SYNOPSYS®

DATASHEET

Synopsys S-Metro

Metrology Data Analysis

Automated assessment of numerical and image-based metrology data for photomask qualification, modeling data preparation, and process characterization

Synopsys S-Metro is a comprehensive and powerful tool for automated metrology data import, image processing, contour extraction, visualization, and analysis. Lithography process engineers use it to assess and visualize critical dimension (CD) metrology data. S-Metro determines key measures that characterize the performance of the lithographic process, such as process window size or exposure latitude. Multiple datasets are analyzed individually, and the overlapping (or common) process window is reported.

Moreover, Synopsys S-Metro supports the review and cleaning of metrology data such as scanning electron microscope (SEM) images within layout context by enabling the visualization of results within the layout viewer and editor tools found in Synopsys, Silicon WorkBench, and Synopsys Proteus™ WorkBench solutions.

Metrology images from any source, whether photomask or wafer, can be processed and analyzed in Synopsys S-Metro as well. Alike images can be stacked and averaged to improve contrast. Contours can be extracted from individual images and averaged, too. Synopsys S Metro provides a large set of options to analyze contours with respect to edge placement error, position, CD, or enclosed area (figure 1).

Synopsys S-Metro automatically processes SEM image and CD data in a consistent and transparent manner, independent on metrology equipment type or vendor. Once collected, image data can be analyzed offline, saving valuable equipment tool time. The infrastructure of Synopsys S-Metro is capable of handling tens of thousands of data points, including images. Distributed processing can be used to accelerate contour extraction and analysis.

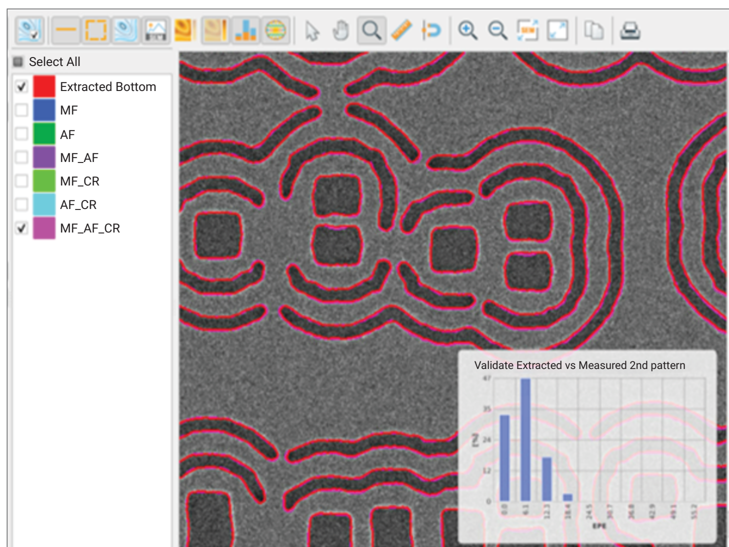

Figure 1: Contour extraction from a mask SEM images including curvilinear assist features; a histogram shows the analysis of the edge placement error for selected 2D pattern

Applications

Synopsys S-Metro is a general-purpose tool that can analyze any multidimensional matrix of numerical observations as a function of two parameters. These observations (input data) are usually CDs of a series of features—measured or simulated—as a function of exposure dose and defocus (deviation from a nominal focus position). Other typical indicators can be sidewall angles of resist profiles or resist thickness loss. Figure 2 shows the graphical user interface. A hierarchical tree of all imported datasets allows selecting, sorting, grouping, or filtering of data. Various chart types can be used to visualize the input data as well as the analysis results.

Based on input metrology data, Synopsys S-Metro determines process performance indicators, such as process latitude or process window size. Rectangular or elliptical fits facilitate the comparison of process windows obtained under different process conditions and allow to report and document of lithography process performance. If multiple datasets are loaded, the application can determine the overlapping process window for a selected series of data, as shown in Figure 2:

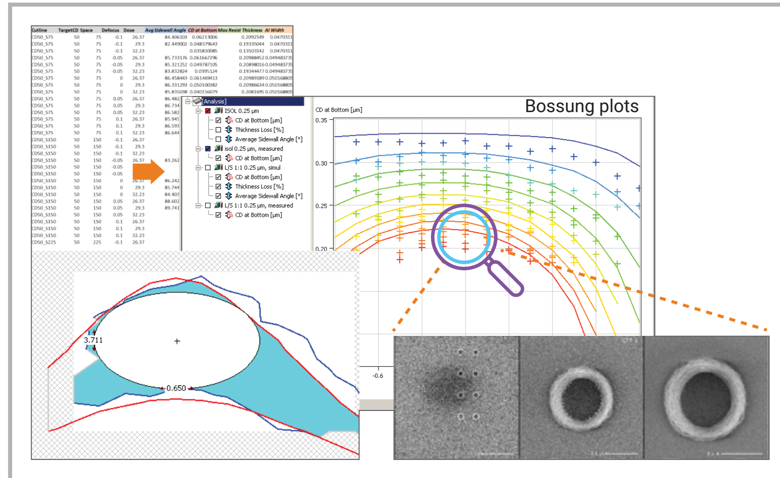

Figure 2: Focus-exposure matrix visualization including modeling, and associated SEM images for a selected data point, and overlapping process window results

The visualization and statistical analysis of numerical metrology data is a key application within Synopsys S-Metro. Dedicated features for data-smoothing are useful to reduce data volume, and remove measurement noise. Additional functionality is available to eliminate invalid data or to apply weights to individual data points, supporting the data preparation for subsequent tasks such as the calibration of rigorous or compact resist models.

