Scanning Transmission Ion Microscopy with the Helium Ion Microscope – Modeling and Selected Applications

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The ORION™ helium ion microscope[1,2] (HIM) is typically used for surface imaging in a manner similar to traditional scanning electron microscopes (SEMs) and gallium focused ion beam (FIB) instruments, but at higher spatial resolution (the HIM has a demonstrated probe size <0.3 nm). However, using a suitable modification, it is also possible to operate the HIM as a scanning transmission ion microscope (STIM)[3,4,5].

To gain an understanding of the expected and observed performance of the transmission imaging mode, we have generated computed transmission data (consisting of exit-position, -energy, and -direction) for helium ions passing through thin foils, for a wide range of beam energies, foil thicknesses and sample materials, using SRIM[6] software (Figure 1 is an illustrated example of one parameter combination). This data was then analyzed to extract characteristics such as beam spread, transmission ratio and angular dispersion. This data is expected to prove useful for the design of new ion transmission detectors, the optimization of sample preparation, and the explanation of image characteristics.

We will present our calculation methods, calculation results, and dependencies on beam energy, sample thickness and sample material in detail. Examples of experimental scanning ion transmission images will also be presented (Figure 2).

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[1] Helium Ion Microscope: A New Tool for Nanoscale Microscopy and Metrology; B. W. Ward, J. 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 NTS, LLC (Peabody, MA); www.zeiss.com/nts.
[3] Sample interaction and contrast mechanisms of the helium ion microscope; J. Notte and B. Ward; Proceedings of SCANNING 2006, April 25-27, 2006, Washington D.C., USA - Scanning **27** (2), p.63 (2006).
[4] Diffraction Imaging in a He^+ Ion Beam Scanning Transmission Microscope; J. Notte IV, R. Hill, S. M. McVey, R. Ramachandra, B. Griffin and D. Joy; Microscopy and Microanalysis, **16**, 599 (2010); doi:10.1017/S1431927610093682.
[5] Scanning Transmission Ion Microscopy and Diffraction Imaging; D. C. Joy, J. Notte IV, R. Hill, S. M. McVey, R. Ramachandra and B. J. Griffin; Microscopy and Microanalysis, **16** (Suppl. 2), 604 (2010); doi:10.1017/S1431927610053791.
[6] www.SRIM.org.

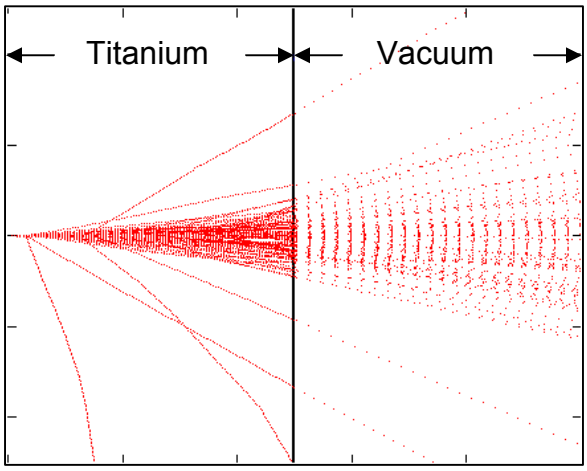

Figure 1: Ion Transmission Modeling: Plot of helium ion trajectories, calculated using SRIM, showing 30 keV helium ions entering and passing through a 25 nm thick Ti foil, followed by a 25 nm dilute hydrogen atmosphere (used to model vacuum, for the purpose of generating this illustration only).

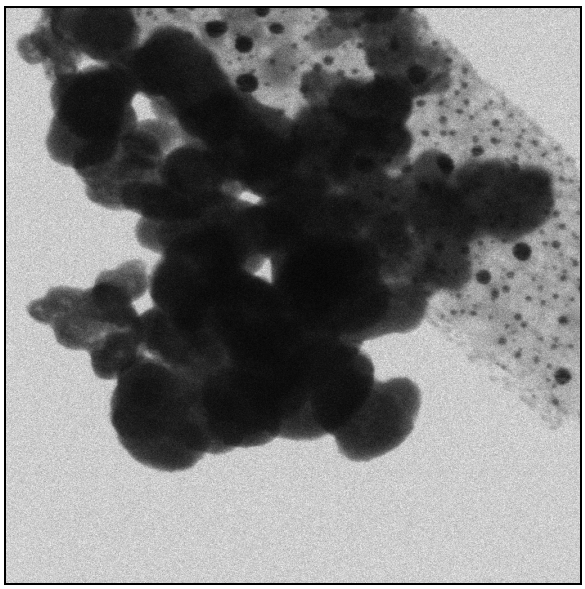

Figure 2: Scanning Transmission Helium Ion Image: Bright field image of an SPI Combined Test Specimen (from SPI Supplies). The field of view is 300 nm. In the image the areas of uniform light-gray background are openings in the specimen. The medium-gray speckled ribbon is a carbon film with small gold islands (imaging darkly), and the darkly imaging clump of larger particles in the foreground is graphitized carbon.