Nano fab and its Applications

Dr. Navid Asadi

Physical Inspection and AttacKs on ElectronicS (PHIKS)

Presented by : Nitin Varshney

One system with Multiple Ion beams

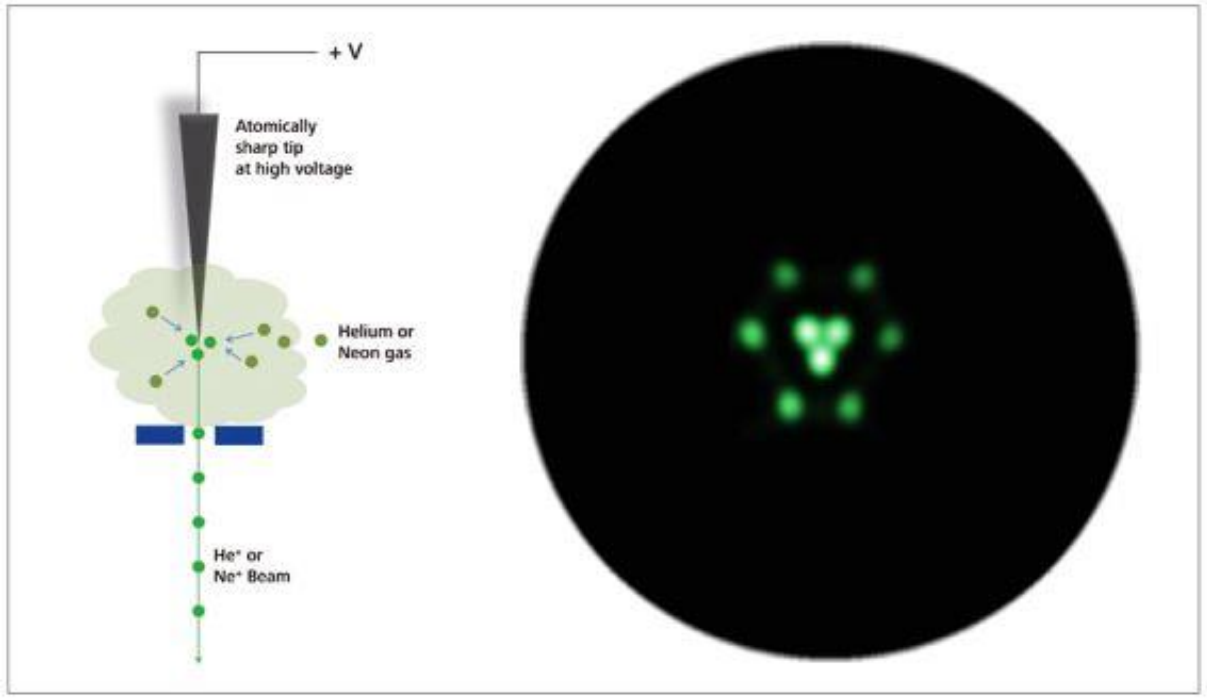
- Fabricate sub-10 nm nanostructures with speed and precision with the ORION NanoFab.
- Use its Neon beam to machine nanostructures at great speed and achieve high throughput.
- Use the helium beam to create delicate sub-10 nm structures that demand extremely high machining fidelity.
- Equipped the ORION Nano Fab with the optional gallium FIB column and it becomes one of a kind: the only system in the world that covers the complete range of micromachining to nanomachining applications using gallium, neon and helium ion beams integrated in a single instrument.

Why Helium Ion Beam more Suitable than Gallium Ion Beam?

Helium Ions FIB	Gallium Ions FIB
Helium Ions are less massive than gallium ions thus helps in removing material at a controlled rate.	Massive and bigger than the Helium and Neon Ions .
Gas Field Ion Source	Liquid Field Ion Source
Helium Ion sputter material from within 5nm radius of beam impact point.	Helium Ion sputter material from within 25nm of beam impact point.
Minimum feature size is 1 nm	Minimum feature size is 25 nm
Spot size at 30 KV is 0.35 nm.	Spot size at 30KV is 5 nm.
Suitable for milling small structures.	Suitable for milling large structures.

