

ORION Nano Fab - 2nd Generation Helium Ion Microscopy

David C Joy¹ and Brendan J Griffin²

1. Dept. of Materials Science, University of Tennessee, Knoxville, TN 37934, and Oak Ridge National Laboratory, Oak Ridge, TN 37996
2. Center for Microscopy, University of Western Australia, Crawley WA, Australia 6009

The ORION ‘NanoFab’ (Orion NF), recently installed at The Center for Nanophase Materials Science (CNMS), at Oak Ridge National Laboratory (ORNL), is the second generation version of the original helium ion microscope (HIM) from Carl Zeiss [1]. The instrument’s capabilities and imaging specification are enhanced when compared to the first generation machine while fitting into a significantly smaller footprint than previously. The ORION NF (figure 1) uses a Gaseous Field Ionization Source (GFIS) gun which is typically operated between about 20keV and 45keV and which can provide beam currents in the range from 10^{-14} to 10^{-11} amps. Although this level of current is small in comparison to those found in a conventional SEM, ion beam SE yields are significantly higher than those generated by electrons in this energy range and so the signal to noise is comparable or superior. For the first time the GFIS ion beam from this instrument can now be switched on demand from He⁺ to Ne⁺, or back again, in as little as about sixty seconds. As demonstrated in figure (2) these two gas choices offer complementary strengths and weaknesses. The brightness of the He⁺ beam is generally comparable with that of a field emission electron source at the same energy and the sputter damage caused to most specimens is small. The Ne⁺ source is predicted to give a rather higher iSE yield for a given beam energy and current [2], and the sputter yield rate is typically one order of magnitude greater than for He⁺ so making it about 40% as effective as a Ga⁺ beam with the same current and energy, and with the advantage residual material is embedded into the specimen. The Ne⁺ option therefore provides an efficient and convenient way to expose, machine, cut, or remove materials. The ORION NF can also support other detectors such as a Rutherford back-scatter (RBS) ion detector for atomic number contrast, or a simple transmission detector. A basic pattern generator capability is integrated into the scan system so that the both He⁺ and Ne⁺ beams can be employed for nanoscale device and structure fabrication.

The wavelength of He⁺ or Ne⁺ ions for typical beam energies (20-50 keV) is several hundred times shorter than that for electrons of the same energy and so the ion optical system is designed to be able to fully exploit this performance. For energies of the order of 30keV the ORION NF can produce a beam with a convergence angle of about 0.5mrad, a final probe size which can be as small as 0.4nm, and a usefully high beam current (>10pA). This combination provides images with a depth of field 10x to 20x higher than that of a conventional SEM at the same field of view, while operating at a working distance of between 3-10 mm. To achieve the highest levels of performance many different operational parameters must be optimized by the operator. To simplify this, as shown in figure (3), the ORION NF is equipped to produce and display the “Contrast Transfer Function” (CTF) of the instrument [3]. The CTF display provides information on the imaging resolution achieved, indicates the operational signal to noise ratio, and can quantify the effects of changing parameters such as the focus

or the size of the limiting image aperture. This makes it possible to optimize, and readily return, to any required ion optical set-up condition.

[1] B. Ward et al, *J.Vac.Sci.Technol*, **B24**, (2006), p2871
 [2] R. Ramachandra, B. Griffin, and D.Joy, *Ultramicroscopy* **109**, (2009), p748
 [3] D Joy, J. Michael, and B. Griffin, *Proc. SPIE* **7638**, (2010), 3J1.
 [4] This research was conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Scientific User Facilities Division, Office of Basic Energy Sciences, U.S. Department of Energy



