Nanometer Scale Patterning and Processing

Spring 2016

Lecture 31

Scanning Helium Ion Microscopy (SHIM)

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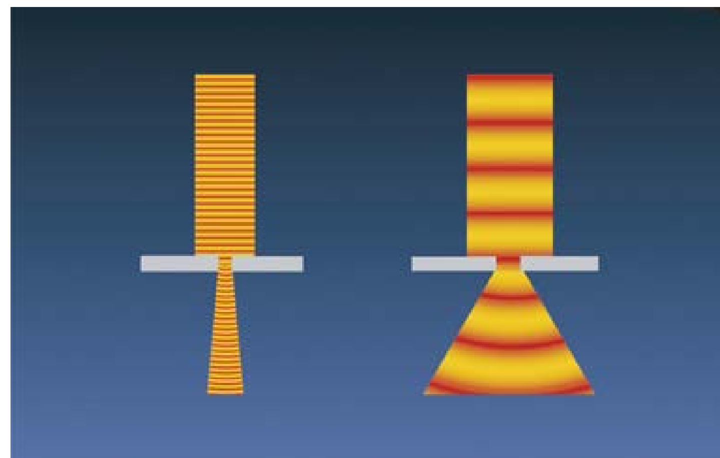
Compared to SEM for high resolution imaging:

- Mass of He ion (Z=2, M=4) is 8000×, so $1/\sqrt{8000}$ shorter wavelength (for same eV), which leads to less diffraction for high resolution imaging.
- He ion has considerably smaller interaction volume (due to smaller penetration depth). This enables SHIM's resolution to be directly proportionate to its spot size which is not always the case with SEM.
- Like SIM using Ga^+, SHIM has quite different material contrast than SEM.
- SHIM can produce ~3-9 secondary electrons per ion compared to ~1 per electron for SEM. Thus SHIM can image properly with ion currents <1pA (small current – small aperture – small beam convergence angle α, so small beam size due to less chromatic and spherical aberration).
- Such small current also means little charging, thus SHIM can image insulating materials better.
- Higher depth of focus (by ~5×).



He ion beam has a DeBroglie wavelength much smaller than an electron beam, resulting in much less diffraction.

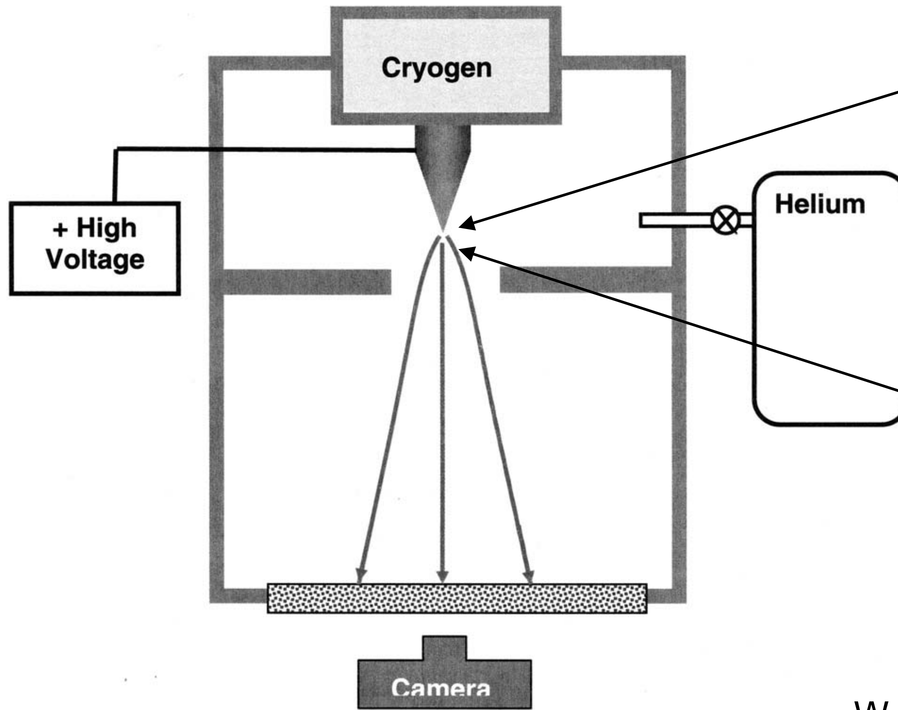
http://addictedtonature.wordpress.com/2007/06/04/the-scanning-helium-ion-microscope/

