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Empirical study of the effect of cathode voids on breakdown rate

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Background

- Simulation work (Aarne Pohjonen, Stefan Parviainen, image on the right) suggests that voids under the surface of the cathode contribute to breakdown rate: The combination of a void and an electric field cause protrusion growth above the void
- We want to test this result by manufacturing void-filled electrodes and measuring their breakdown rate

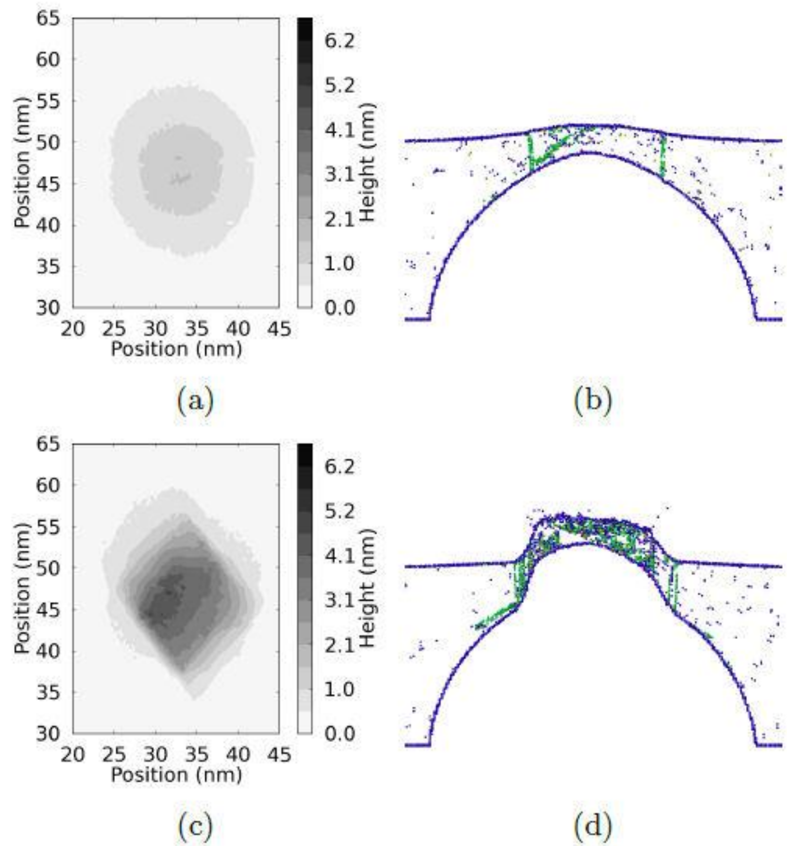


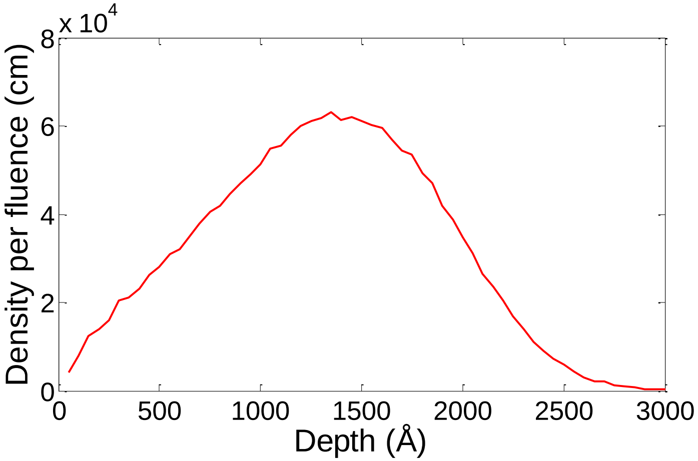
FIG. 3: a) and b) show the top view and a slice of the system at time $t = 114.0$ ps when stacking faults have formed. c) and d) show the same, at time $t = 130.1$ ps when stacking faults are clearly visible. Evaporated atoms are not shown in a) and c) for clarity.

Sample manufacturing

- 12 copper discs (diameter 1.7 cm) were manufactured and pre-processed at CERN, then sent to Helsinki

- Overall (original) plan:
  - Inject He^+ into samples using ion implantation accelerator
  - Anneal samples to get the He to nucleate into larger bubbles (voids), and to let it out
  - Confirm successful manufacture through positron annihilation spectroscopy

Irradiation



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

- Relationship between implantation depth and ion energy was studied with SRIM:
- Irradiation of samples was conducted using ion energy of 30 keV, dose chosen to yield 5 atom-% He at most common stopping range
- Each of the 12 samples had half of it masked with aluminium tape to provide a control sample
- Possible impurity issue caused by evaporating glue

Status quo

- After implantation, two samples were sent to the positron spectroscope at Aalto University
- Result: Void size decreases monotonously with depth, close to the surface (≤ 25 nm) lowest estimate of void size 8-10 missing atoms
- Question: To anneal or not anneal? Consensus so far to anneal one sample, do breakdown measurement for the annealed sample and one non-annealed sample; if either gives clearly better results, do that to every sample

Proposed measurement

- Use DC Spark System II. Since voids are likely consumed in the process, little point in going for high rep-rate. Instead, make every spot and every breakdown count
- Do a field emission measurement sweep at first, see if different β between irradiated and pure half
- At each spot, ramp up voltage until breakdown happens, collect statistics on breakdown voltage
- Use into-contact-at-one-spot method for calibrating gap distance control