An analysis of sub-surface beam spread and its impact on the image resolution of the helium ion microscope

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By virtue of its extremely bright gaseous field ion source, the ORION™ helium ion microscope[1,2] (HIM) has demonstrated a probe size smaller than 0.3 nm, and due to the nature of the interaction of the helium beam and the sample, it is capable of providing unique image data[3]. When operating the microscope in its (typical) high-resolution imaging mode (i.e. surface imaging with secondary electron signal) the HIM produces images showing strong topographical contrast and crisp surface-specific detail, when compared to traditional scanning electron microscopes (SEM) and gallium focused ion beam (FIB) instruments.

To gain an understanding of the effects of beam-sample interactions on HIM resolution, we have combined models of beam broadening and signal generation, for a wide range of beam energies and sample materials. To study beam spread, transmission data (consisting of exit-position, -energy, and -direction) for helium ions passing through thin foils was generated using SRIM[4] software. A small subset of this data is illustrated in FIG. 1. IONiSE[5] software was used to generate data on secondary electron generation and escape.

The combined data was then used to calculate the impact of beam spread on image resolution. As the ion beam penetrates the sample deeper it experiences broadening, but secondary electrons generated deeper into the sample are less likely to escape the sample surface for detection. It was found that the effect of beam spread is strongly dependent on sample material and beam energy, being smaller for the lower Z (atomic number) sample materials, and at higher beam energies. However, it was concluded that under typical operating conditions, beam spread does not currently limit the microscope's image resolution. This paper will present our calculation methods, calculation results, and dependencies on beam energy and sample material in detail.

[1] Helium ion microscope: A new tool for nanoscale microscopy and metrology; B. W. Ward, John A. Notte, and N. P. Economou, J. Vac. Sci. Technol. **B 24**, 2871 (2006), DOI:10.1116/1.2357967.
[2] The ORION™ HIM is a product of Carl Zeiss SMT Inc. (Peabody, MA); www.smt.zeiss.com.
[3] Contrast Mechanisms and Image Formation in Helium Ion Microscopy; David C. Bell, Microsc. Microanal., **15** 147 (2009), DOI 10.1017/S1431927609090138.
[4] www.SRIM.org.
[5] Modeling for metrology with a helium beam; Ranjan Ramachandra, Brendan J. Griffin, and David C. Joy: Proc. SPIE, **6922**, 69221W (2008), DOI:10.1117/12.772300.

All scales are in nanometers.

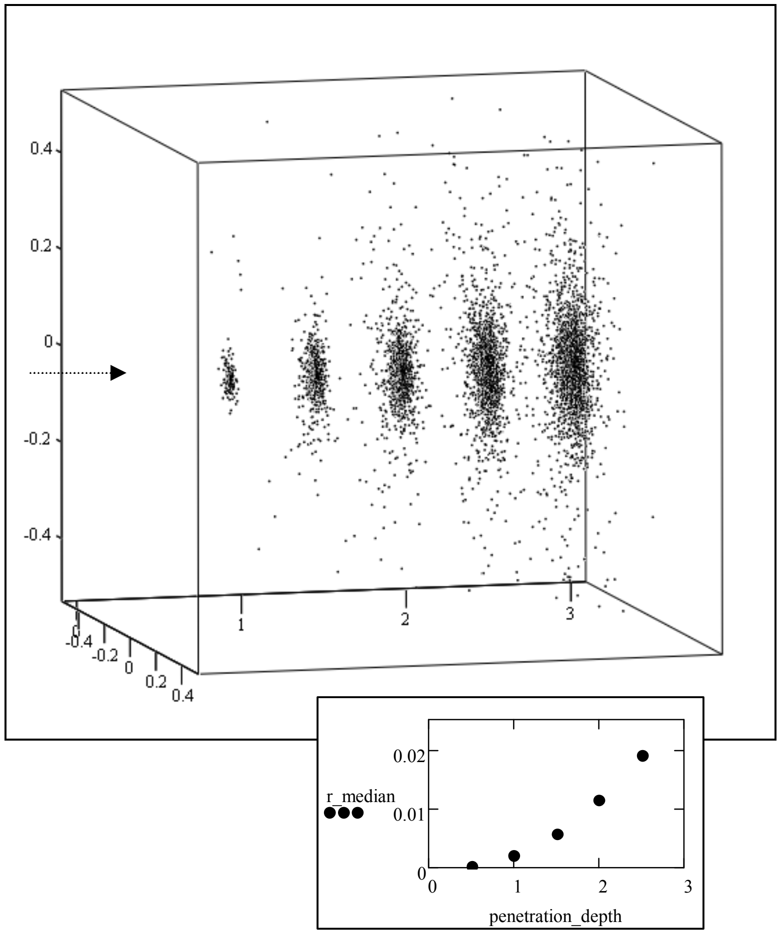

FIG. 1.

Scatter plots for helium ions entering a titanium sample after traveling 0.5, 1.0, 1.5, 2.0 and 2.5 nm into the sample respectively. The initial ion energy is 30 keV. The distributions are tighter than the plots visually suggest. For example, for the broadest grouping (at 2.5 nm depth) the median displacement from the beam axis is smaller than 0.02 nm (see inset).