The Harvey M. Krueger Family Center for Nanoscience and Nanotechnology

האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

Studying dislocations role in nucleating breakdowns

Updates from the Hebrew University

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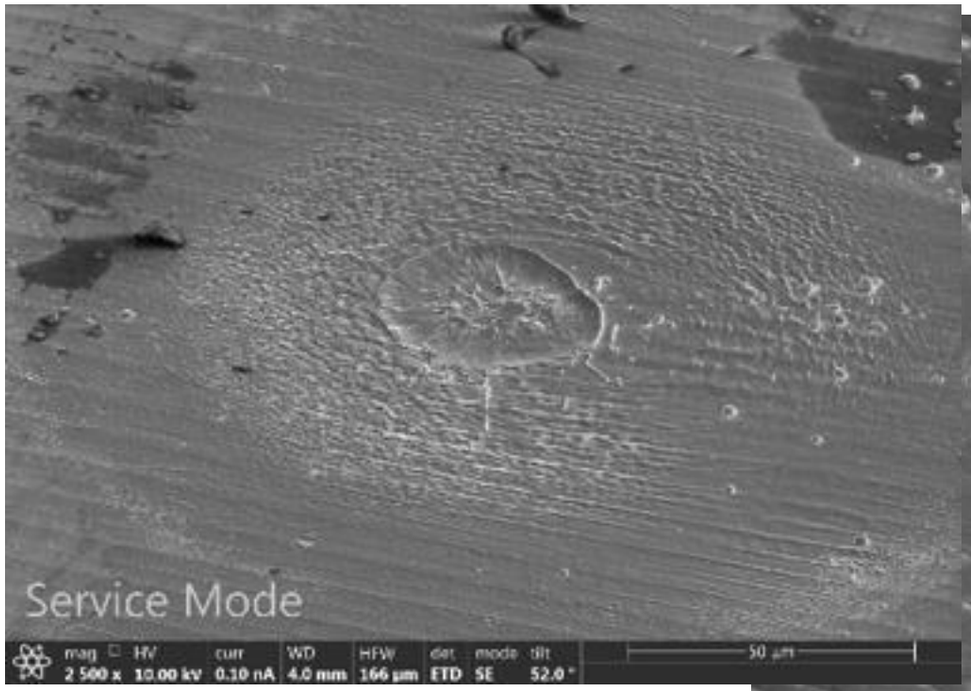
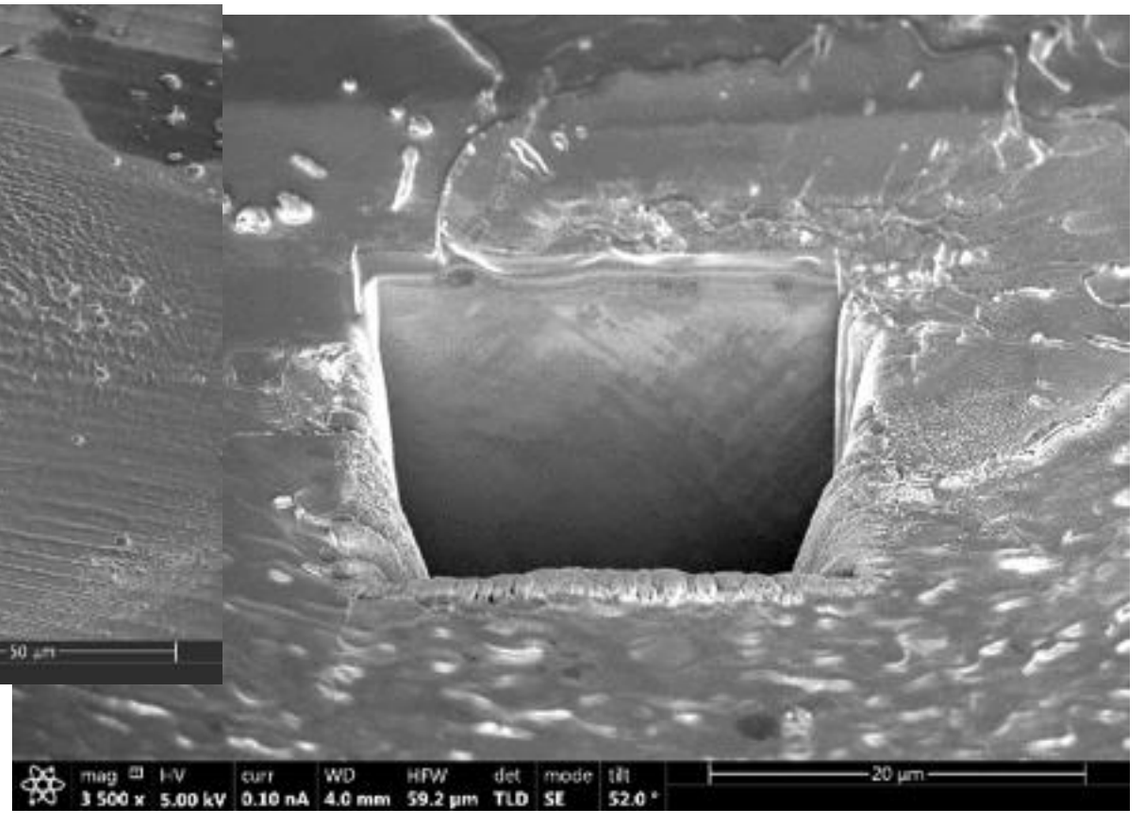
Outline

- Model - Stochastic model for a critical transition driven by dislocation multiplication
- Dark Current measurements - identifying distinct features - proposed features, time + resolution requirements
- Microscopy - SEM + TEM. Identifying tradable quantifiable criterions.
- Acoustic emission - DC setup + Acoustic transducers
- Initial trials at finite element modelling (Elasto-plastic source function)

