Charge state effects in mirror degradation

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Purpose:

- *Understand the importance of multiply-charged ions in the degradation of EUVL optics.*
- *Provide charge state and material specific data for modeling plasma/surface interactions.*

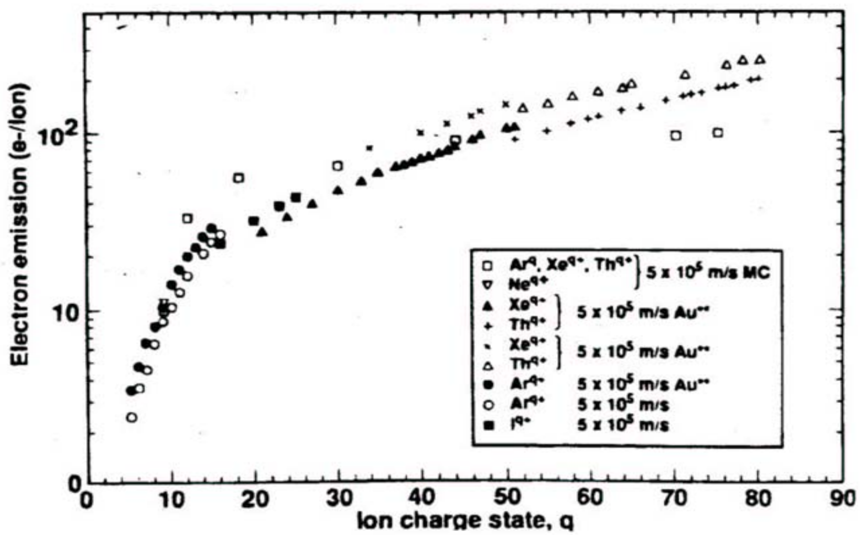
Abstract

Although it is well-known within the EUV source community that ions from source plasmas can degrade mirror performance, it is perhaps not widely known that multiply charged ions can cause dramatically more surface damage than their singly charged counterparts, even at very low kinetic energy. This charge state effect has been seen by a small community of researchers who are studying the fundamental science of highly charged ions. Large charge state effects have been reported in secondary particle emission [1] (ions, electrons and neutrals) as well as surface modification (topographical [2], electrical [3] and optical [4]). We are now exploring the importance of charge state in the degradation of EUV optics by bombarding surfaces with ion beams such as Xe^{10+}, and observing the resulting surface modification with scanning probe microscopy techniques. Such charge state specific data is valuable for modeling mirror degradation and for engineering EUV sources.

1. Schenkel T *et al*., Progress in Surface Science, 61 23 (1999).
2. Ratliff, LP, and Gillaspy, JD, *Applications of Accelerators in Research and Industry – Sixteenth International Conference*, Ed. By JL Duggan and IL Morgan. p. 935 (2001).
3. Meguro T *et al.,* Appl. Phys. Lett. 79 (23)ha 3866 (2001).
4. Hamza, AV, *et al*., Appl. Phys. Lett. **79** (18), 2973 (2001).

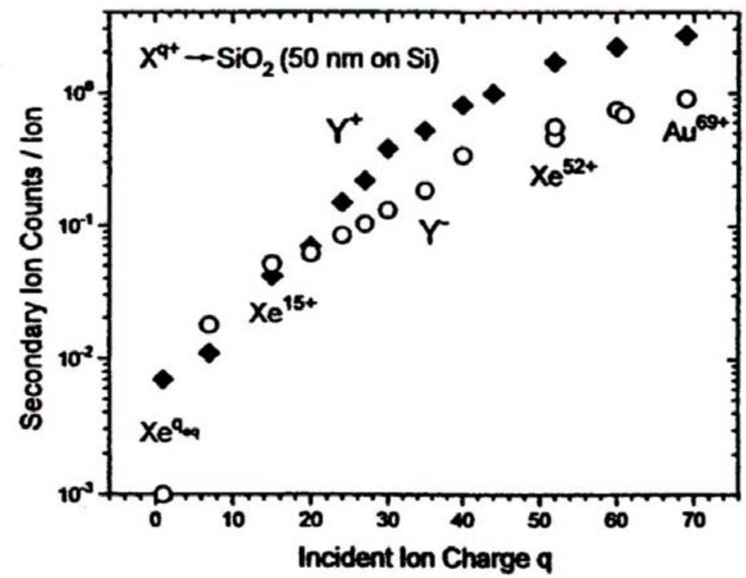
Background:
highly charged ion/surface interactions

