Understanding the Relationship Between True and Measured Resist Feature CD and LER using a Detailed SEM Simulator

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Line edge roughness (LER) is one of the top concerns for current and future high resolution photoresist patterning. Critical dimension scanning electron microscope (CD-SEM) tools have been and will likely continue to be one of the most commonly used metrology tools for the determination of both critical dimension (CD) and LER in patterned resists. Unfortunately, CD-SEM tools provide a two-dimensional representation of a three-dimensional (3-D) structure. Although the use of such CD-SEM tools is pervasive in semiconductor manufacturing and research, the majority of users do not in fact know how accurately the SEM represents the actual roughness of the true 3-D resist structure, i.e. in terms of the amplitude and periodicity of the roughness. In addition to experimental resist pattern characterization, there have also been multiple groups, including our own, who have investigated the effect of changing parameters such as resist formulation, patterning conditions, etc. on the final patterned resist roughness through the use of highly detailed mesoscale resist and lithographic process models. These models give a three dimensional roughness profile for the simulated resist feature, but thus far it has not yet been made clear how to faithfully relate the results from such models to those obtained experimentally from a CD-SEM. To address both of these issues, we have recently developed a detailed SEM simulation tool to examine the relationship between CD and LER as determined from SEM and true three-dimensional resist feature CD and roughness. This new SEM simulation tool and several interesting insights gained from the use of this tool will be discussed in this paper.

This new SEM simulation tool is one of the most rigorous such tools that we are aware of at this time. Both discrete elastic and inelastic scattering events are considered, and as a result the generation of secondary electrons that are crucial to the SEM imaging process can be simulated with high fidelity. Inelastic scattering is determined using a combination of the complex dielectric function for the material in which the electron is propagating and Penn's algorithm, while elastic scattering is determined using the partial wave expansion of the Mott cross section for the material. Figure 1 shows the trajectories of 200 primary electron (10 keV) trajectories in bulk PMMA as obtained from the model. Figure 2 shows a comparison of the top-down view of a three-dimensional resist line edge generated from a detailed mesoscale resist model with the simulated SEM image of the same line edge using our new SEM modeling tool. This paper will further discuss the SEM model and the physical assumptions made. It has been found that the choice of threshold for defining the line edge during the analysis of SEM line scan data can have a large effect on the accuracy of CD and LER measurements. As a result, a new optimal SEM data analysis algorithm has been discovered that provides superior matching of measured CD and LER to the "true" pattern CD and LER. This result, along with the relationship between the true resist roughness and that obtained by SEM under various imaging and data analysis conditions will be discussed.

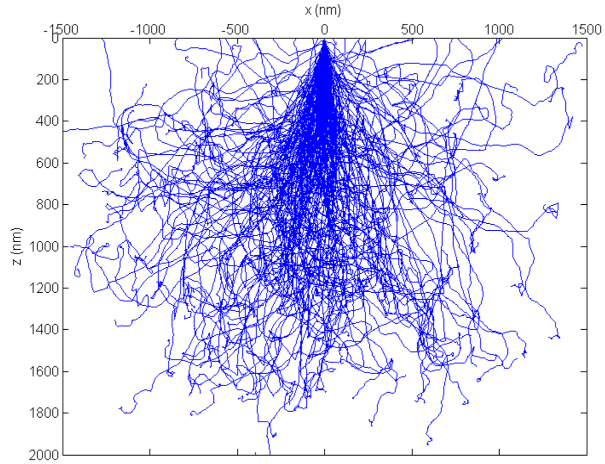

Figure 1. Example of 200 primary electron (10 keV) trajectories in bulk PMMA.

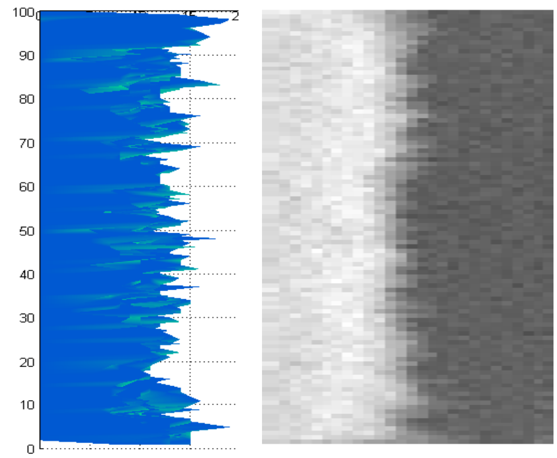

Figure 2. Comparison of top-down view of a three-dimensional resist profile and the corresponding SEM as obtained from the simulation.