function help identify out-of-spec features, but this analysis would be nearly impossible to perform manually with the traditional AIMS™ software.

4. Conclusion

A novel way for the semi-automated analysis of AIMS™ images has been shown. Solutions have been provided to requirements users have dealt with during the progression of the aerial image measurement system from a research tool to a production tool relied upon for most advanced photomasks. Throughput of the analysis process has been improved along with an increase in result stability and reliability due to the reduction in user decisions. Contact-hole analysis has been greatly streamlined and simplified with a semi-automated threshold determination process and a fully automated defect/repair analysis process. The structured process discussed is providing new and flexible options for users to analyze various types of photomask layouts while being confident in the results.

5. Acknowledgments

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EDITORIAL *(continued from page 3)*

largely intact helping to keep the data volumes at bay. The adoption in this area is lagging by about one technology node – according to our data achieving >50% adoption at the 45nm node. This could also largely be an expression of internal data format standardization after the CAD teams gained confidence in the new format.

The adoption of the OASIS standard at mask manufacturing stage – represented here by the fracture step is much slower. Significant adoption is reported at some customers at the 32nm node – three nodes after the adoption at the OPC stage.

A number of factors need to be taken in to consideration to explain these results – technical, economical and environmental factors affect the adoption. The introduction of OASIS into semiconductor manufacturing was led by the area with the largest gain – the OPC step. The early adoption happened where the interfaces of data hand-off are controlled internally and qualification does not require cross-company coordination.

The adoption was also impacted by the fact that the cost for disc space as well as for data transmission bandwidth is falling over time. These peripheral trends can not completely offset the impact of increased data volumes but have reduced the difficulties in data handling between the integrated device manufacturers and the mask manufacturers.

Using OASIS.MASK data in the mask manufacturing requires for the critical equipment – mask writing, mask inspection and mask metrology - to support the new format. This infrastructure is still under development. Only recently the first equipment company formally announced support for the P44 standard format. The development lead times and update cycles for hardware are longer than for software and technology development for the mask process needs to be frozen earlier than for the wafer process. This can explain the off-set in the adoption curve.

So – is the data volume explosion under control? The trend of increasing data volumes continues and the extension of optical lithography to the 22nm node and beyond will add complexity in form of new resolution enhancement techniques. By establishing new data standards – OASIS (P39) and OASIS.MASK (P44) the industry has put a framework in place to mitigate the impact. The current state of deployment proves the viability and robustness of the technology. The mask manufacturers need to work with their equipment suppliers and EDA tool vendors to complete the infrastructure for OASIS.MASK and to enable the full benefit of unified, standardized and compact data formats in the data preparation flow. Together with continuous progress in the computer, storage and networking infrastructure this will enable the industry to handle the data volume challenges ahead.

For a more detailed analysis and background information on this topic please refer to the publication "Deployment of OASIS in the Semiconductor Industry – Status, Dependencies and Outlook" by Joseph C. Davis et. al. presented at EMLC 2010.

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Industry Briefs

The Other NGL that is also not Quite Ready...

Much has been reported about the progress of lithography's final frontier—EUV. Yet another NGL option also keeps a steady presence, and at least one of the largest foundries keeps investing in ML2 as an option to increase prototyping activities, and raise the number of design starts. TSMC's Burn Lin has been advocating EBDW over EUV for a couple of years now.

Semiconductor International reports that "At a panel discussion at the DATE (Design, Automation and Test in Europe) conference last month in Dresden, representatives from GlobalFoundries and TSMC said they are working to develop closer cooperation with EDA and IP vendors. The comments were part of a panel discussion on the "Impacts of Continuous Scaling".

Design and manufacturing costs are increasing sharply, reducing the number of leading-edge manufacturing companies from 22 at the 65 nm node to a ~dozen manufacturers at the 22 nm generation.

While fewer companies may have the resources to tackle leading-edge design and manufacturing, the rewards may be richer than ever as smart phones and other systems reach extremely high volumes

Design starts are shrinking at a faster pace, going from 1012 65 nm SoC design starts to 562 at the 45/40 nm generation, 244 32/28 nm tapeouts, and only 156 22 nm design starts

To design a leading-edge SoC now takes longer than the product life, as debug and verification take longer and as design teams struggle with leakage issues.