Secondary electron yield



D.G.H. Schneider and M.A. Briere
Phys. Scr. 53 (1995) 228

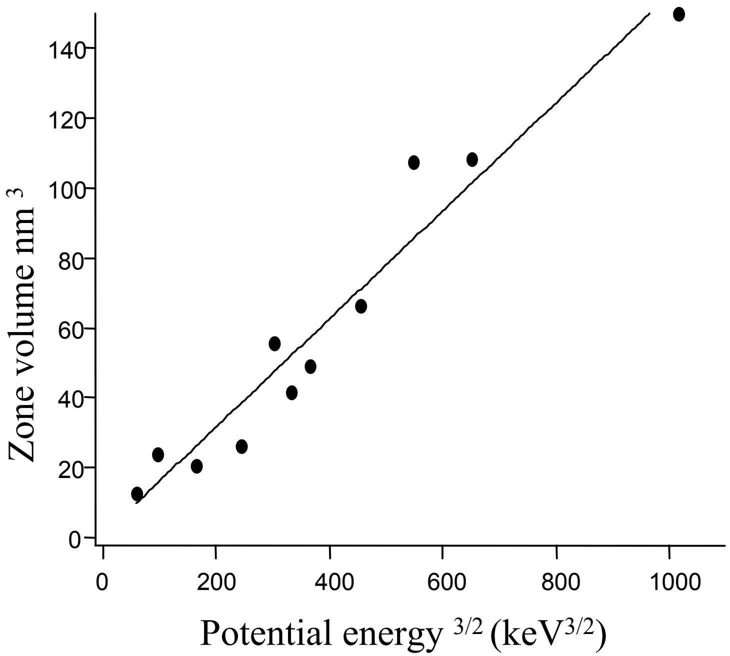
Secondary ion yield

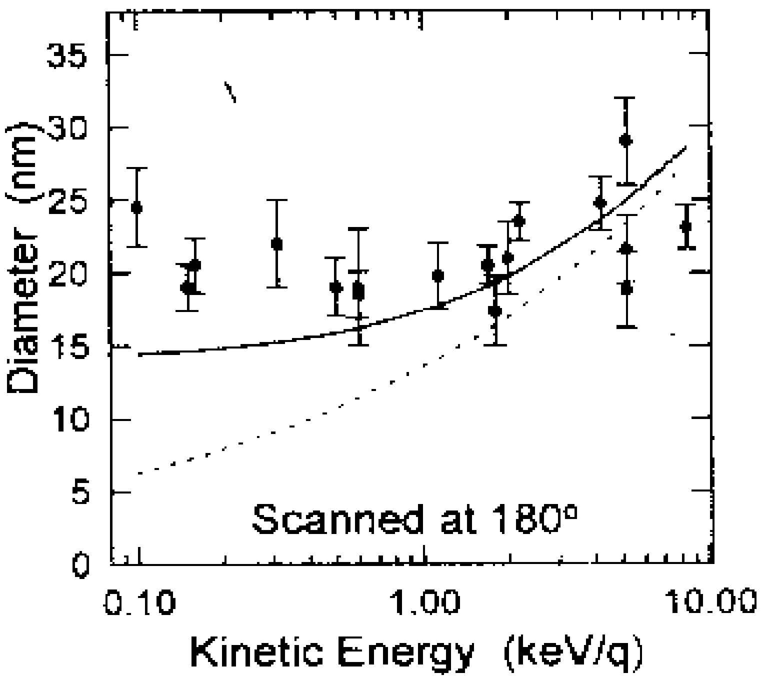


T. Schenkel *et al.* NIM B 125 (1997) 153 - 158

Both increase dramatically with charge state

The single ion damage zone size varies strongly with potential energy...