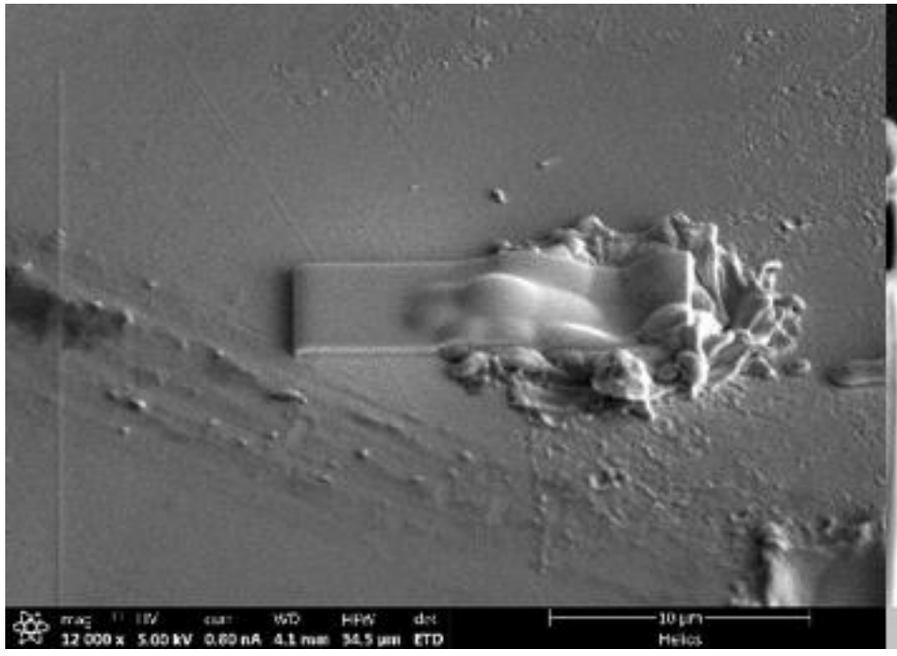
Looking for Sub-Surface damage

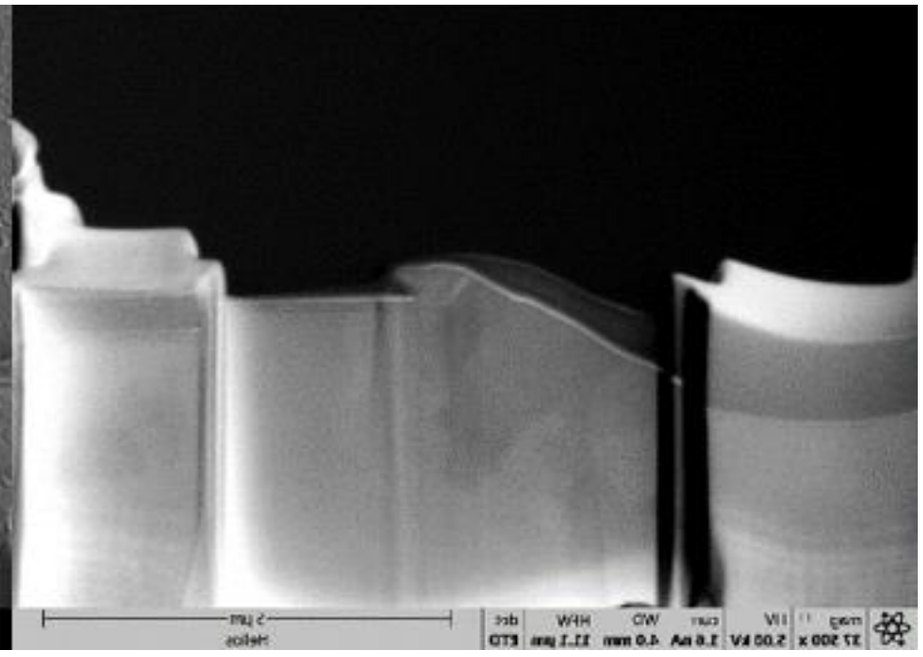
- BD damage



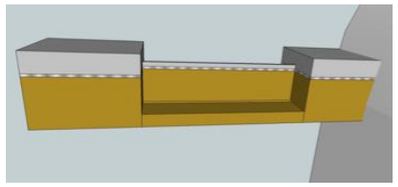


- FIB+TEM





Sample evolution under electric field - Microscopy exposed samples



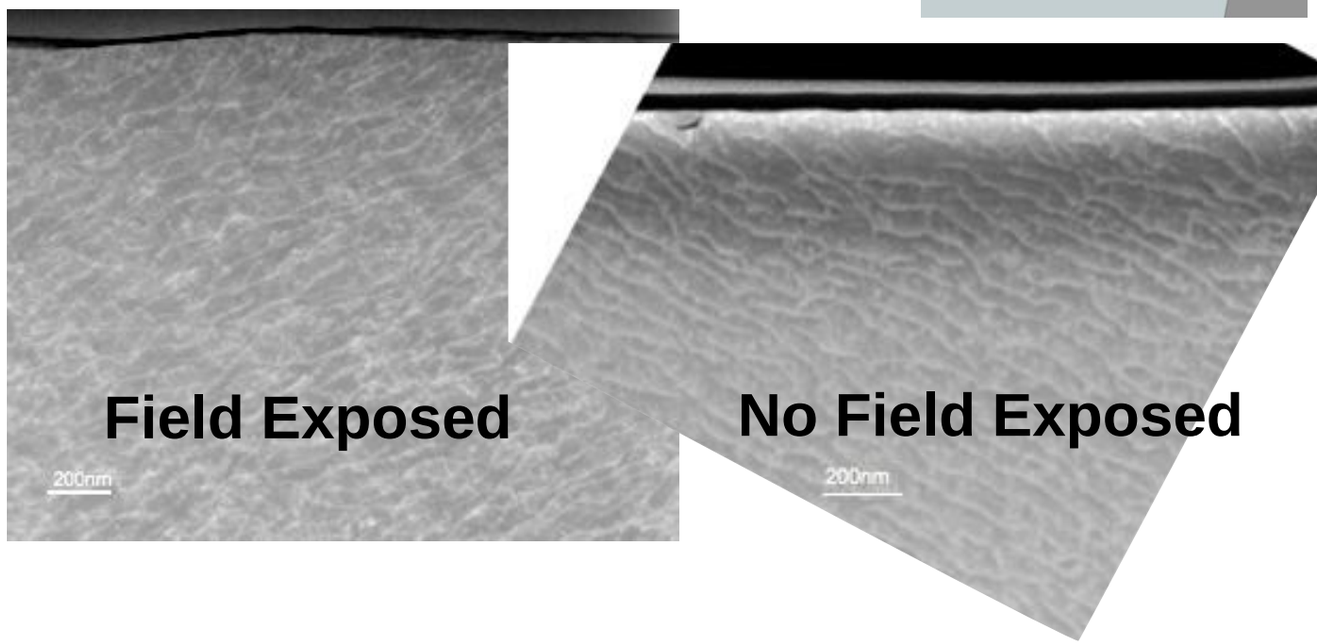
- Establish method for quantifying dislocation content using FIB and STEM measurements