Advantages

1. Gas Field Ion Source Technology

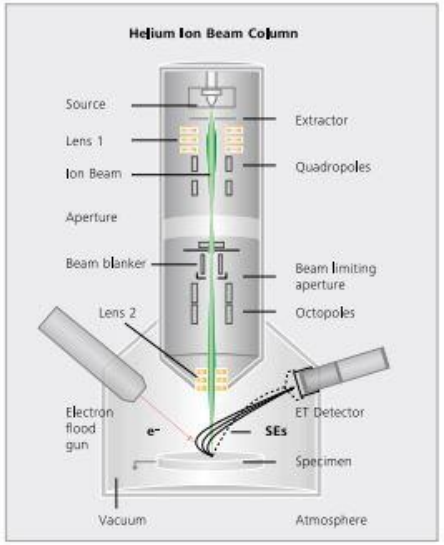


- A finely sharpened needle is made even sharper through a proprietary process.
- Individual atoms are stripped away from the source until an atomic pyramid is created with just three atoms at the very end of the source tip – a configuration called the trimer.
- With ionization happening in the vicinity of a single atom, the resulting ion beam appears to beemanating from a region that is less than an angstrom in size. This produces an extremely bright beam that can be focused to an extraordinarily small probe size.

Advantages

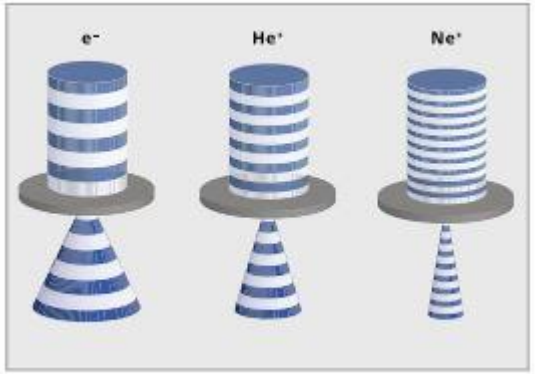
2. Advanced column for ultra accurate beam Focus

- This GFIS source is combined with an advanced electrostatic ion column that focuses the beam with sub-nanometer precision.
- For nanofabrication, the beam can be controlled to execute a user selected pattern with prescribed dosages.



3. Minimize diffraction

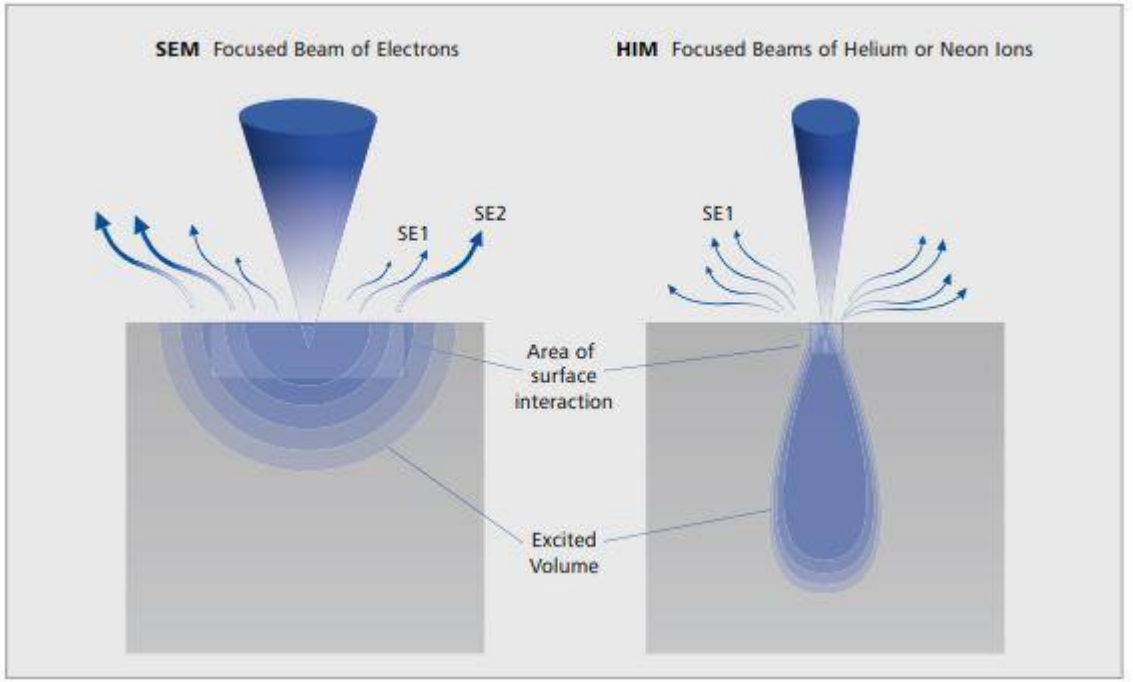
Helium or neon ion beam exhibits very little diffraction when passed through an aperture or across an edge. Since the helium or neon ion beam is not affected by diffraction, it can be focused to a very small spot size.