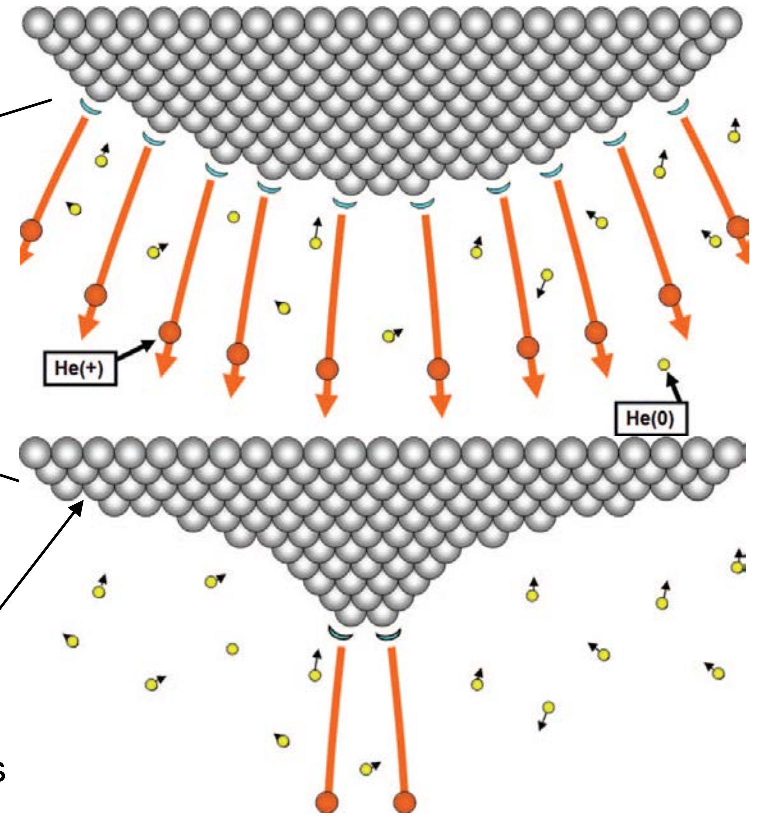
SHIM vs FIB with Ga^+

Compared to FIB using Ga^+ ion:

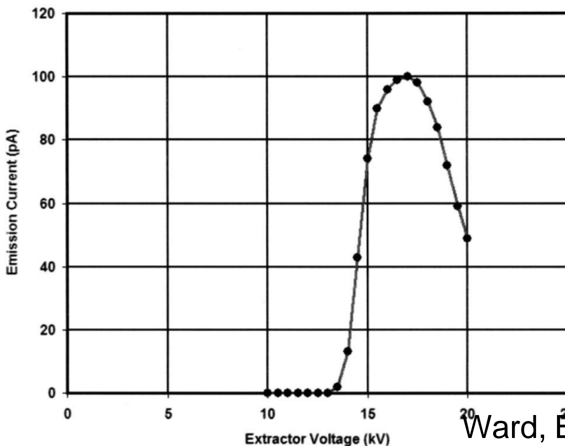
- He ion is much lighter, so much less damage and no “staining”
- That is, He implantation doesn’t hurt much, whereas Ga does. At very high He dose, He bubble will form beneath sample surface, which may eventually blow off the surface.
- Little sputtering during imaging, so can image fine structures.
- It can still be used to mill material such as TEM sample preparation, without the negative aspects when using Ga^+ FIB.
- Milling is very slow (since He is light), but can be chemically-assisted (add XeF_2 gas…) to get fast.
- It can also be used for material deposition.

