Incorporation of EELS Data for Monte Carlo Simulation of Secondary Electrons in EUV and Electron-Beam Lithography

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When a photoresist is exposed to EUV photons or 100 eV to 100 KeV electrons, molecules in the resist are ionized thereby creating secondary electrons. The mechanisms by which these electrons interact with the molecules in the resist play critical roles in every aspect of EUV and e-beam lithography and are the subject of active research through simulation and experimentation. We have studied multiple aspects of such interactions, including photoacid generator cross sections,[2] charging effects in EUV[3] and thickness loss studies.[4] Recent work by Manfrinato et al.[5] has shown the importance of measuring interactions between electrons and resist by means of electron energy loss spectroscopy (EELS).

Most Monte Carlo simulation programs use models that are less valid in the sub-20 eV electron energy regime, due to the difficulty in categorizing all possible energy loss interactions at those energies. One approach would be to carry out a full first principles calculation of a commercial resist, but this would be cumbersome and limited to a full knowledge of resist composition. Given the various types of commercial resists, such an effort would be laborious at best.

In this paper, we will describe a method for incorporating experimental EELS data into LESiS (Low energy Electron Scattering in Solids), a Monte Carlo code, to simulate energy losses in resists for polymethylmethacrylate (PMMA) (Figure 1) and some open-source resists. In this work, we show simulated energy loss spectra for PMMA using LESiS configured with a jellium plasmon model and Gryzinski ionization cross sections, supplemented with extrapolated low energy stopping power from the literature, and compare it to experimental EELS data. To address the discrepancy between the two, we calculate energy loss cross sections from experimental resist EELS data to incorporate these mechanisms in Monte Carlo code by replacing the plasmon and low energy stopping power mechanisms. With this addition, we can perform accurate simulations of the scattering range of EUV secondary electrons down to sub-20 eV energies. We will show results for PMMA and open source resists.

References:

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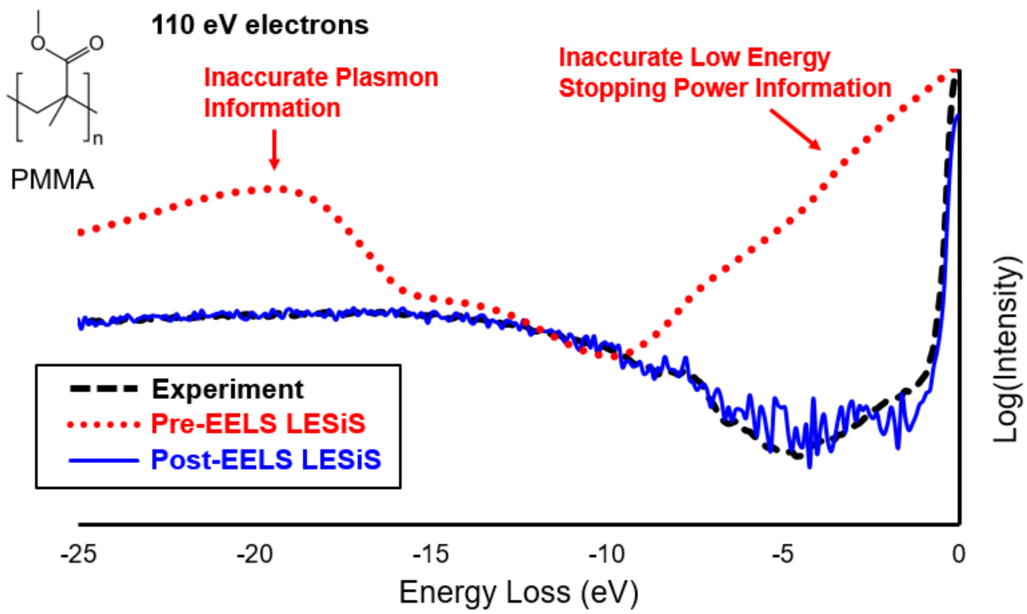

Figure 1. Modeling improvement by inclusion of EELS data to the Monte Carlo program LESiS. Experimental EELS data and Pre-EELS LESiS simulation show poor agreement. Post-EELS LESiS simulation shows better agreement