Effects of Multiple Energy $^4$He$^+$ Bombardment on Cathode Materials Such As W at High Temperatures
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Introduction & Motivation
- Will the W cathode grid wires in IEC devices be eroded as atomic and molecular ions and neutrals of various energies bombard them?
- How much erosion by ion-impact sputtering of the W occurs?
- Mono-energetic $^4$He$^+$ ions cause subsurface damage to W surfaces, producing sharp points that can contribute to high voltage breakdown across IEC cathode grid wires, resulting in a lower maximum cathode voltage and lower fusion rates.

MITE-E
- MITE-E is used to simulate fusion reactor conditions by irradiating metal samples with He or D under specific conditions:
  - Temperature ranges from 500 to 1000°C.
  - Ion energies from 10 to 60 keV with ion currents of 200 ± 10 μA.
  - Fluence ranges of 1.0x10$^{21}$ to 1.0x10$^{23}$ ions/m$^2$.
- A variable power Nd:YAG laser provides the sample heating.
- Sample sizes are ~ 1cm x 1cm x 1mm.
- Physical changes in a sample are analyzed with theFocused-Ion Beam, Scanning Electron Microscope, Electron Backscatter Diffraction, and mass loss measurements.

Ion Impact Damage to W
- Two PCW samples were irradiated with mono-energetic $^4$He$^+$ ions and suffered significant mass loss; some grains did not display severe damage.
- One PCW sample was irradiated with 10, 20, and 30 keV $^4$He$^+$ ions in sequence to a fluence of 1x10$^{22}$ ions/m$^2$; all grains exhibit surface damage.
- Erosion of grains can be seen with increasing fluence. Grains of the [111] orientation appear to be less eroded than the surrounding grains.

Conclusions
- The multiple energy bombardment with $^4$He$^+$ ions causes more He to be trapped in the W lattice leading to greater erosion rates and more damage of the PCW on all grains.
- At high temperatures this trapped He is allowed to diffuse and escape through the surface leaving a “grass” structure behind.
- This surface structure has sharp points that can contribute to:
  - a high voltage breakdown across IEC cathode grid wires,
  - a lower maximum cathode voltage achievable, 
  - and lower fusion rates.
- W grid wires are not highly resistant to particle damage as they suffer a mass loss with increasing fluence.
- Multiple energy bombardment creates highly eroded surfaces on all grains of PCW; due to this there is no orientation that is completely radiation resistant.

Mass Loss
- Sample areas are 5.03 x 10$^{-5}$ m$^2$.
- $^4$He$^+$ ions eroded the multiple energy sample as much as the mono-energetic sample irradiated to the sample fluence.

References