Advantages

4. Localized beam-sample interaction for higher resolution images

- When electron beam strikes a surface, it is subjected to a beam scattering effect due to interaction with the surrounding material causing the emission of secondary electrons from an area that is somewhat larger than the size of the beam itself.
- When the helium or neon ion beams strike the sample, the particles do not scatter near the surface.
- This translates into a smaller area of surface interaction and much higher resolution images for the Ion microscope.



Advantages

5. Imaging Capabilities:

Imaging of insulating samples –Helium Ion beam excels at imaging uncoated insulating samples.
Unlike in SEM, the samples accumulate only a positive charge in an ORION Nano Fab which is very elegantly neutralized by a built-in electron flood gun. This means that one doesn't need to coat the samples with conductive over coat in order to get nanometer resolution images.

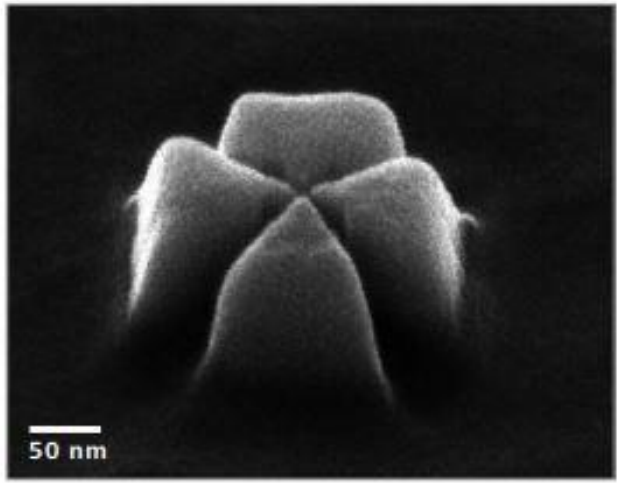
Large depth of field – The images generated by ORION Nano Fab have 5-10 times depth of field as compared to those generated by a high-end FE-SEM. If you have a highly three-dimensional sample, this will result in an image that shows all high and low points of the sample in great detail and focus.

High resolution surface-sensitive imaging- Due to the interaction physics of helium ion beam and sample, it turns out that secondary electrons are generated from the sample from the top 5 nm only. In addition, these secondary electrons are SE2 only. This results in immense surface sensitivity in the images therefore, surface details at high resolution can be seen.

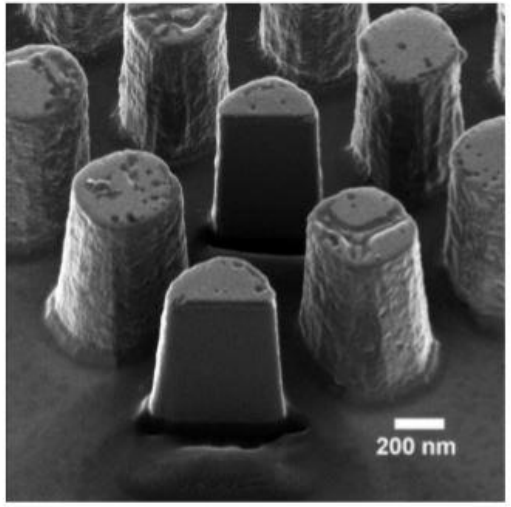
Applications

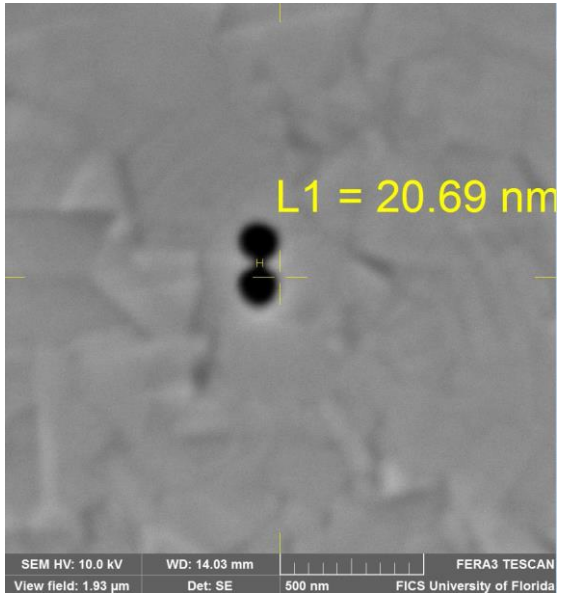
1.Sub- 20nm Nanofabrication:

- ORION Nano fab equipped with Helium and Neon ion beams is ideal to make sub-20 nm structures by sputtering.
- Much smaller structures with better accuracy can be made than what is possible using a gallium FIB.



