

Model Sensitivity Studies in Low Energy Electron-Matter Interaction Simulations

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To reliably interpret scanning electron microscope (SEM) images, accurate knowledge is needed of the interaction of electrons with matter. Our group has previously developed an open-source Monte Carlo simulation tool, Nebula [1], intended to simulate SEM images. The tool contains the best possible physics models to describe electron scattering in materials, such as the Penn model for inelastic scattering, Mott cross sections for high energy elastic scattering (> 200 eV), electron-acoustic phonon scattering for low energies (< 100 eV), and a quantum mechanical boundary crossing model. However, several assumptions underlying these models become increasingly uncertain below 200 eV, and simulations for gold show discrepancies with experimental data (Figure 1, transition 100 eV curves).

To gain insight into the breakdown of the model assumptions and where these need to be improved, we have performed a sensitivity study by varying simulator inputs and studying their effect on observables such as electron emission yield, emission electron energy, spatial and angular distribution. Scattering cross sections are varied by factors representative of differences between models in literature, the work function is varied to account for differences in sample properties, and the transition energy separating electron-phonon scattering and Mott scattering is shifted (Figure 1). The results show that using Mott scattering down to between 10-20 eV improves the match between simulated and experimental total electron emission yield, while the simulated yield is most sensitive to the inelastic and boundary crossing models. Agreement with the experimental energy spectra improves most when the work function is reduced, although this may partly reflect the effect of surface contamination in the experimental data, and thus requires further investigation. The findings of this work identify priorities for the development of improved low-energy physics models and provide insight into which aspects of electron-matter interaction most strongly influence SEM simulations.

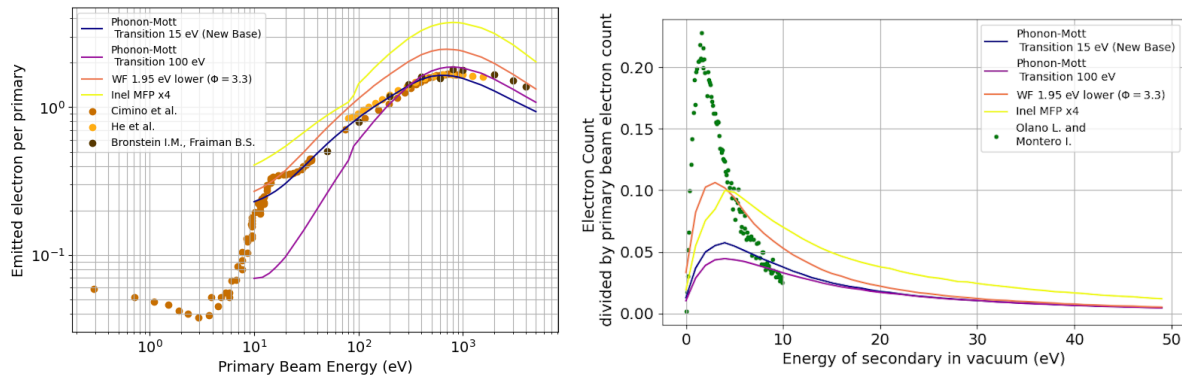


Figure 1. Effects of variation of work function, inelastic MFP and phonon-Mott energy transition on an ideal flat gold sample on simulated total emission electron yield and secondary electron emission spectra, compared to experimental data: Cimino [2], He [3], Bronstein [4] and Olano [5]

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