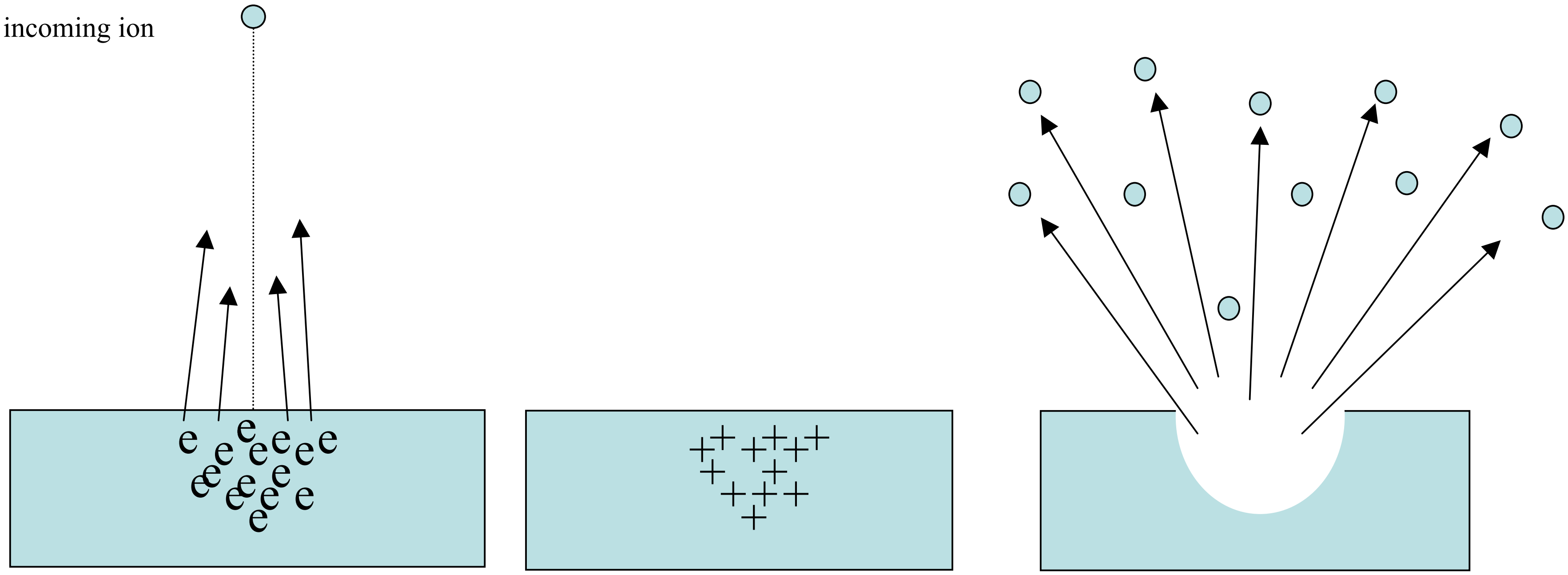


Parks *et al.*, JVST B 13(3), p. 941 (1995)

… but very weakly with kinetic energy.

Coulomb explosion model:

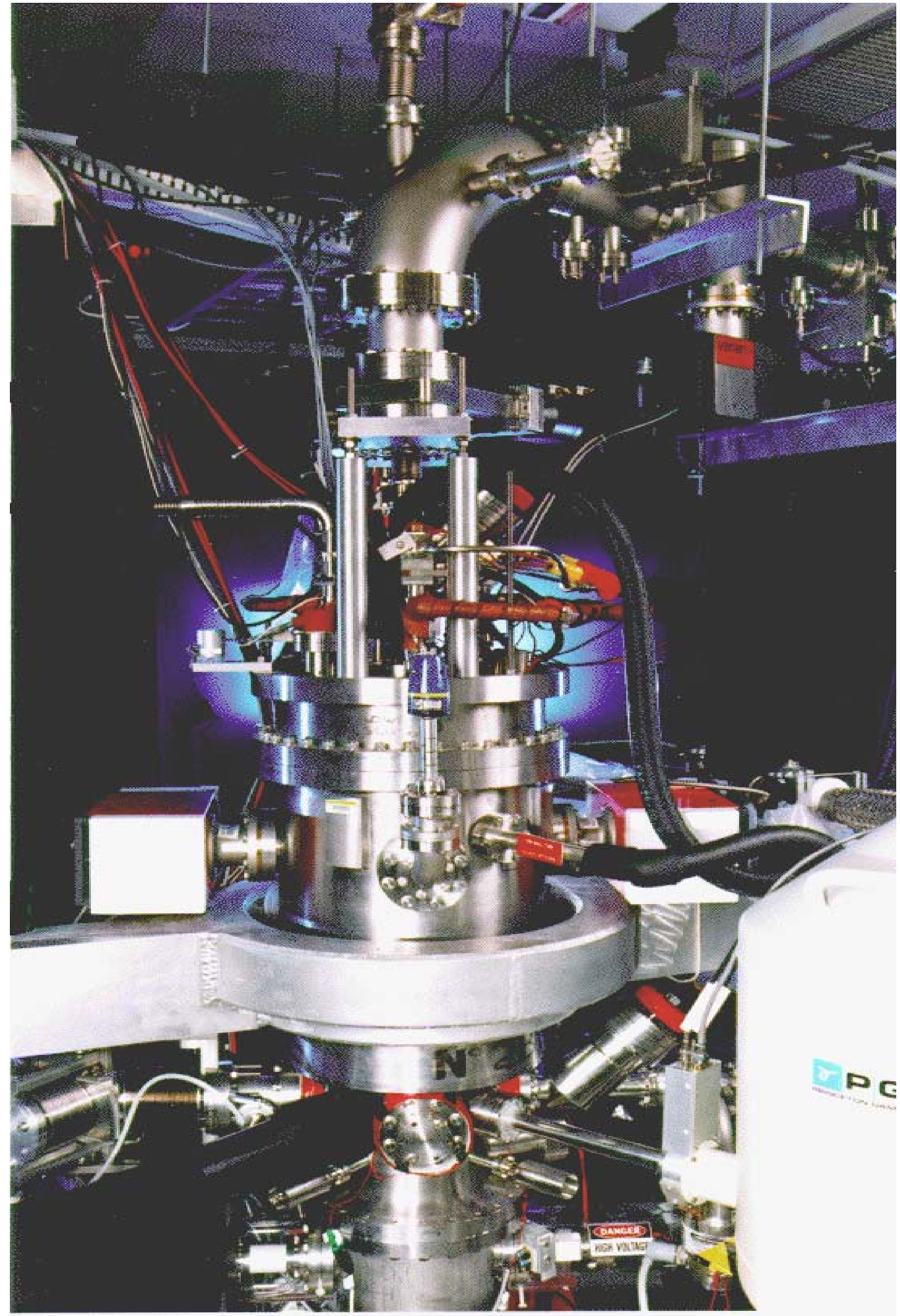
- A single ion removes a large number of electrons from the surface.
- If they can not be replaced from the bulk, a charge imbalance develops.
- The surface explodes!
- Leaving a crater.