Figure 1. ORION NF ion microscope

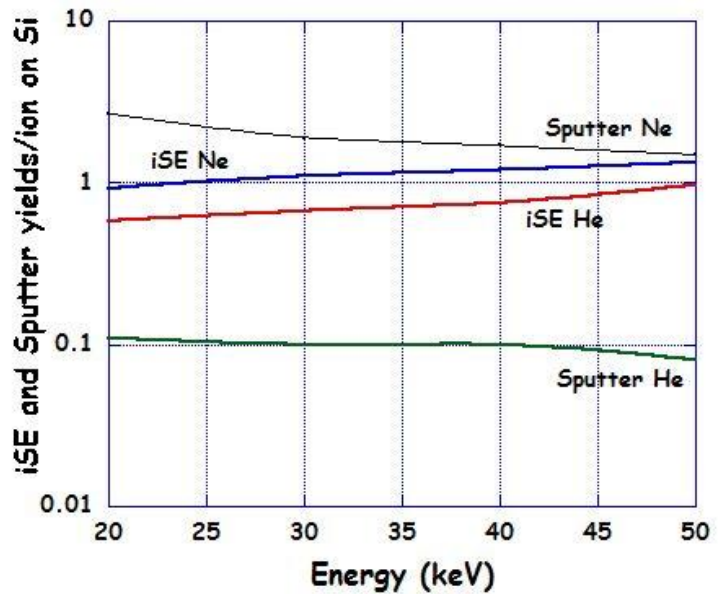


Figure 2. iSE and sputter yields for He+, Ne+

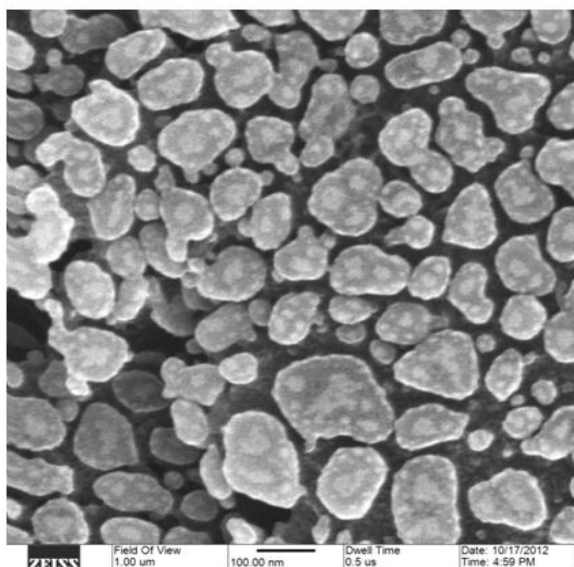


Figure 3. iSE nanoparticles FoV 1micrometer

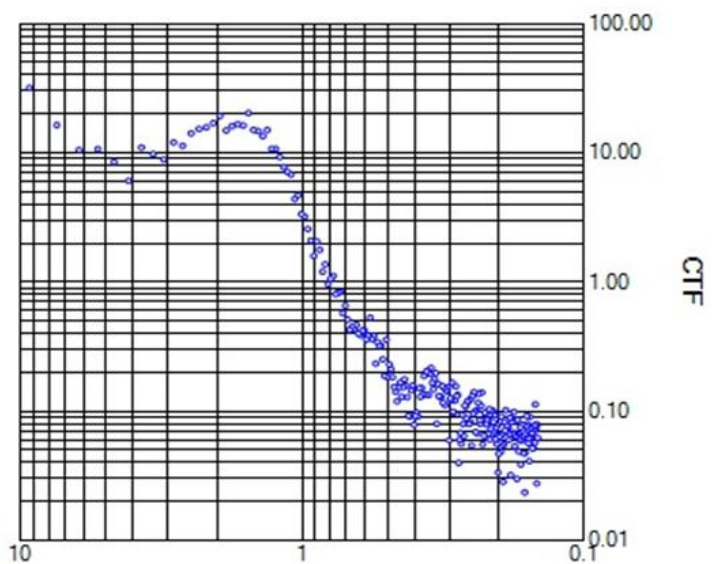


Figure 4. CTF plot showing <0.5nm cut-off