- Main findings:

  - Dislocation densities:

    - Reference soft Cu: ~10^{10} (1/cm^2)

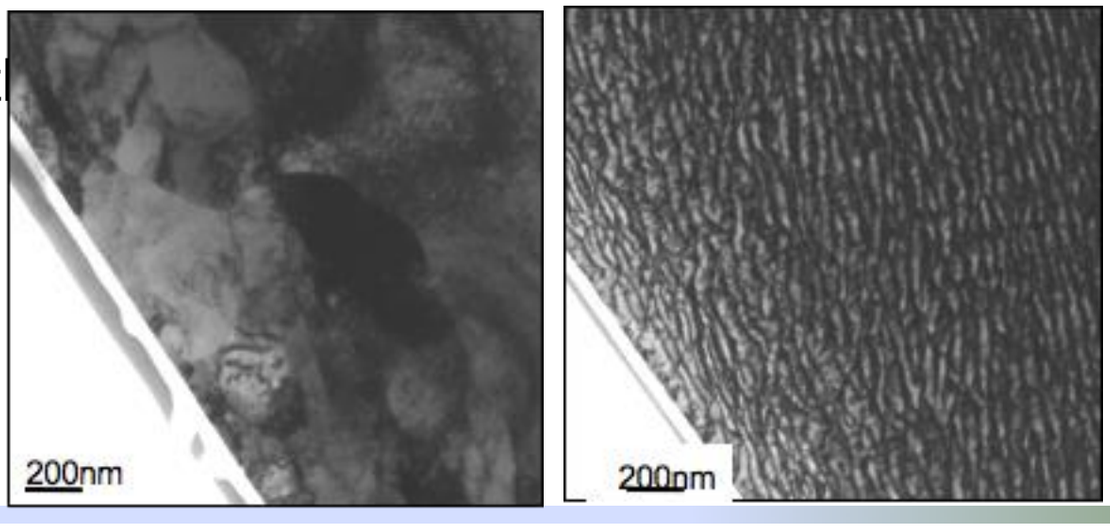
    - RF exposed to Field: ~$2*10^{10}$ (1/cm^2)



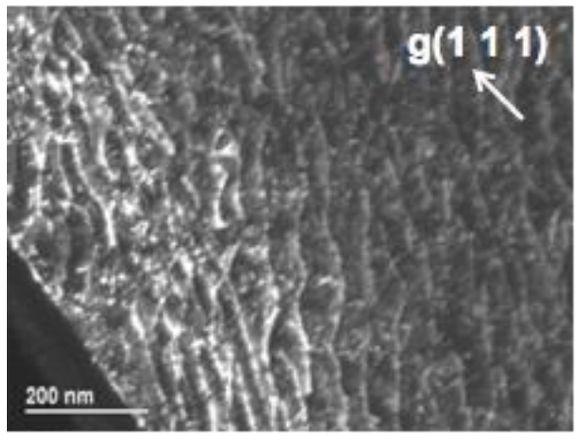
- Thin (~100 nm) hardened high density layer (~$4*10^{10}$ (1/cm^2)) formed after Field exposure.

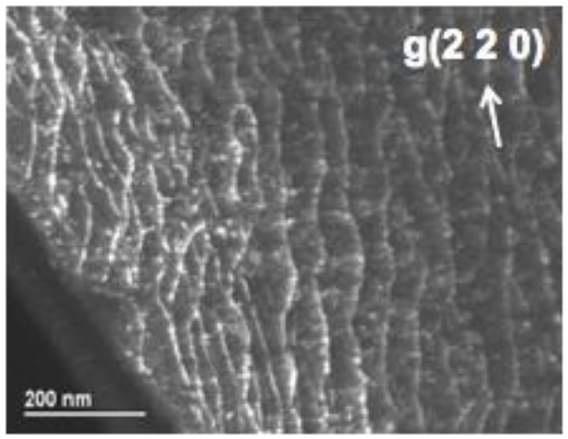
- No identifiable change between response in the various regions of the RF sample - consistent wit “no BD” conditioning.

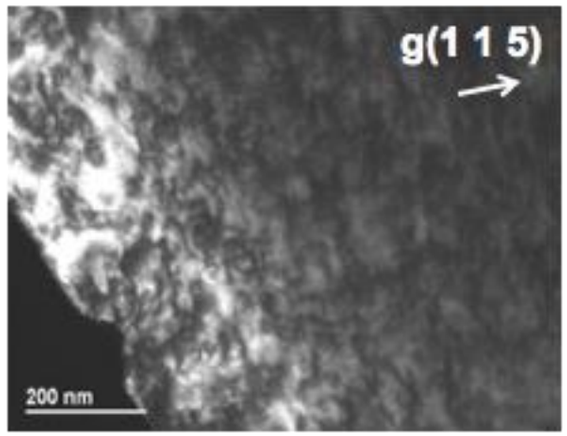
- Hard CU - something completely different.