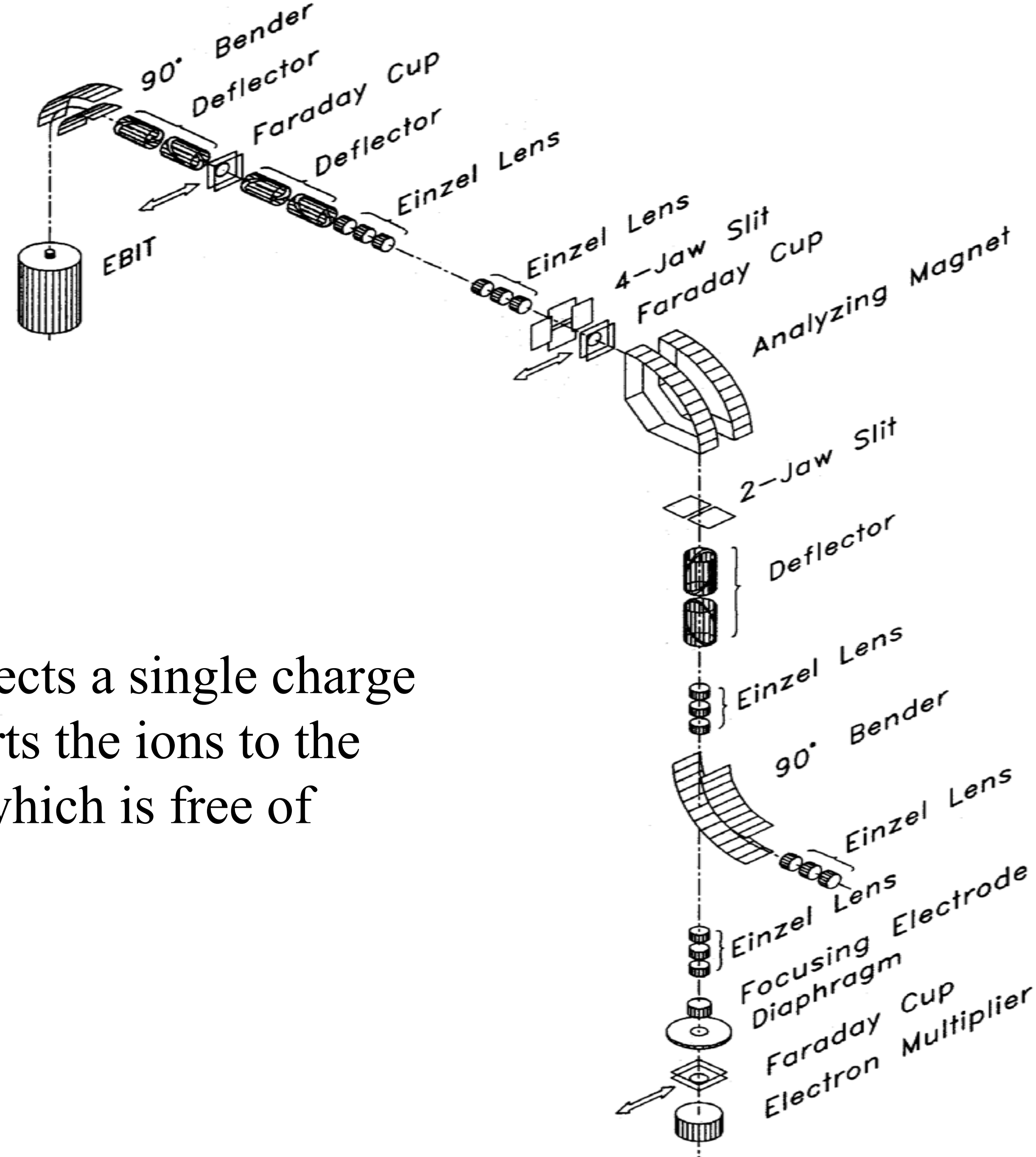


Experimental Approach

- Expose smooth, well characterized, surfaces with xenon ions of various charge states.
- Use scanning probe microscopies to characterize the damage.

