# Nanoscale Imaging, Analysis and Nano-fabrication Using Helium Ion Microscope

D.C. Bell
*School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138*
*dcb@seas.harvard.edu*

Current research in the areas of nanomaterials and nano-biology requires the corresponding ultra-high resolution imaging techniques that allow examination of the specimens with minimal damage and sample preparation. The Helium ion microscope developed by ALIS Corporation (Orion microscope) has emerged as a new and unique imaging and nano-fabrication tool for novel nanomaterials and composites.

The image formation principle in the helium ion microscope involves interaction of a relatively low energy He ions with the specimen producing secondary electron signal that is mainly confined to the surface of the material [1, 2]. The resulting secondary signal exhibits superb resolution and image fidelity. Imaging of non-conductive materials becomes fairly straightforward as compared to SEM, where such specimens would require coating or use of low vacuum environment. Optional RBS (Rutherford Backscatter) detector is sensitive to atomic number difference (z-contrast) and the image in essence becomes a real time spectral map of materials constituents.

This paper will present our results using He ion microscope to image a wide variety of nanomaterials including: graphene structures, nanotubes, nanowires, nanoparticles, composite materials, polymers, multi-layer fabricated devices and biological materials. One of the goals of our research is to understand the underlying physics of the image formation, sample/ion interactions and subsequent image contrast interpretation. A direct comparison between ultra-low voltage SEM and Orion microscope imaging will be presented and possible unique contrast mechanisms will be discussed.

A unique application of the Orion microscope – milling of beam sensitive materials using He ions – will be presented as well. While using He ion source the sputtered target atoms occur at a rate of 100 times less than Ga ions in a conventional FIB system, meaning long imaging times without sample alteration and no sample-altering ion implantation. Materials that would be termed 'difficult' in a Ga FIB and would possibly require cryo conditions for stabilization can be gently milled or sputtered in the He ion microscope without contamination or thermal effects as normally seen in FIB system [3].

Our review will show that the Orion microscope has a potential to evolve into a "must have" instrument for the 21$^{st}$ Century.

References

1. J. Notte and B. Ward, Scanning Vol 28 (2006)
2. D.C. Bell, Microscopy and Microanalysis, 15 (2009), pp. 147-153
3. D.C. Bell, M.C. Lemme, L.A. Stern, J.R. Williams, C.M. Marcus, Nanotechnology 20 (2009) 455301

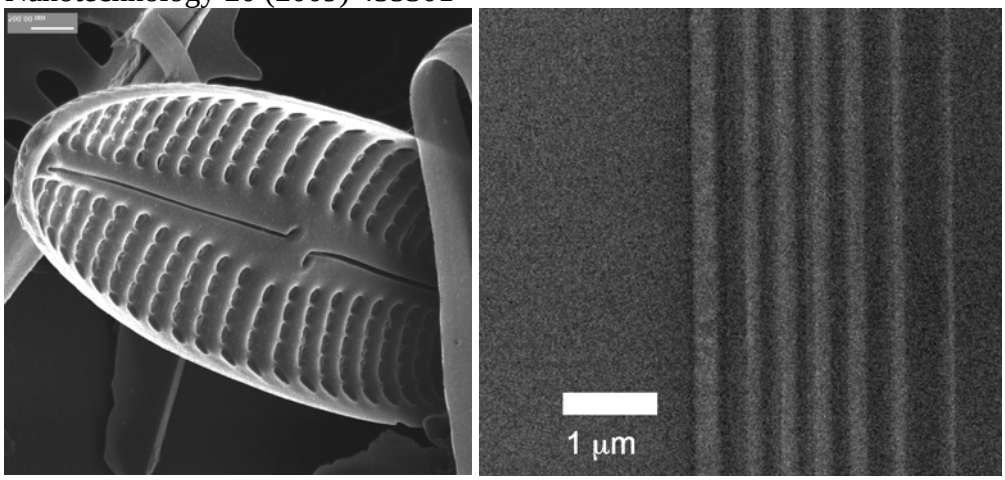


Figure 1. Imaging with HeIM: left – diatome; right – dopant layer contrast.

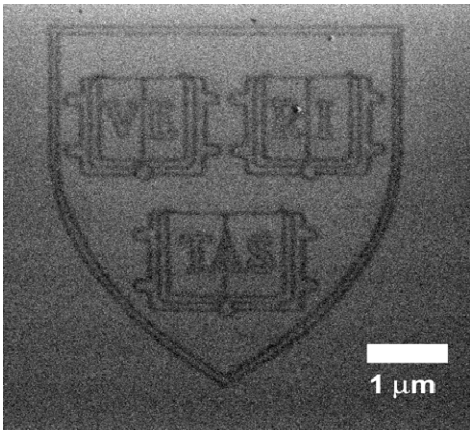


Figure 2. Helium ion beam etching of a graphene sheet (from Ref. 3)