SEM metrology data in various formats imported into Synopsys S-Metro. The data structure of Hitachi High Tech and Applied Material is directly supported. Associated SEM images for each measurement point can be processed as well. Moreover, Synopsys S-Metro provides a high degree of flexibility in loading all data of a specific directory and assists in categorizing, sorting, and filtering data.

Contour extraction and analysis

A core functionality of Synopsys S-Metro is the fast and robust extraction of contours from SEM images, with or without having access to the corresponding layout information to snap to. Multiple algorithms are available, allowing the user to transparently tune extraction parameters, depending on image quality and contrast. Any image from any source can be processed. Synopsys S-Metro supports the user in finding optimum extraction parameters, including matching extracted contours to given CD measurement results.

In case GDS or OASIS layout information is available, Synopsys S-Metro can utilize the information to align images to the layout by adjusting translation, rotation, and magnification of the data. All layout operations are supported through layout tools such as Synopsys Silicon WorkBench or Synopsys Proteus WorkBench.

The contour extraction for individual images can be parallelized, allowing the processing of up to tens of thousands of images within a short time. The infrastructure of Synopsys S-Metro has been optimized for high data volume, enabling efficient filtering and sorting on very large data sets.

Synopsys S-Metro supports various averaging techniques to improve image contrast for contour quality. If multiple, redundant images are available, averaging can be done on image or contour level, which significantly improves contour quality if data is noisy.

Subsequently, contour data can be analyzed with respect to edge placement error, taking the design target or another contour (e.g., model contour) as a reference. Extracted contours can be exported as GDS or OASIS files, and the Edge Placement Error (EPE) analysis results are reported as a histogram or heat map, amongst other options.

In the case of mask metrology data, extracted contours can be fed into rigorous simulation tools such as Synopsys S-Litho™ to predict the outcome of a lithography process, based on realistic mask data. The analysis and extraction of corner rounding parameters deliver valuable information on the mask manufacturing process, which can be used to improve the overall model quality when being used within the calibration of rigorous or compact litho models.

Synopsys S-Metro is also capable of investigating uniformity and variability amongst nominally identical features within a single field of view (FOV), for instance for an array of contact holes (Figure 3). After extracting the contours for all features within an area of interest, the result is automatically decomposed into isolated polygons which are then averaged. Various result parameters can be analyzed, including the placement errors and variability, or the enclosed area by each contact hole contour. Figure 3b shows the distribution of the pitch-X data for all contact holes within the FOV, figure 3c shows a distribution of the contact hole area for all features.

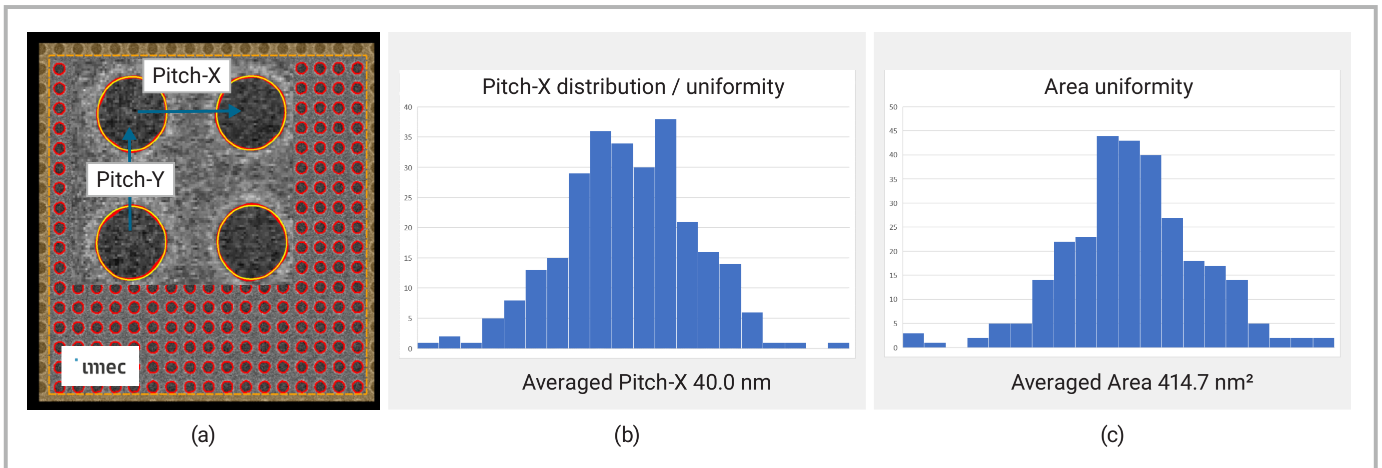

Figure 3: (a) intra-image averaging of nominally identical features within a field-of-view, and analysis of variability

Contours of more complex 2D features printed on wafers are becoming a topic of increasing interest when it comes to the calibration of models representing a given lithography resist process. A few images can already cover a large portion of the design space, enabling the building of resist models based on very few data points. Data collection, tool, and engineering time are significantly reduced, while model quality and predictive power improve.

Complex tasks or the integration into flows can be easily realized through automation and scripting, as all Synopsys S-Metro functionality can be accessed through an API.

For more information about the Synopsys S-Metro and the Synopsys S-Litho product family and other Synopsys products, support services, or training, go to synopsys.com/silicon.html

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