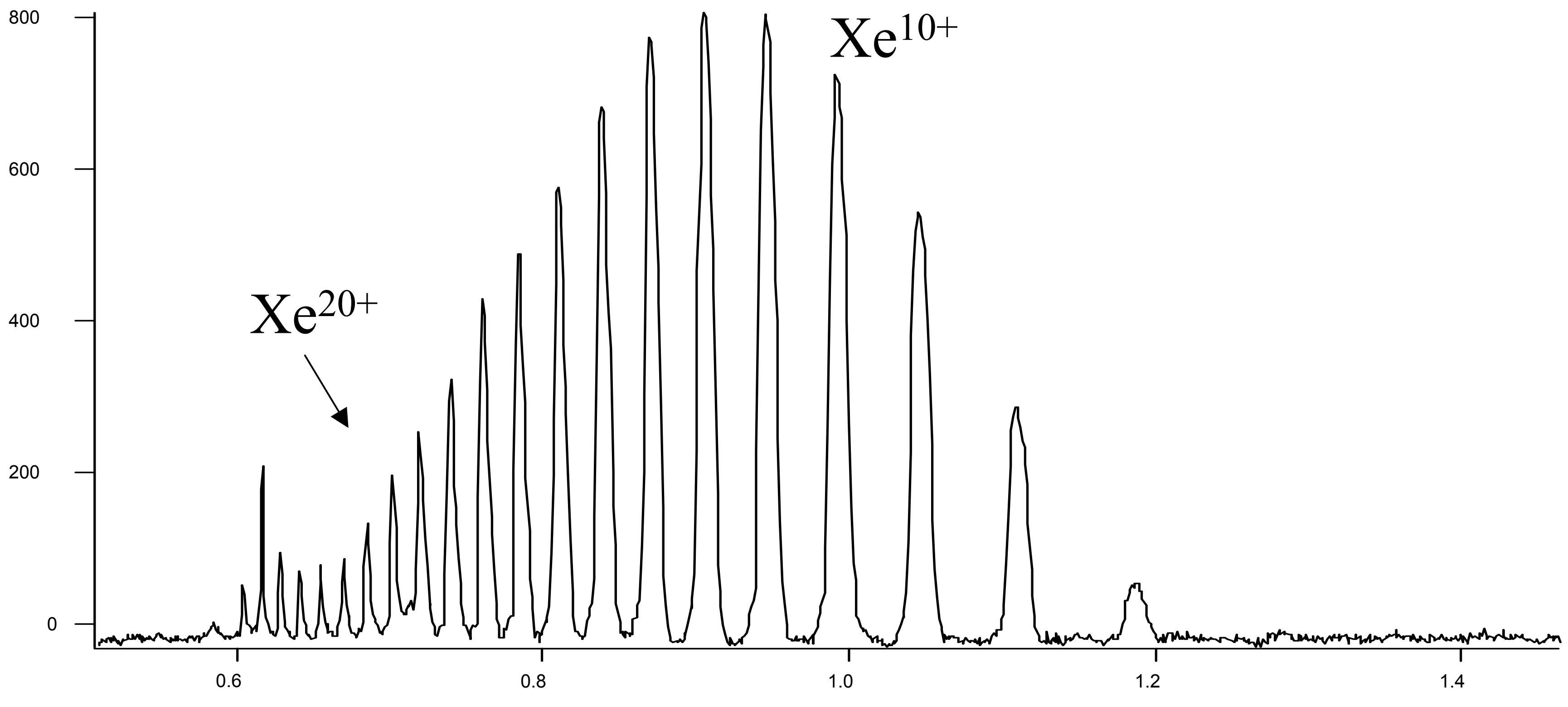
- The EBIT, electron beam ion trap, makes ions of virtually any mass and charge state.