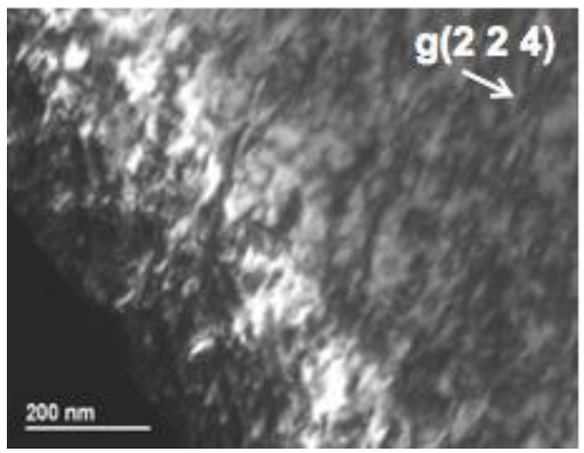


Dislocation identification









Using Two-beam diffraction, only one point in reciprocal space is excited (indicated as g). The points at which the contrast vanishes, is used to identify the burgers vector.

Here for soft Cu reference sample, pattern vanishes at g=(224) and g=(115) indicating a [1-10] burgers vector.

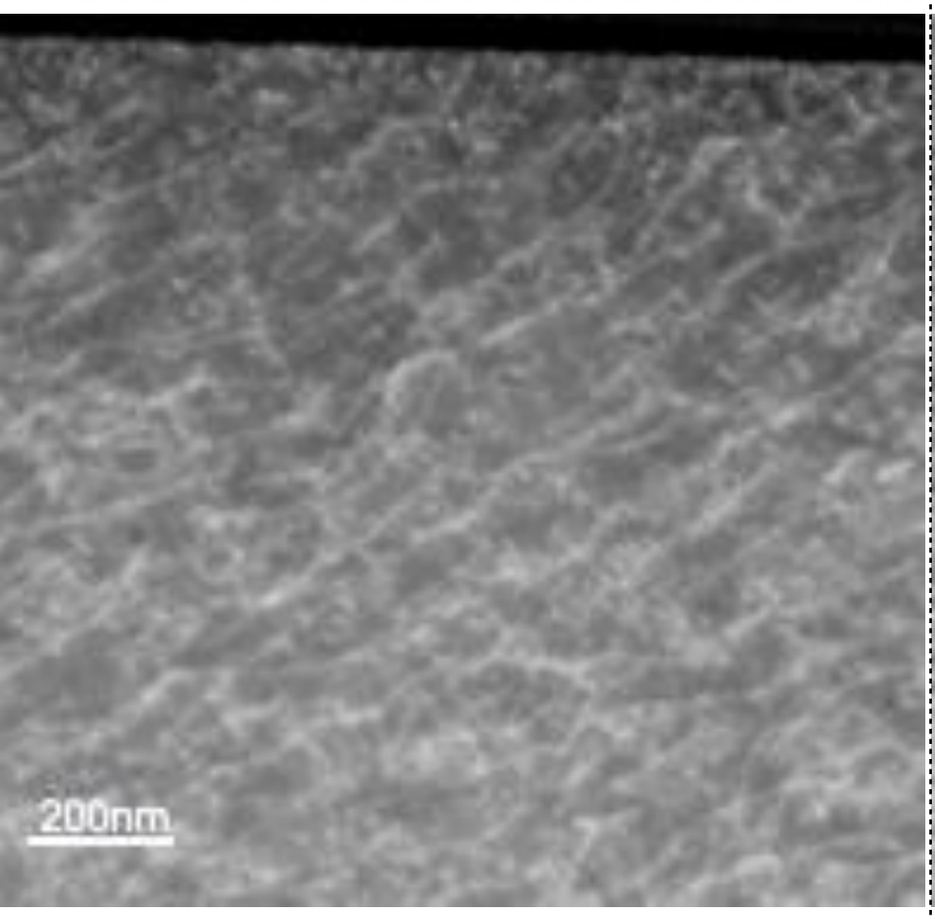
Similar results for all soft Cu samples.

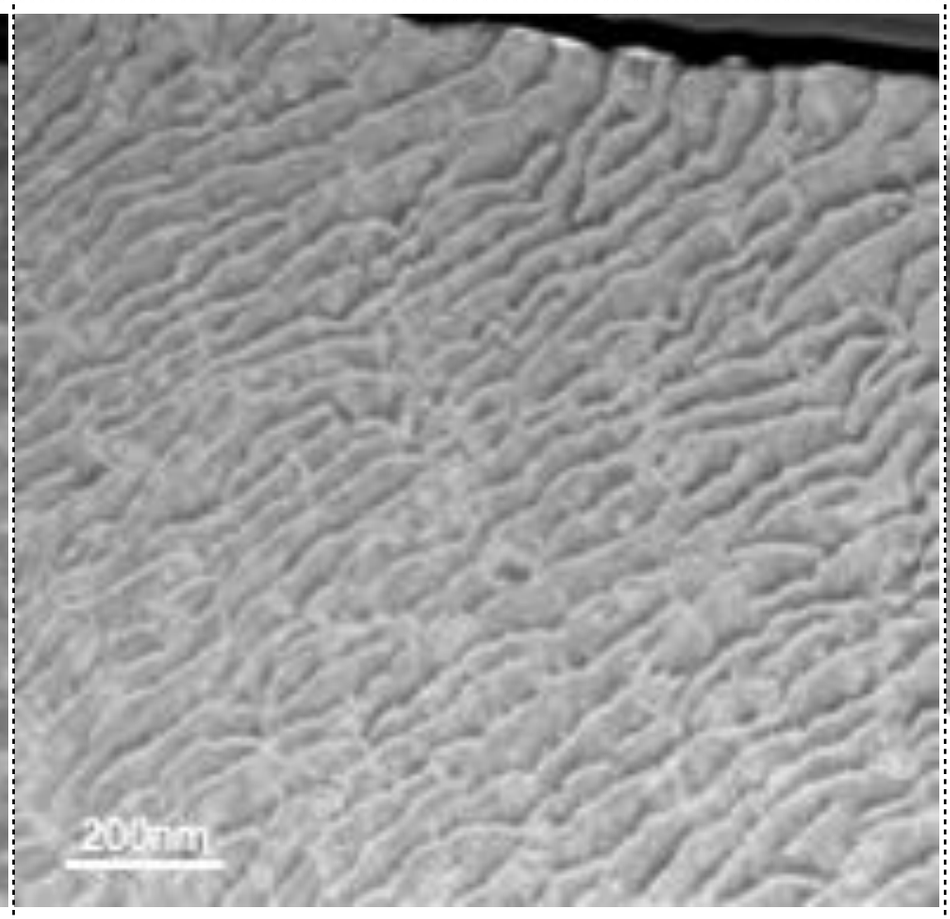
Dislocation structures - Field vs No field (Soft Cu)