A plasmonic antenna fabricated in single step in 100 nm thick freestanding gold film using helium ions. The gap beween the two tips is 4 nm.

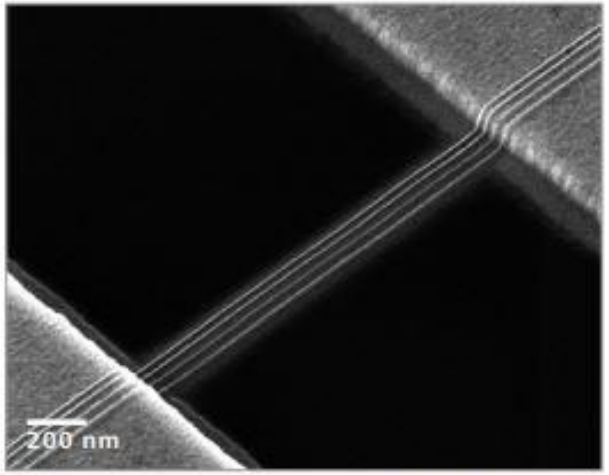




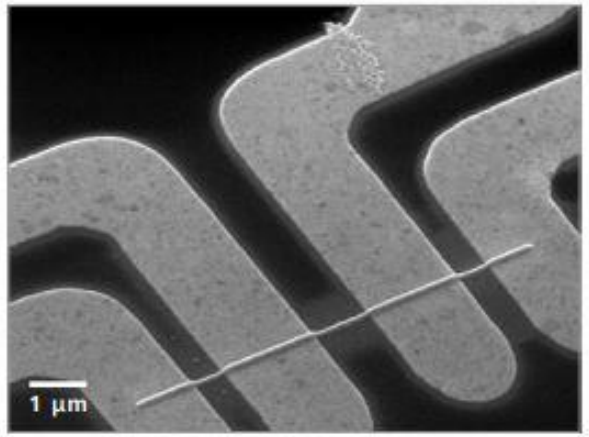
Applications

2.Circuit analysis and modifications:

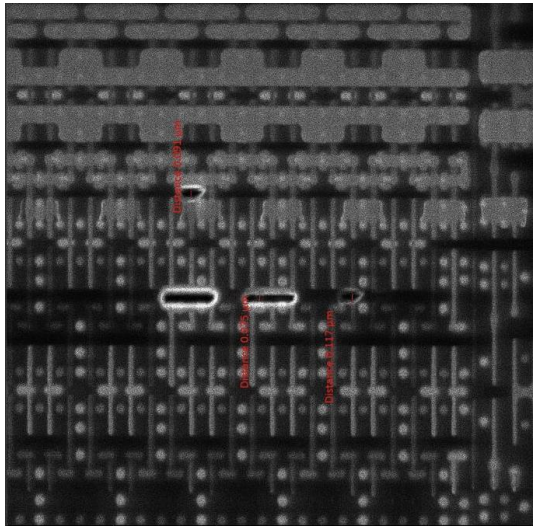
- Helium and Neon ion beams is ideal for making cuts and conductive connections in circuit analysis applications .
- Much smaller circuit modifications with better accuracy can be made than what is possible using a gallium or Plasma FIB to sub-10nm level.



10 nm metal lines direct deposited with helium with resistivity of < 200 μohm.cm.