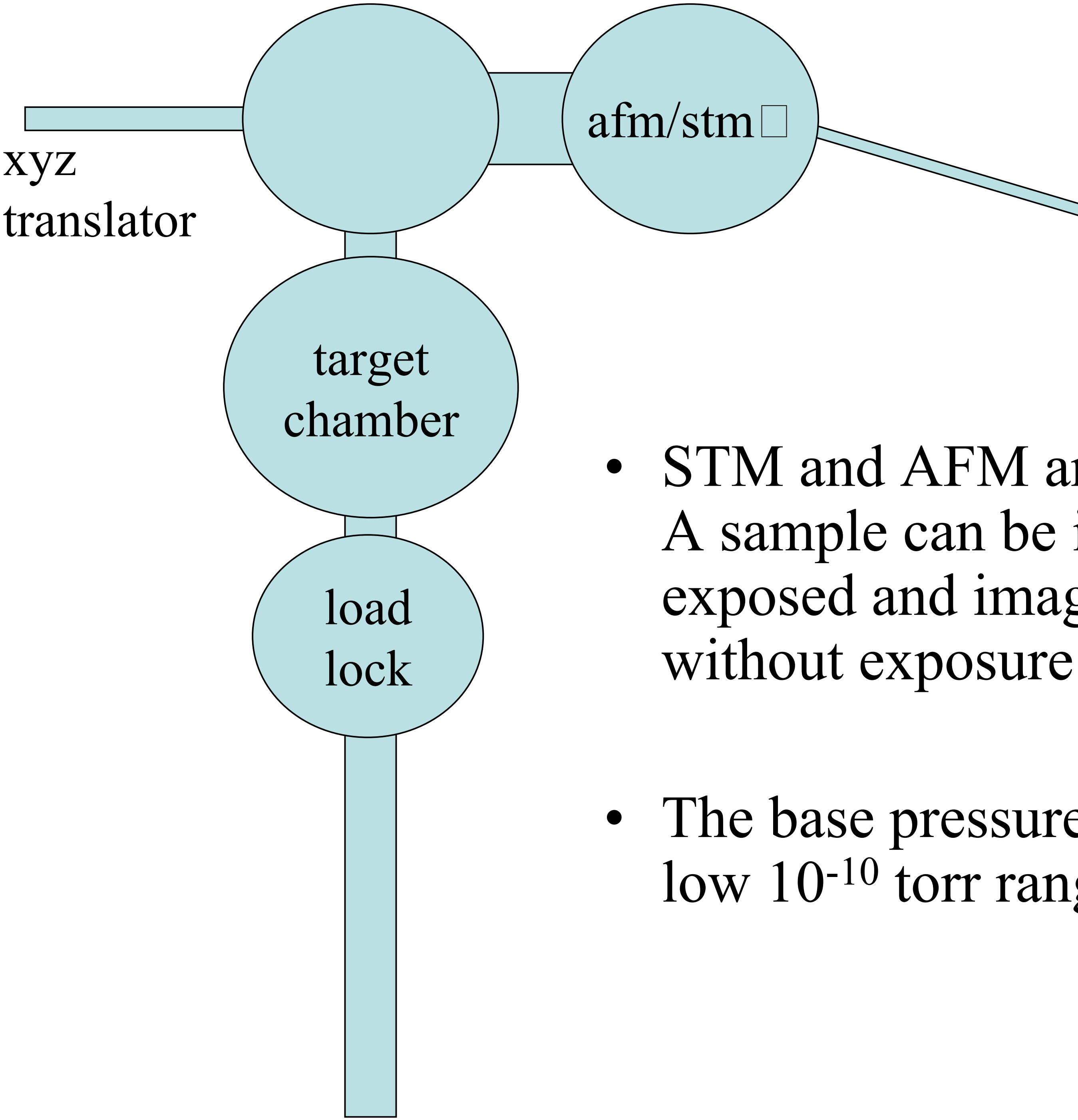




The beamline selects a single charge state and transports the ions to the target chamber, which is free of photons.

By scanning the analyzing magnet, and looking at the the current at the end of the beam line, we get a charge state spectrum of the ions in the EBIT