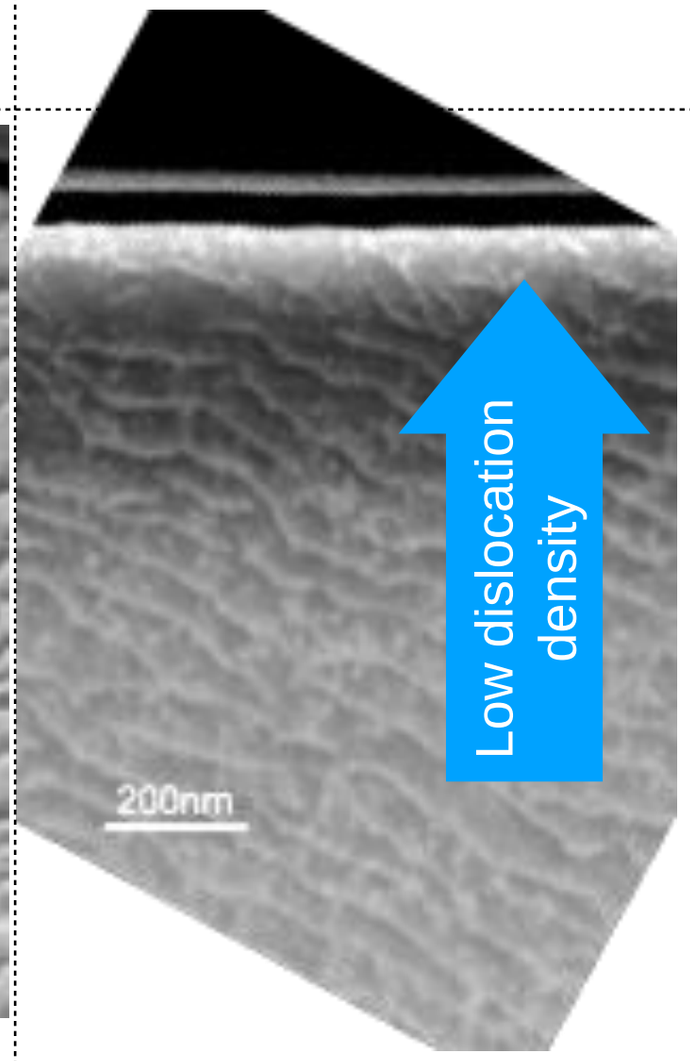
RF Far from Iris

RF Max BD region

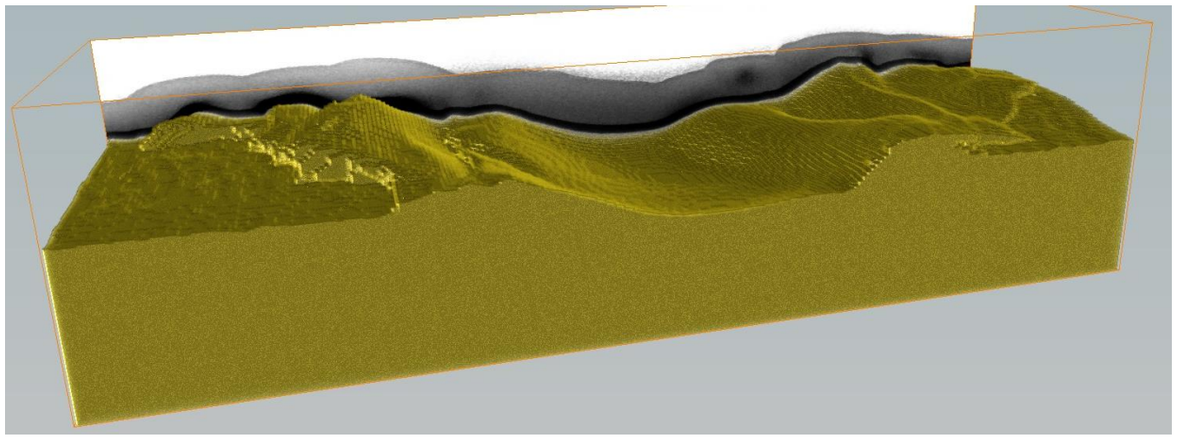
Soft Cu - Reference sample



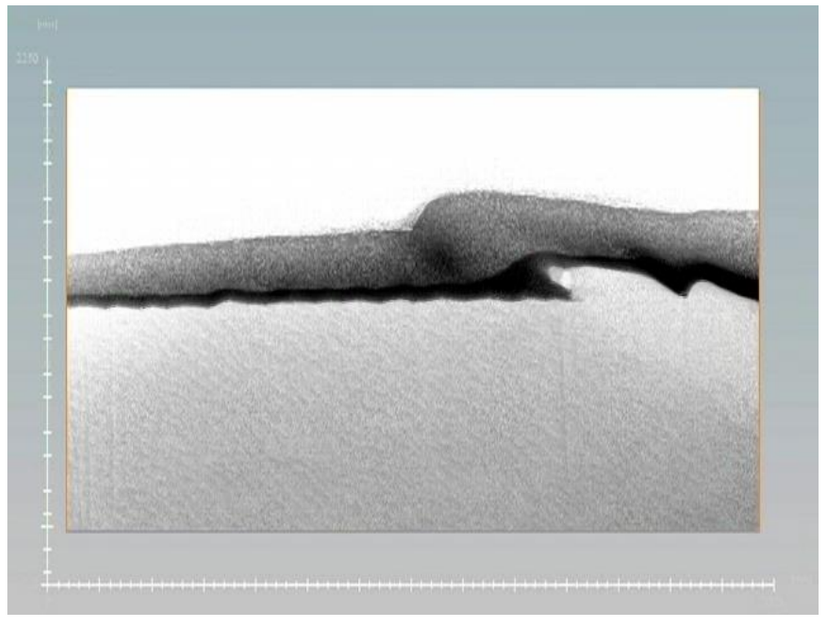


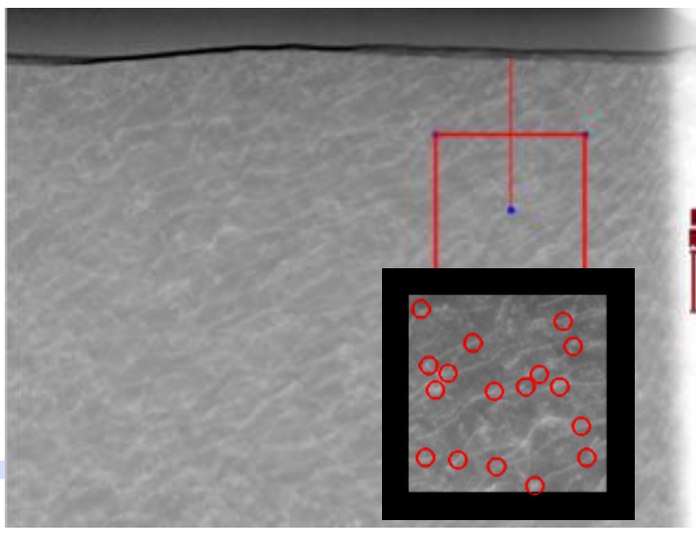


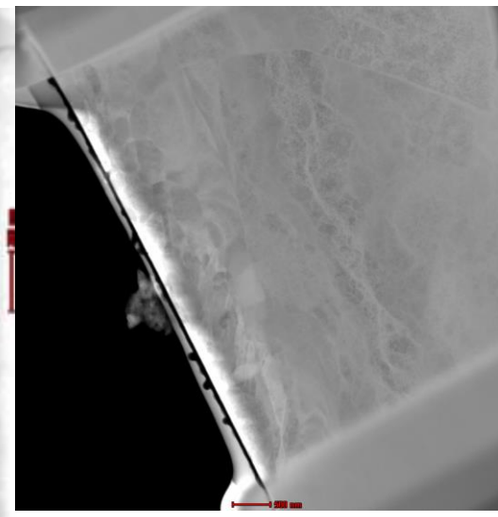
Microscopy cont.



- Fib based tomography:
  - Trials at identifying nature of dislocation structure: filaments? - in progress