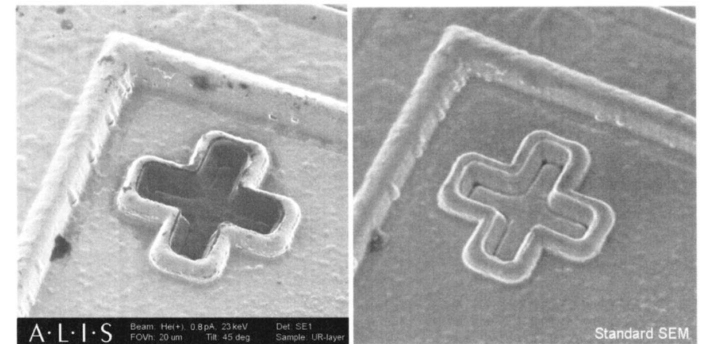
Field Ion Microscope: Helium Ion Source





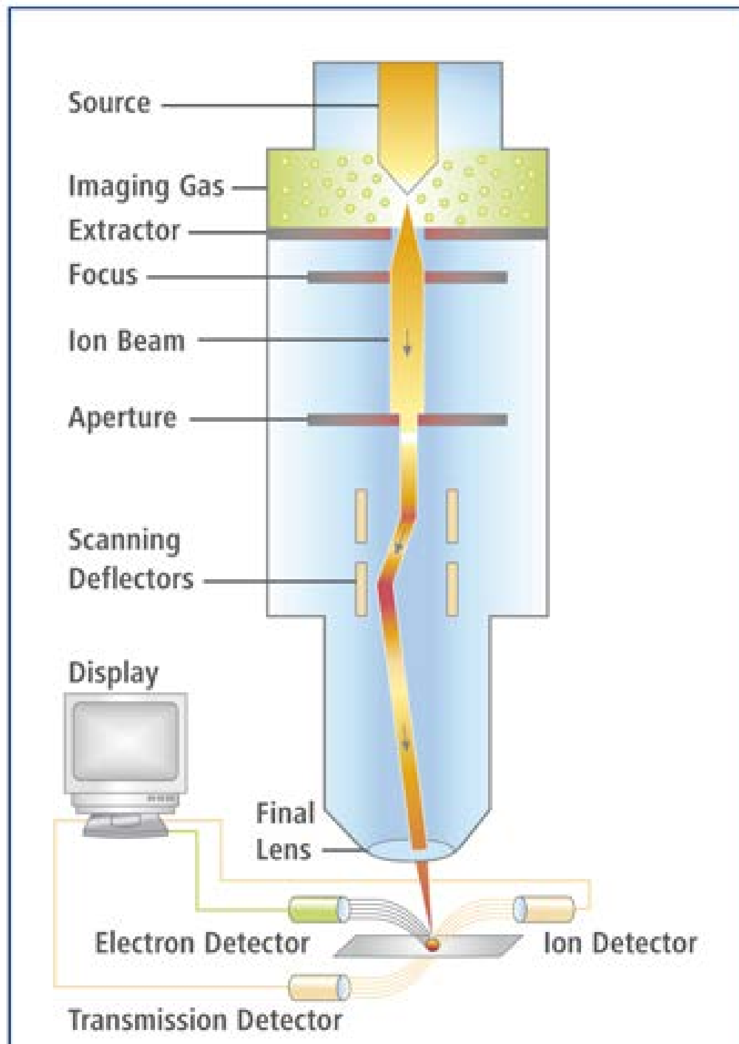
W atoms





Ward, B. W. Notte, J. A. Economou, N. P., J. Vac. Sci. Technol. B, 24, 2871 (2006)

SHIM structure



The “trimmer: for extremely sharp tip

- A finely sharpened needle is made even sharper - individual atoms are stripped away from the source until an atomic pyramid is created with just three atoms at the very end.
- This repeatable process can be accomplished in-situ. Once the trimmer is formed, the tip is maintained under high vacuum and cryogenic temperatures.
- The helium gas is attracted to the energized tip where it is ionized.
- With ionization happening in the vicinity of a single atom, the resulting ion beam appears to be emanating from a region <1Å in size.
- This produces an extremely bright beam that can be focused to an extraordinarily small probe size.

Image of the atoms at the end of the source tip emitting helium ions. Since each atom can be individually seen, the virtual source size must be much smaller.

Detectors:
Ion (backscattered He); Electron (secondary electron)
Transmission detector (for thin sample, He gets through)

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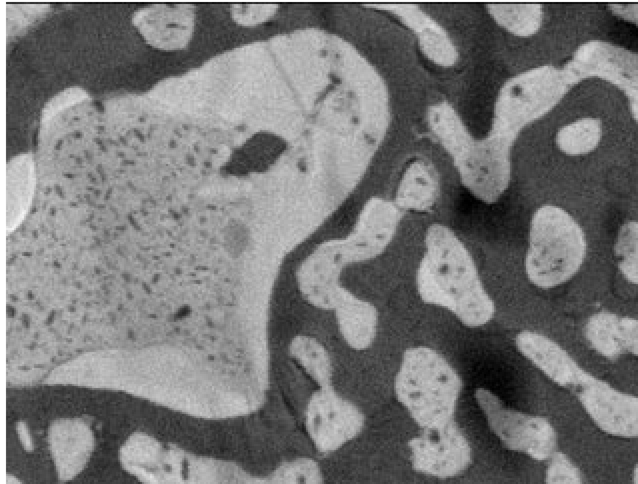
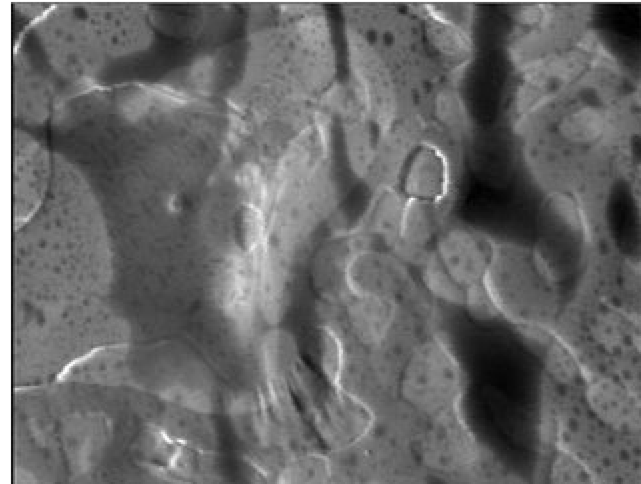
Applications of SHIM





Left: SHIM image of a solder bump showing the difference in the lead and tin sections. Right: SEM image of the same sample.