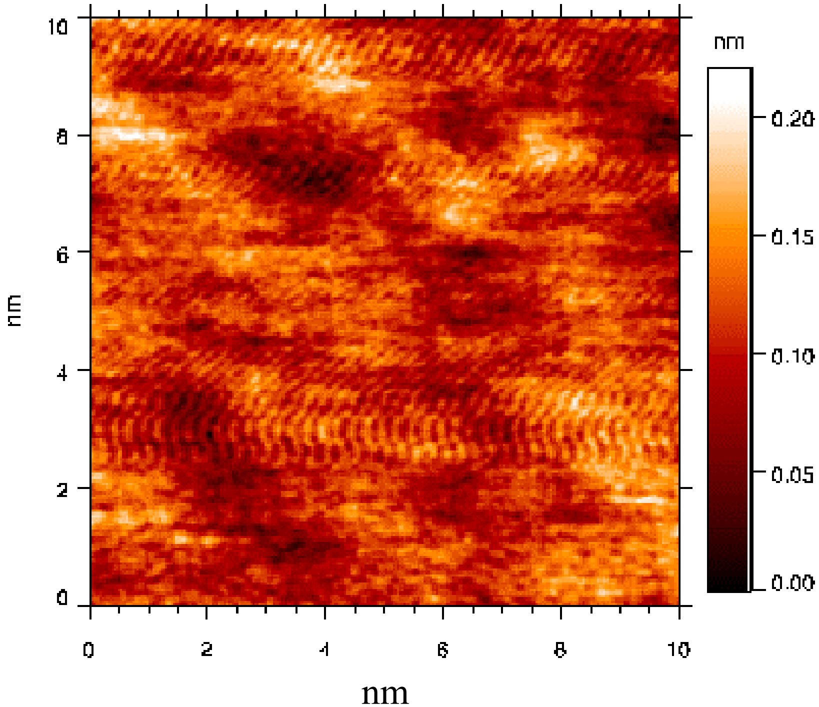




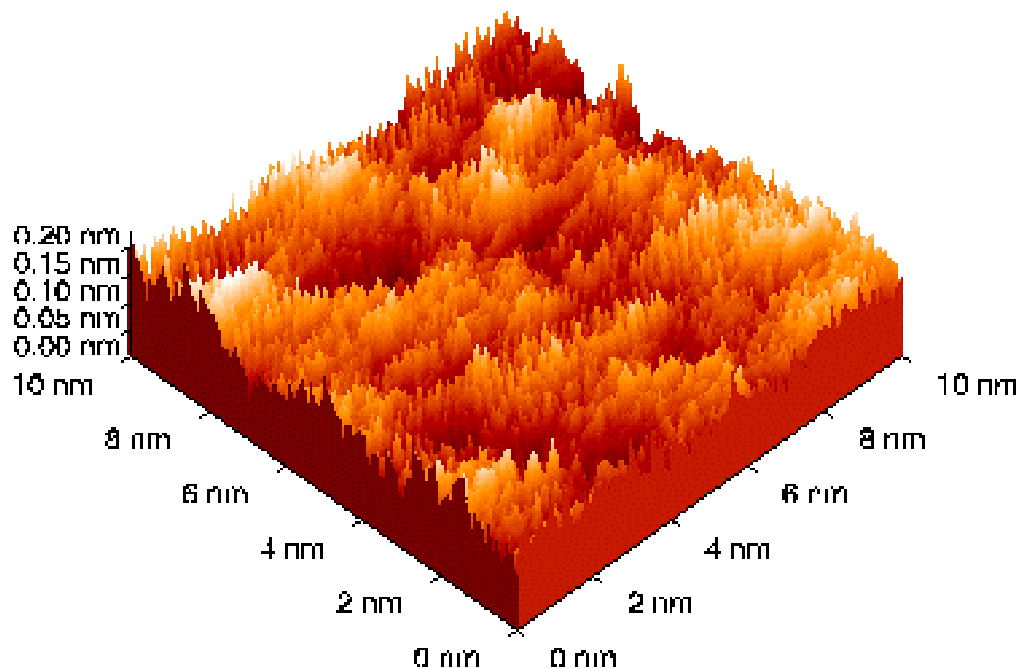
- STM and AFM are *in situ*. A sample can be imaged, exposed and imaged again without exposure to air.

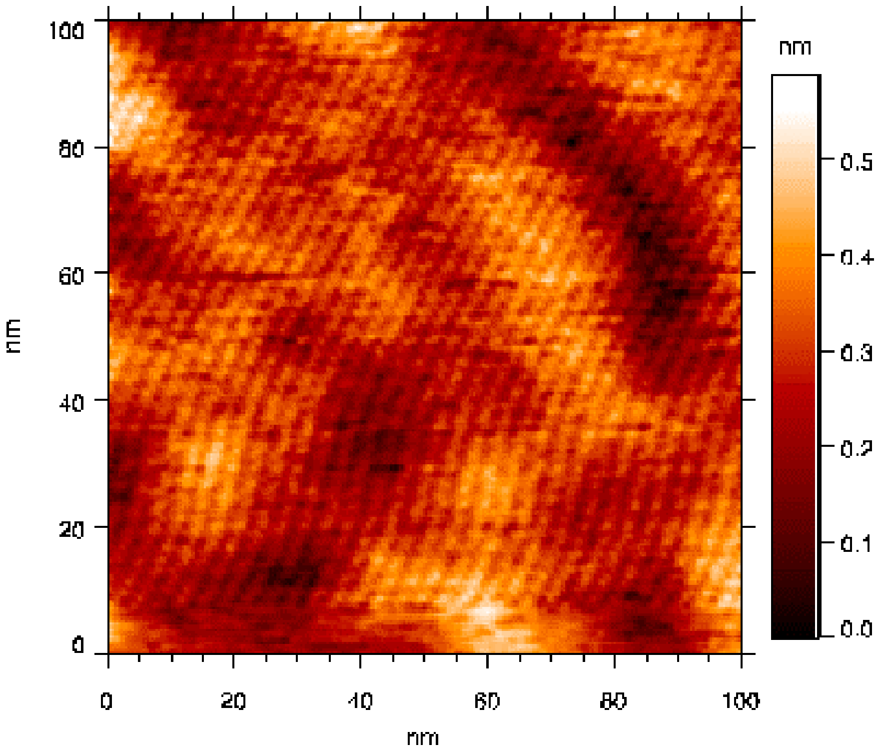
- The base pressure is in the low 10^{-10} torr range.

