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Manufacturing of void-filled cathodes for breakdown experiments

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Background

- Theoretical and simulational work at the University of Helsinki indicates that the presence of voids (diameter: a few nm) near the surface of a cathode are a significant contributor to the mechanism of vacuum breakdown

- To validate these results experimentally, we are manufacturing samples with voids in Helsinki to be used for breakdown experiments in the DC spark setups at CERN

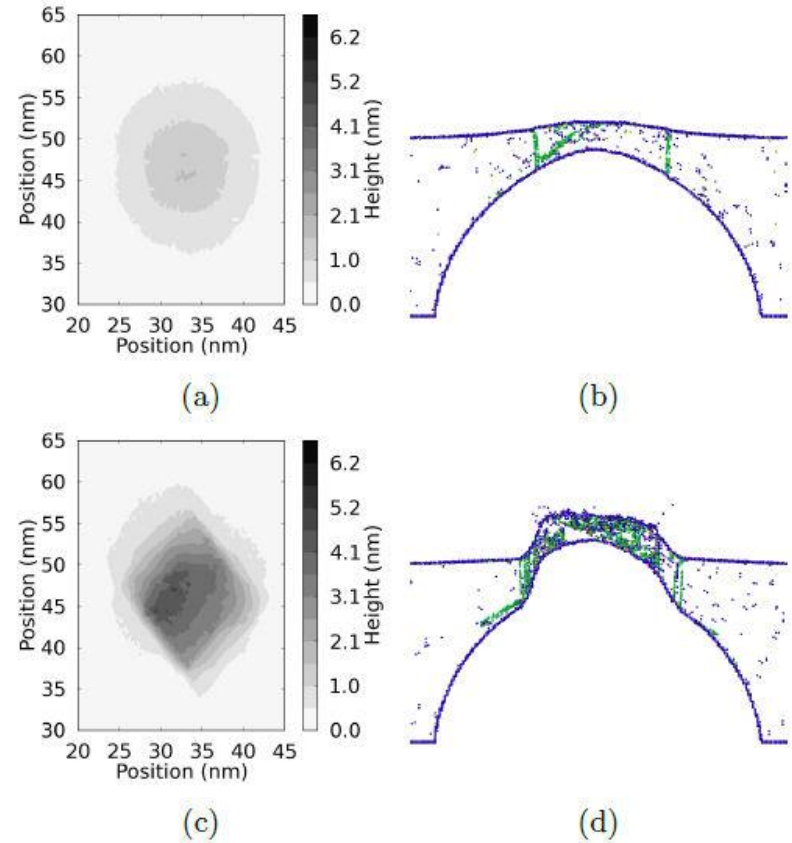


FIG. 3: a) and b) show the top view and a slice of the system at time $t = 114.0$ ps when stacking faults have formed. c) and d) show the same, at time $t = 130.1$ ps when stacking faults are clearly visible. Evaporated atoms are not shown in a) and c) for clarity.

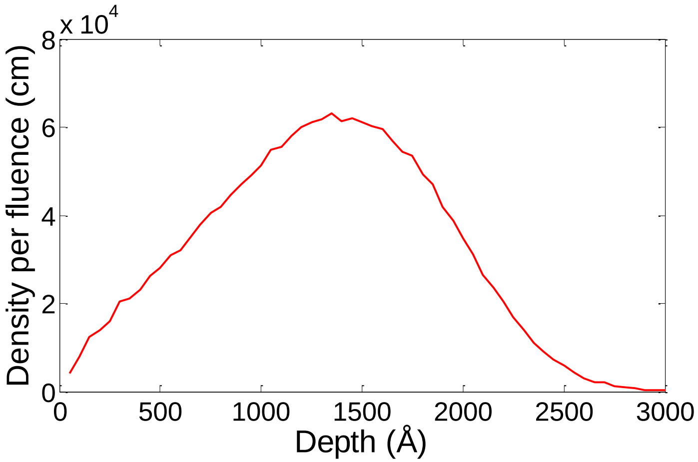
Pohjonen et al, University of Helsinki

Overview

- Overview of process
  - Irradiation: Introduce He^+ into sample with an ion implantation accelerator
  - Annealing: Heat the sample to get the He^+ to nucleate into bubbles, then leak out, leaving empty voids behind
- Status quo: Irradiation done. To anneal or not to anneal, and how?
- Means at our disposal
  - Ion implantation accelerator
  - Annealing oven including a mass spectrometer
  - Positron annihilation spectroscopy lab (at Aalto University)