Costs are going up—it costs x4 as much to develop a 32/28 nm process compared to the 130 nm process. The payback at the 22 nm node will come largely from the huge sales of 4G/LTE generation smart phones. Computing, some consumer SoCs, and certain automotive applications also will drive 22 nm volumes.

Litho awareness has to start at the IP level. DFM at the IP cell is a critical piece to improving yields."

In related news, Globalfoundries, Jeol, KLA-Tencor, NuFlare Technology, Petersen Advanced Lithography and Samsung Electronics have joined the eBeam Initiative.

The eBeam Initiative was launched in Feb 2009. The effort initially had 20 companies including EDA vendors, ASIC suppliers, makers of e-beam tools, photomask suppliers and others. The group is lead by Direct2Silicon Inc. (D2S) and guided by a formal steering committee that includes Advantest, CEA/Leti, e-Shuttle, Fujitsu and Vistec.

The semiconductor industry has long been interested in applications of direct-write e-beam technology, which removes costly photomask sets from the equation and enables patterning of circuitry directly on a wafer.

Yet EE Times reports that "Direct-write litho still facing uphill climb".

"Chip makers continue to look longingly at direct-write lithography, which could potentially reduce or remove the need for photomasks, which are getting more expensive—according to data presented by [Kurt] Ronse [IMEC], the cost of a mask set doubles at each new technology node. Analysts and industry executives label the rising cost of masks as the chief culprit behind an ominous trend: declining ASIC starts.

But technical issues—including unacceptably slow wafer writing times—have to date kept e-beam direct write lithography from moving closer to commercial production.

Providing an overview of the latest direct-write development work being done by three European-based companies, Ronse said: "It's a very interesting technology, and I have a lot of respect for the people developing it.But in terms of overlay and throughput I think there is a long way to go."

That there remain so many distinct direct-write development efforts is testament to the technology's potential market opportunity. Anyone who can bring to production an e-beam direct-write lithography technology stands to cash in, particularly in light of next-generation extreme ultraviolet (EUV) lithography being pushed out further to target production at the 16-nm node. This means lithographers will push 193-nm immersion lithography down to at least 22-nm, but there is widespread consensus that that technology is not extendible to the 11-nm node.

At this year's Monterey Symposium BACUS is dedicating its Special Session entirely to Maskless Lithography. Please come and join us.

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)
- Complimentary Subscription *Semiconductor International* magazine
- Eligibility to hold office on BACUS Steering Committee

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Corporate Membership Benefits include:

- One Voting Member in the SPIE General Membership
- Subscription to BACUS News (monthly)
- One online SPIE Journal Subscription
- Listed as a Corporate Member in the BACUS Monthly Newsletter

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Calendar

2010

SPIE Photomask Technology

13-17 September
Monterey Marriott and
Monterey Conference Center
Monterey, California, USA
spie.org/pm

*To better accommodate the needs of the Photomask community, we are extending the abstract submission deadline to **5 April 2010**.*

Late submissions will be considered by Chairs.

SPIE Lithography Asia - Korea

13–15 October
Hyatt Regency Incheon
Incheon, South Korea
http://spie.org/la/

Photomask Japan

13-15 April
Yokohama, Japan
http://www.photomask-japan.org/

2011

SPIE Advanced Lithography

27 February-4 March
San Jose Marriott and
San Jose Convention Center
San Jose, California, USA

*Abstract submissions to open in **May 2010**.*

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

SPIE is an international society advancing light-based technologies.

SPIE

International Headquarters
P.O. Box 10, Bellingham, WA 98227-0010 USA
Tel: +1 888 504 8171 or +1 360 676 3290
Fax: +1 360 647 1445
customerservice@spie.org • SPIE.org

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

SPIE Europe

2 Alexandra Gate, Ffordd Pengam, Cardiff,
CF24 2SA, UK
Tel: +44 29 20 89 4747
Fax: +44 29 20 89 4750
spieeurope@spieeurope.org • www.spieeurope.org