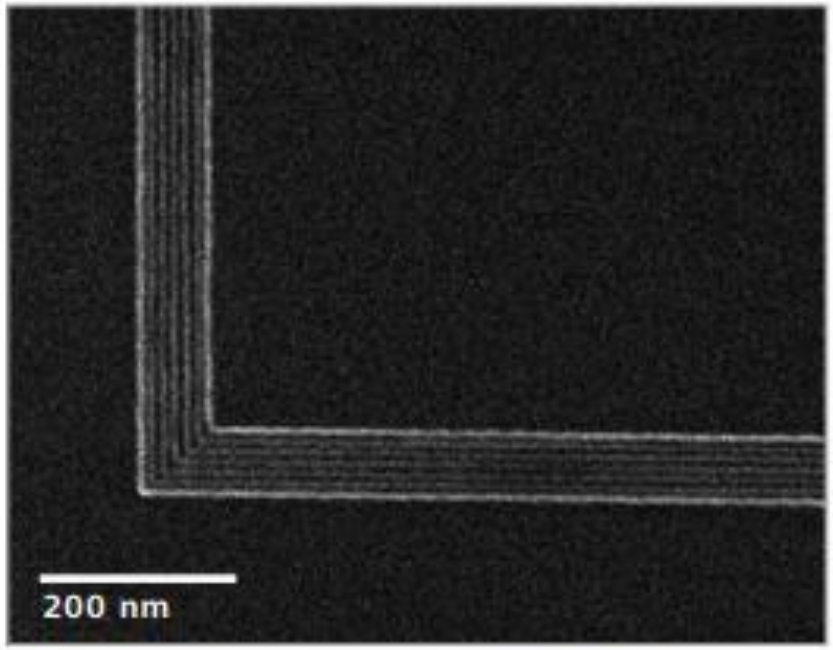


100 nm wide tungsten wire deposited using neon beam on a test structure.

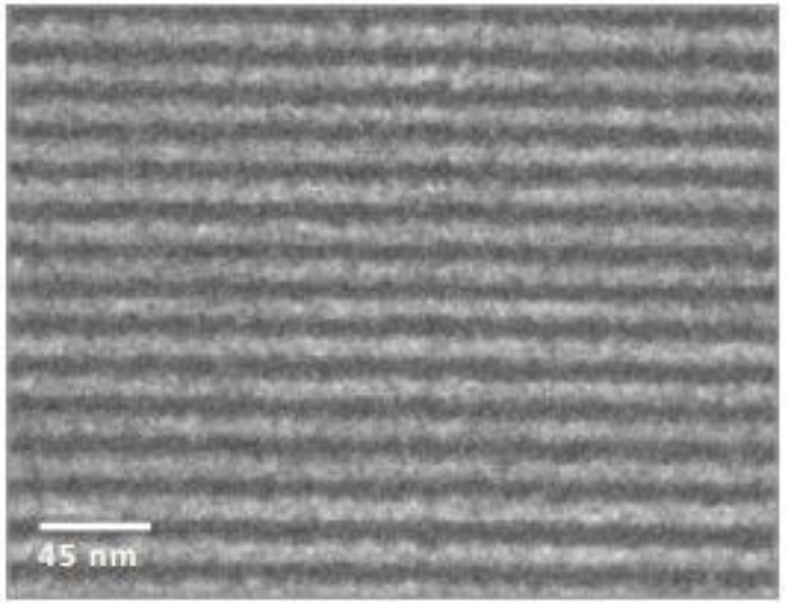


Applications

3.Lithography: ORION Nano Fab is ideal for lithography as photoresist can be exposed without proximity effects using helium and neon beams resulting in smaller and more uniform features than what is possible using electron beam lithography.



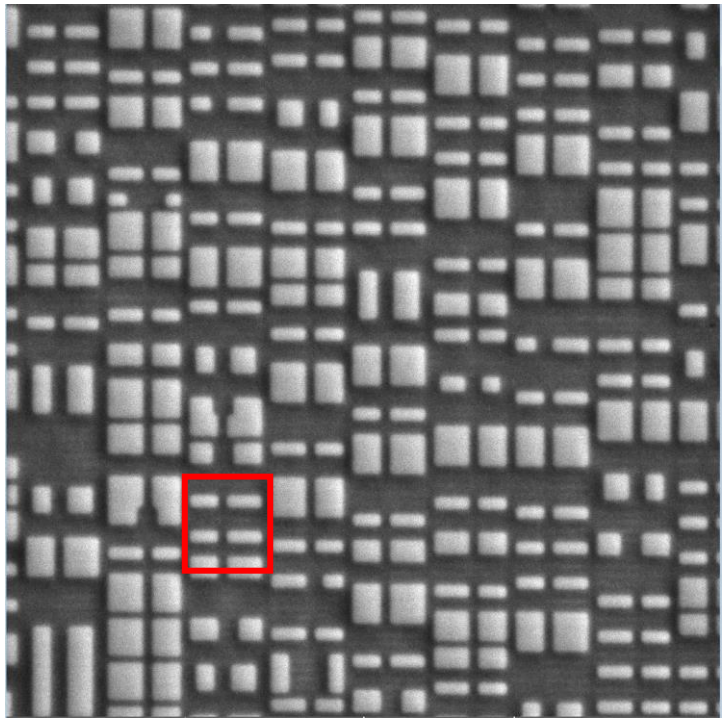
6 nm nested lines in HSQ fabricated by helium ion lithography.