Irradiation

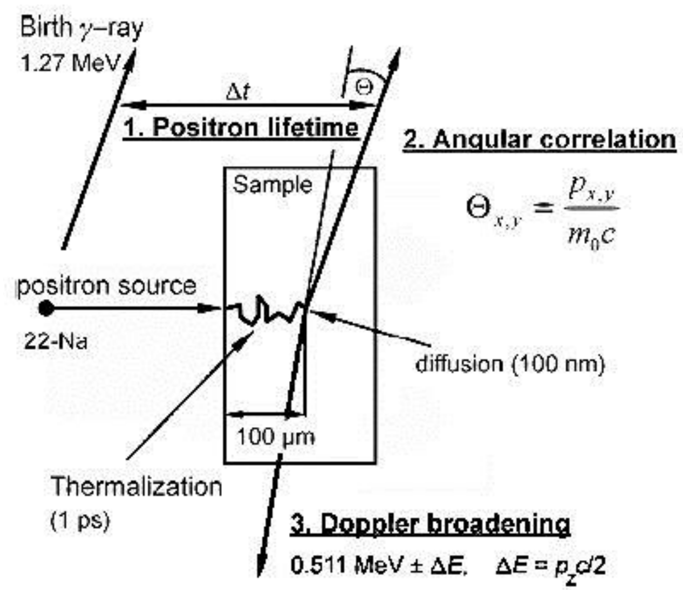
- Samples are 12 copper cathodes manufactured at CERN: Annealed, diamond-turned and solvent-cleaned
- Irradiation (30 keV He^+ beam) was simulated using SRIM:
- A dose of ~30 atom% is known as the limit where blistering of the surrounding copper matrix happens
- Hence, the dose was chosen to give 5 atom% at most common stopping depth
- Half of each sample was irradiated while the other half was covered to provide a clean, un-irradiated reference for comparison



SRIM simulation of He ion implantation into Cu sample, ion energy of 30 keV

Positron annihilation spectroscopy

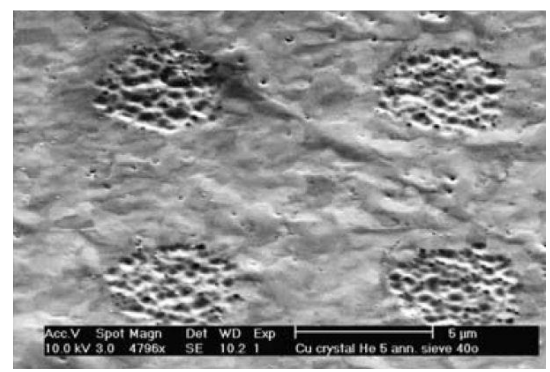
- Two samples were sent to the positron lab, measurement took place ~ 3 months after irradiation
- Overview of PAS:



- Result: Clear difference between irradiated and reference side, vacancy clusters already detected at ~25 nm depth. Size of clusters at least ~10 missing atoms, possibly a lot larger

Annealing

- Strength with which a He^+ is tied to a bubble increases with bubble size
  - The larger the bubble, the higher the temperature needed to make He^+ escape
  - Ostwald ripening: Net diffusion of He^+ from smaller to larger bubbles, the larger devour the smaller
- Desired outcome of annealing: Make He^+ consolidate into larger bubbles, then leak out of the sample
- Risk with annealing: Rupturing of the surface of the sample, cave-in of voids near surface



Ruptured ”microsieve” surface due to helium escape, Galindo et al 2004

Proposed annealing protocol

- Put the mass spectrometer and the thermostat of the annealing oven in a feedback loop:
  - If no He^+ comes out, increase temperature
  - If He^+ comes out, decrease temperature
  - Stop when temperature has been at an upper limit for a given time, and no more He^+ has come out during it
- Rationale
  - Only the least tightly bound He^+ move, causing the smallest bubbles present at any time to evaporate while keeping the larger intact
  - Rate at which He^+ exits the sample is at an achievable minimum, minimizing risk of surface damage