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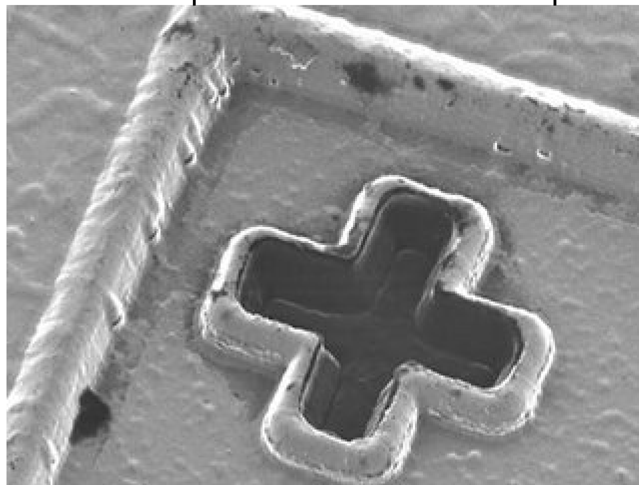
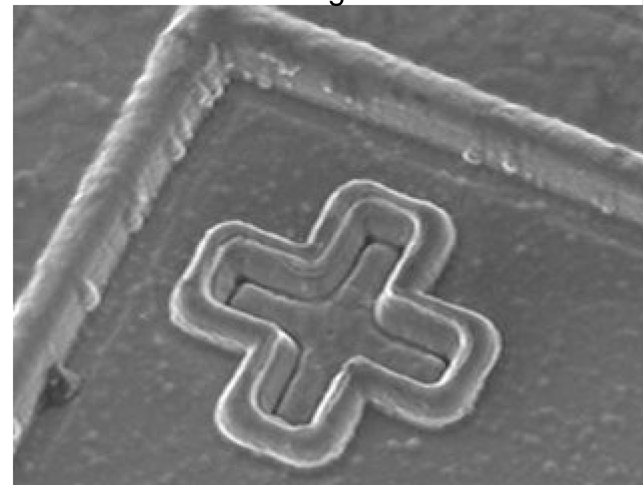
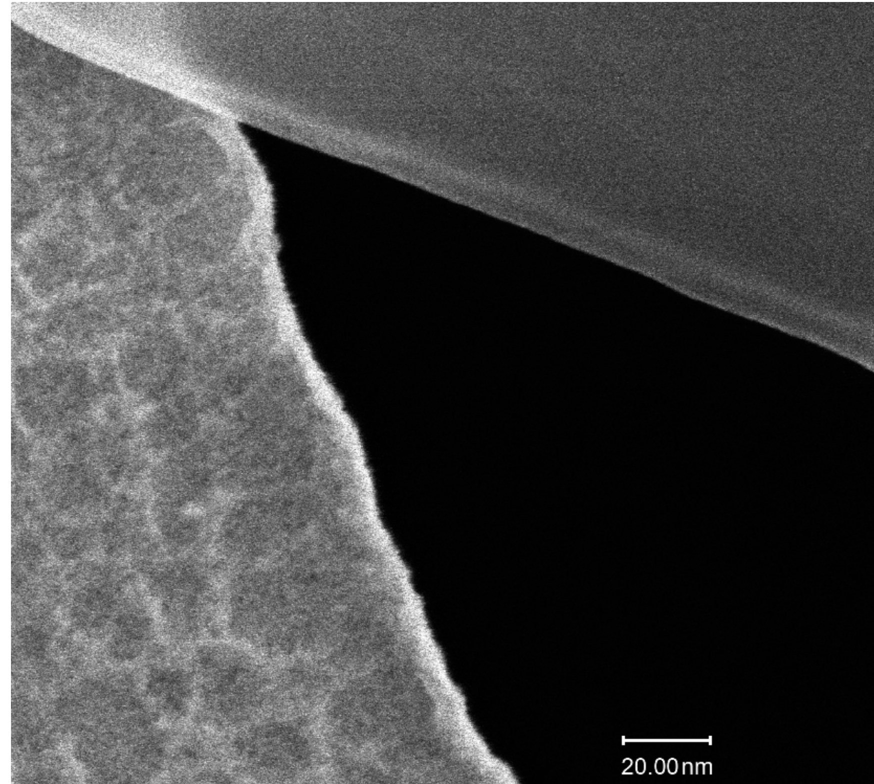




Left: SHIM image of a sample showing the material in the cross is different from the outside. Right: SEM image of the same sample.

0.24 nm Resolution of He Ion Microscopy



- a line-scan over the very sharp edge of an asbestos fiber on a thin holey carbon foil

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