  - Trying to establish a quantifiable microscopic property linking hard, soft and alloyed samples using number of junctions?







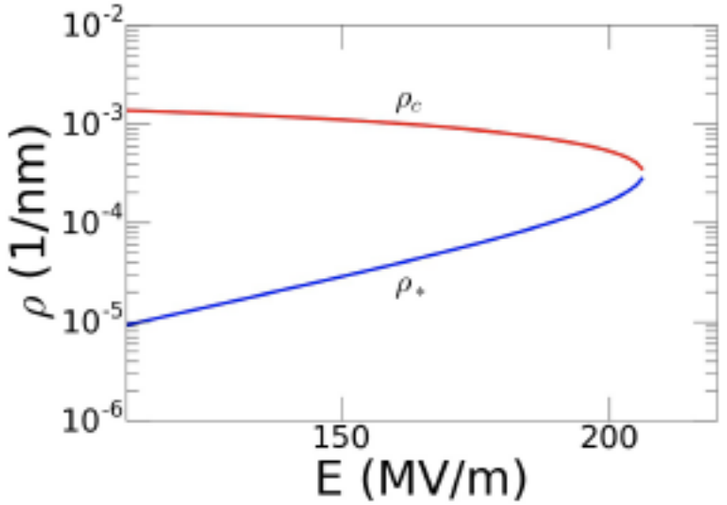
Model reminder

- Describing mobile dislocation population evolution

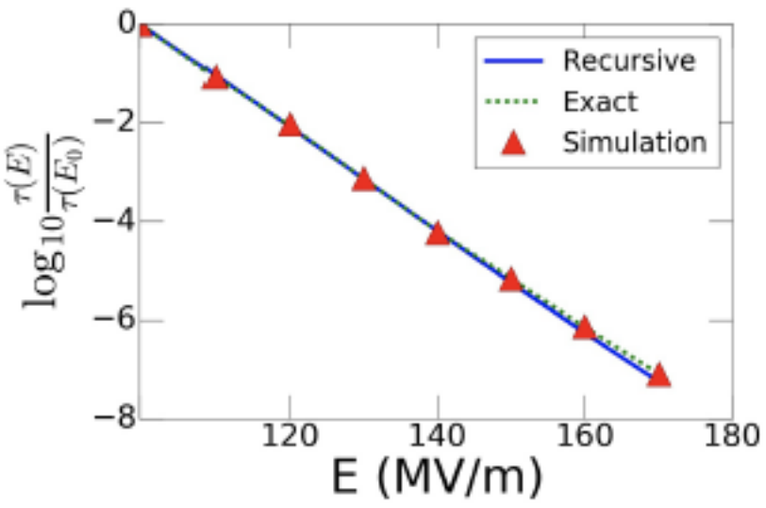
$$\dot{\rho}^{+} = \frac{25\kappa C_t}{G^2 b}(\rho + c)\sigma^2 e^{-\frac{E_a - \Omega\sigma}{k_B T}}$$

