Computational Scanning Electron Microscopy

Leili Baghaei Rad and R. Fabian Pease
Department of Electrical Engineering, Stanford University, Stanford, California 94305

Scanning electron microscopy (SEM) is capable of providing images with excellent resolution and is being employed in a wide range of applications such as photomask inspection, nanotube analysis, and biology studies. Unfortunately, it is generally much more difficult to interpret SEM images than optical images. Hence we are developing an algorithm for extracting 3-D topography from SEM images, which we call Computational Scanning Electron Microscopy (CSEM).

We initially focused on the topography extraction of binary patterns, such as photomasks. We proposed the long-range pattern complexity analysis approach which proved to be quite successful for binary patterns but is limited in use for more complex three-dimensional surfaces. In figure 1 we employ image segmentation technique and the physical model of Secondary Electrons (SE) to determine the edge slope thus the physical edge locations. This method yields stronger edge signal for certain edge areas than edge detecting method based on pure image processing techniques, and combining them yields a better hybrid algorithm

We have now turned to topography reconstruction using multiple SEM images based on applying physical models of the SEM imaging process. We assume that an observed SEM image is a two-dimensional representation of the three dimensional topography of the material. The mapping to the SEM image is a function of not only the three-dimensional topography but also of the material characteristics and the configuration of the SEM apparatus. Thus, for the ith SEM apparatus configuration, we have the following

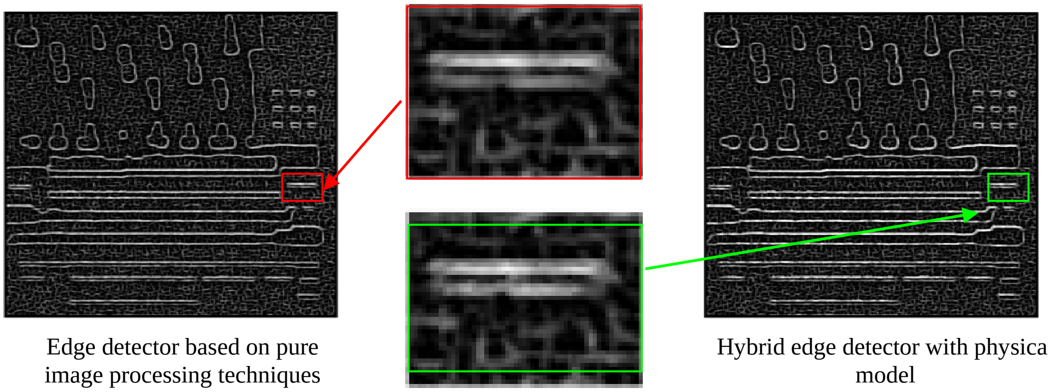
$$\text{SEM\_image}(i) = F(\text{topography}, M, C(i))$$

Where F is a function that is determined by electron beam physics, M is the material characteristics and C is the SEM configuration. A possible method of determining the resulting image is by Monte Carlo simulation of the statistical behavior of a large number of electrons. However, this is computationally expensive due the large number of incident and generated electrons that must be tracked.

In [1] a library of pre-computed results for edge profiles is developed and used to measure line widths. We further this work by developing a more comprehensive library of edges, corners and surfaces. Each library element will not only contain the yield at the sampled points but also the direction and energies of the electrons. A complex asymmetric surface is decomposed into simpler structures and an expected SEM image is constructed from the library elements. The additional information present in each library element will be used to model the effect each component has on surrounding components.

Keywords: 3D topography reconstruction, library based model, Monte Carlo

References: [Villarrubia01] Villarrubia, J. S., A. E. Vladár, et al. (2004). “Dimensional Metrology of Resist Lines using a SEM Model-Based Library Approach.” Metrology, Inspection, and Process Control for Microlithography XVIII Proceedings of SPIE Vol 5375: 199-209.



Edge detector based on pure image processing techniques

Hybrid edge detector with physical model

Figure 1. Demonstration of the edge extraction with physical model.