Preliminary results

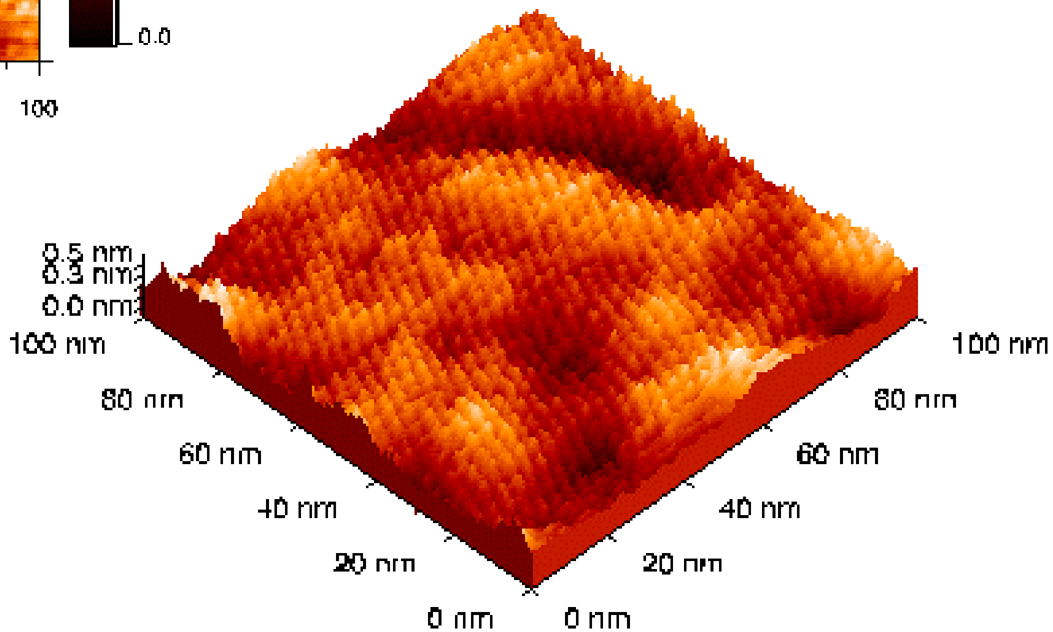


Baseline images of ruthenium coated multilayers provided by S. Bajt, LLNL
RMS roughness less than 2 angstroms

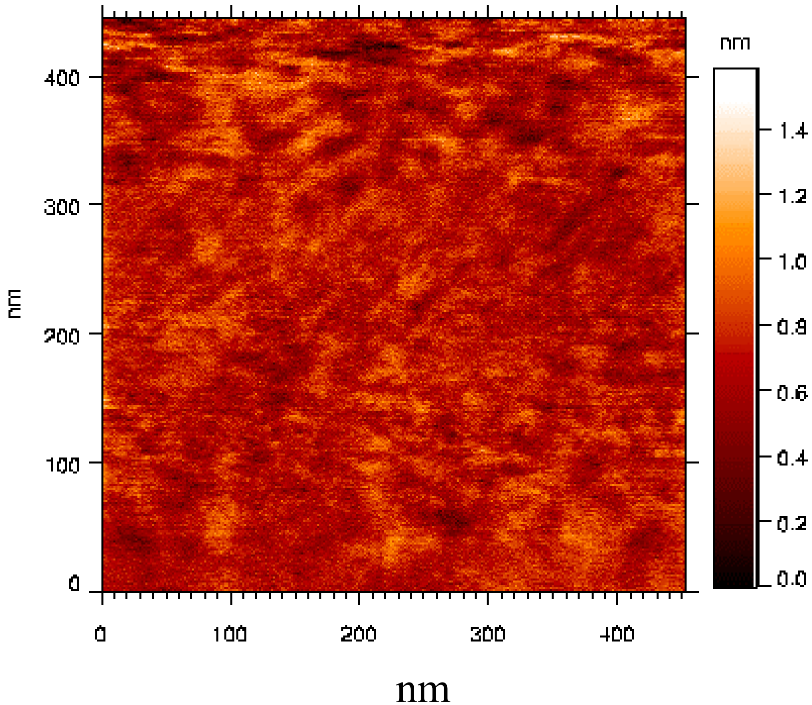


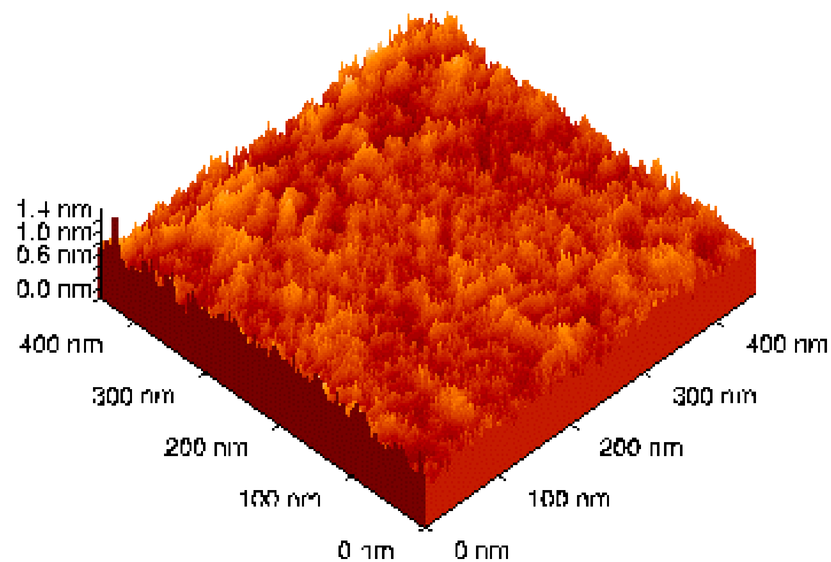


100 nm images of ruthenium coated multilayers



450 nm images of ruthenium coated multilayers





Within the next month we will begin to expose ruthenium-capped mirrors with multiply-charged xenon ions in the range, q = 6 - 18

Tungsten surfaces be studied next.