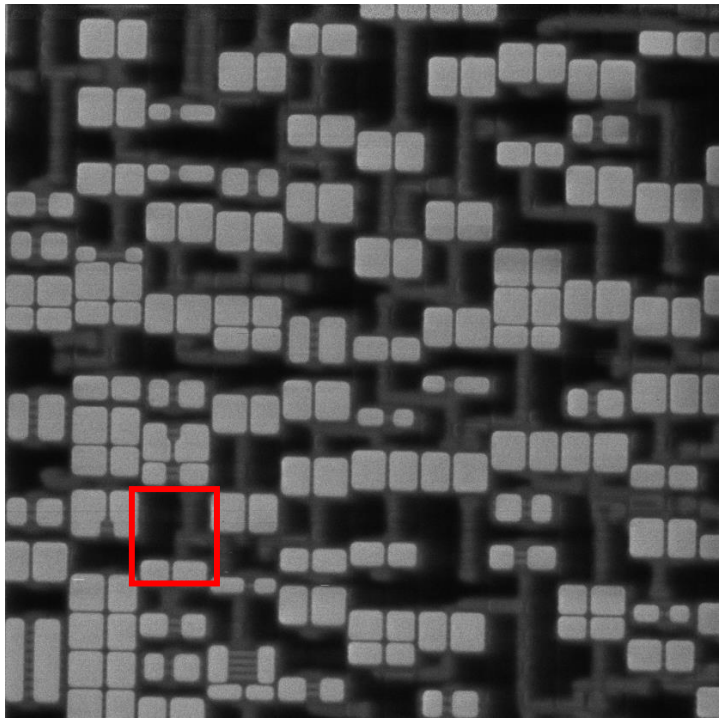
7 nm wide lines patterned in HSQ at a 15 nm pitch using helium ion lithography. The line width is independent of the pitch of the lines - no proximity effect was observed.

Applications

4. Voltage and Channeling Contrast Imaging:

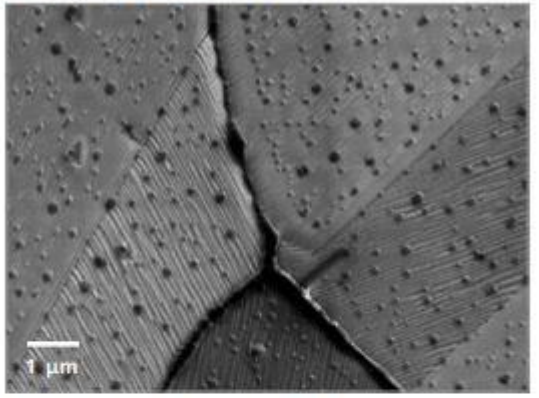


SEM IMAGE



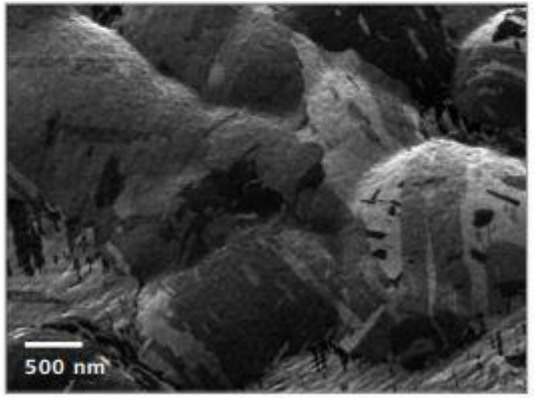
Nano fab IMAGE

Beam used for imaging: Helium



Surface of polycrystalline platinum showing grain boundaries. Note the channeling contrast between different grains.

Beam used for imaging: Neon



Polycrystalline gold surface imaged with neon beam. Note the remarkable channeling contrast in the image.