$$\dot{\rho}^{-} = \frac{50\xi C_t}{G}\sigma\rho(c + \rho)$$

$$\sigma = \beta\epsilon_0 E^2/2 + ZGb\rho$$



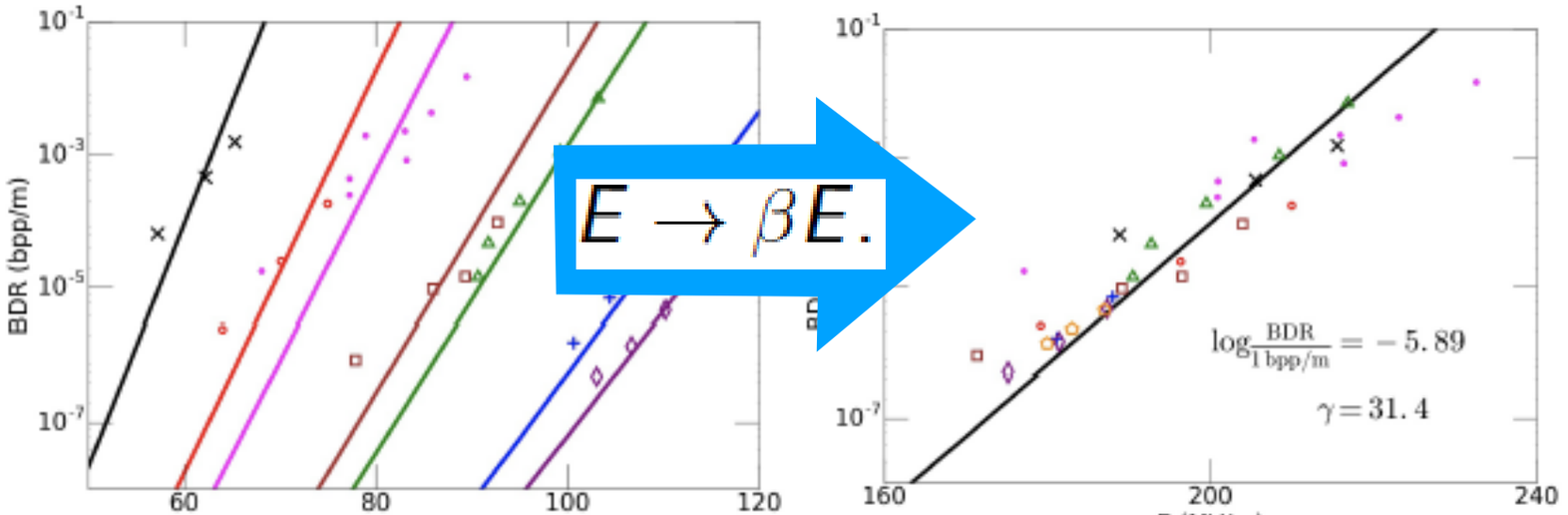
- Leads to an exponential decay



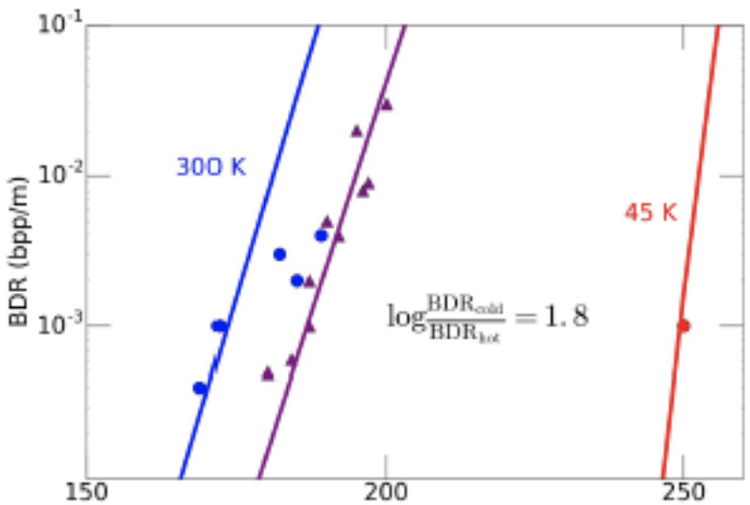
$$\tau \sim e^{-\gamma\frac{E}{E_0}}$$

Model fit

- Describing mobile dislocation population evolution

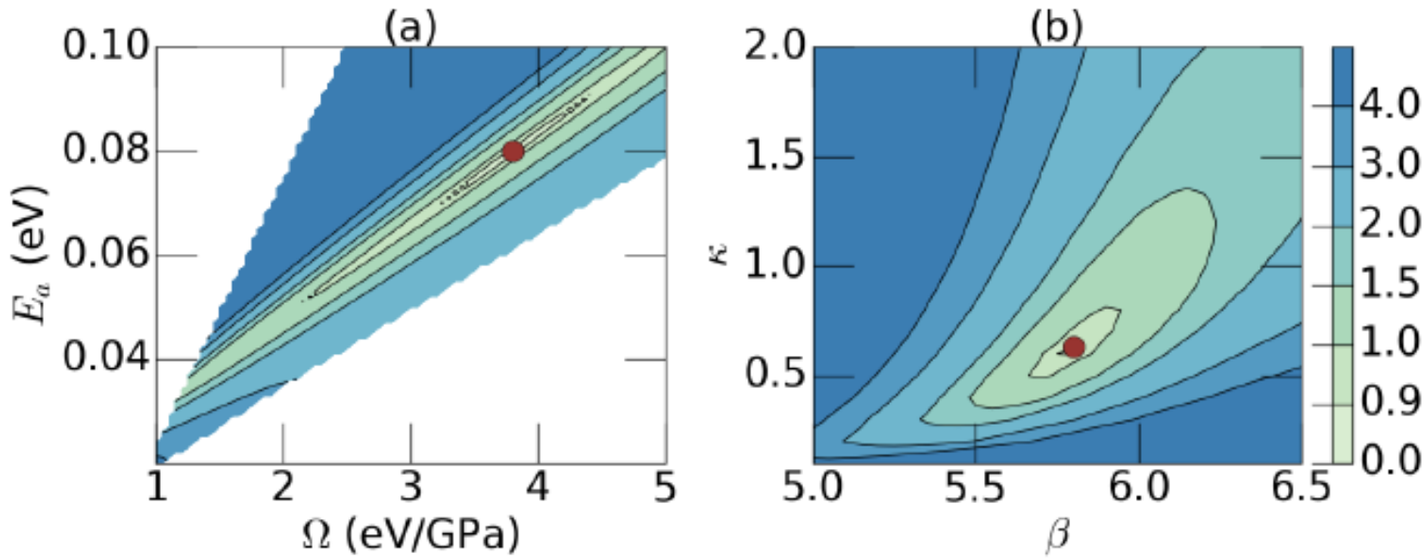


Grudiev et al, PRST-AB 2009



Cahill et al. IPAC 2017

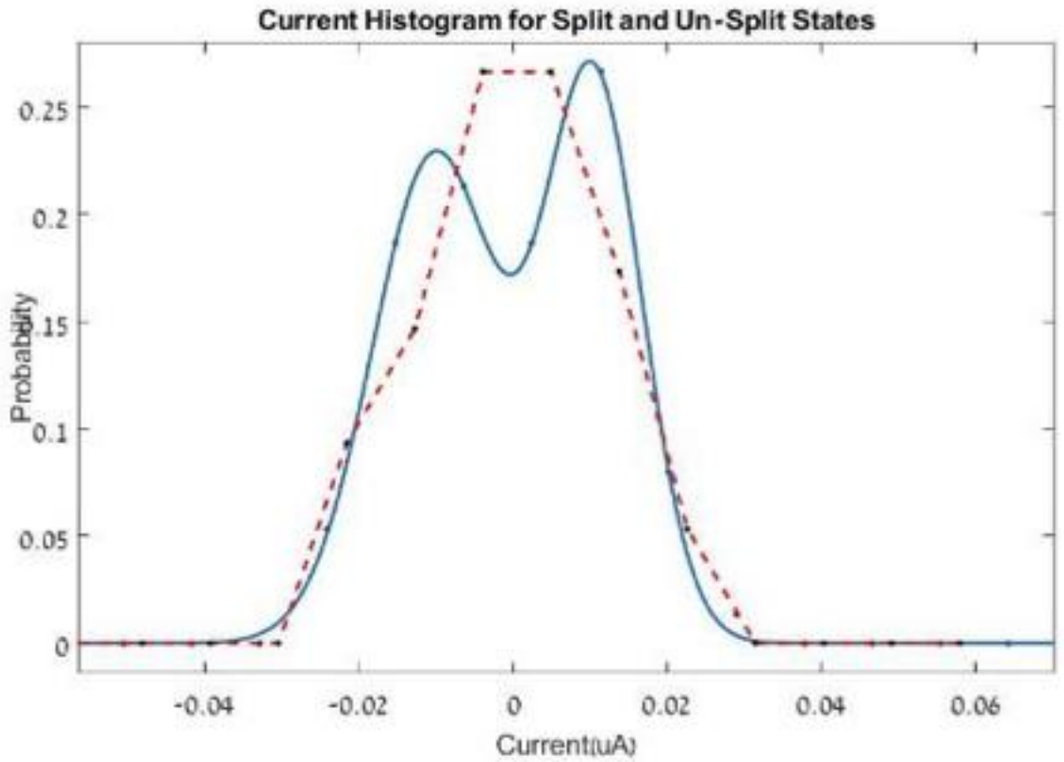
- Stable LSQ fit



