Modeling for Multi-Beam Ion Imaging and Analysis

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The arrival of scanning ion microscopy (SIM) offers many advantages for imaging, metrology, and nano-fabrication as compared with scanning electron microscopes (SEM). In particular, when operating a SEM the only experimental variable is the ability to change the incident electron energy while a scanning ion microscope can offer both a choice of beam energy and the option to use one of several different ion beams. This then offers new opportunities to optimize ion beam interactions to achieve specific experimental goals. To investigate these options requires a detailed model of the ion-solid interactions. In the work reported here the IONiSE Monte Carlo simulation[1], which requires appropriate values for the excitation energy ε and the ion induced secondary electron(iSE) diffusion length λ, was used to predict iSE yield data. For He+ ions experimental iSE yield data is available for comparison for many elements and compounds[2], but for other ion beams of interest little comparable data is available within the energy range of interest and so only values obtained from the IONiSE model were available for this preliminary study. Figure (1) compares the size and shape of the interaction volumes of H+. He+, Ar+ and Ga+ in Molybdenum at 40keV. Both H+ and He+ beams result in interaction volumes whose shape and form resembles that of an electron beam, but whose range is only about 10 - 15% of the comparable e-beam value. By comparison the form of the interaction volume for Ar+ and Ga+ is quite different to that for electrons showing predominantly forward scattering, with minimal backscatter but with considerable straggle, and a range which is reduced by a further factor of 5-6x relative to the lighter ions. As shown in figure (2) iSE yields from Si for different ions as a function of energy differ in form and by as much as one order of magnitude over the energy range. This variety in iSE yield behavior will provides a valuable tool for optimizing the imaging of complex materials. Further, as shown in Figure (3), different ions produce significant variations in their topographic yield with angle of incidence so, for example, a Ga+ beam will provide significantly higher topographic contrast than a proton beam. The effect of the choice different ion beams on factors such as the yield of Rutherford backscattered ions and the sputter rate will also be discussed.

(1) R. Ramachandra, B.J.Griffin, and D.C.Joy, Ultramicroscopy **109**,748 (2009)
(2) A preliminary data base of iSE yields is available from djoy@utk.edu

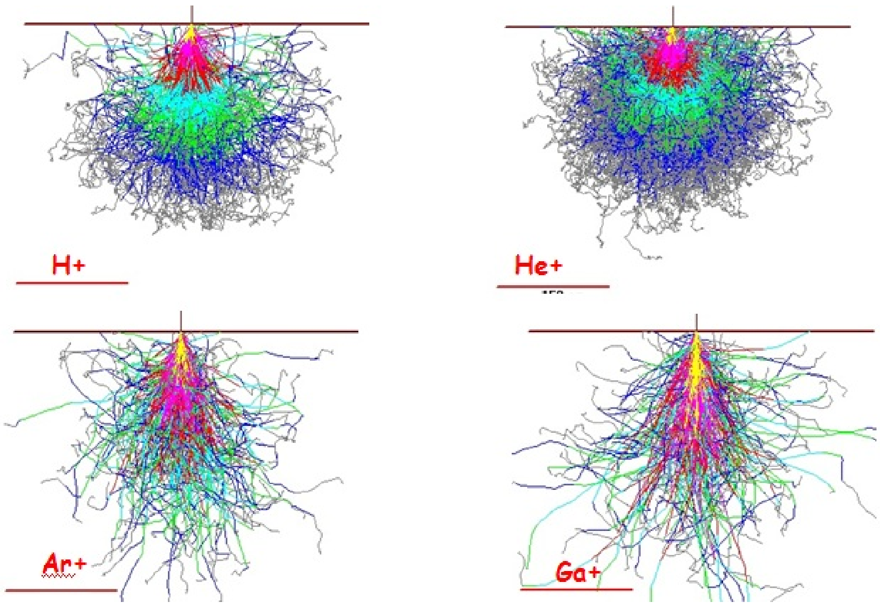

Figure 1: 40keV interaction volumes of (top) H+ and He+ beams in Mo – scale marker 140nm and (bottom) Ar+ and Ga+ beams - scale marker 25nm

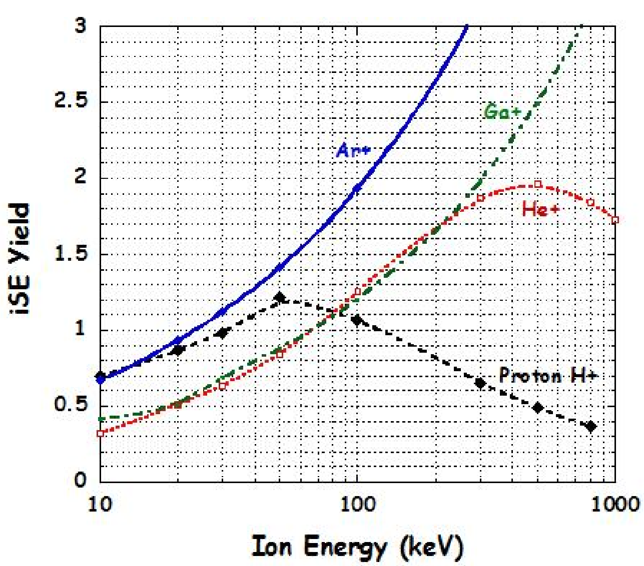

Figure 2: iSE yield vs energy from Si with H+, He+ ,Ar+ and Ga+ beams

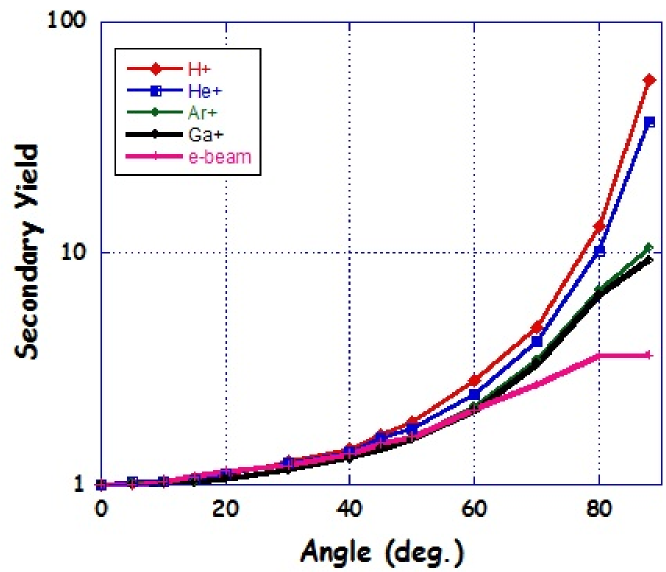

Figure 3: Topographic yield curves H, He ,Ar, Ga beams, Si @40keV