PRL - still under optimistic review

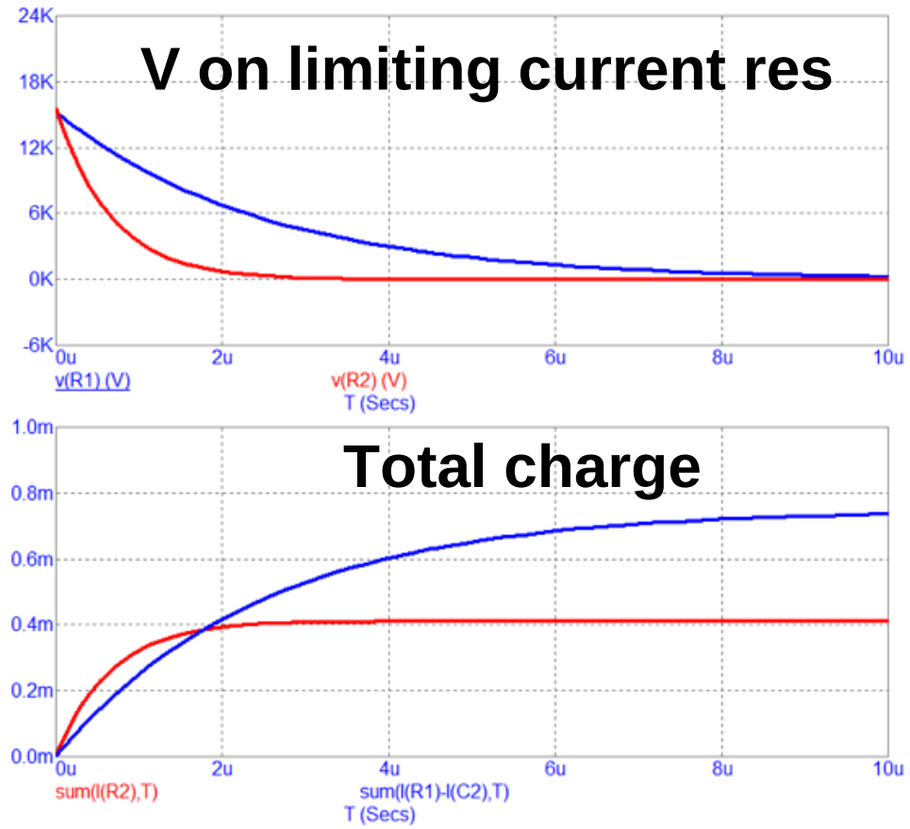
Dark Current Fluctuation analysis

- Trying to locate detectable dark current signal due to pre-BD fluctuations
- The initial premise - dark current RMS fluctuations will serve as predictable early warning signal for ensuing BD nucleation
- Previously - various experimental problems….. until today no real usable high frequency measurements
- Current aim - quantify observable fluctuations in dark current.
  - Field dependence
  - System noise?

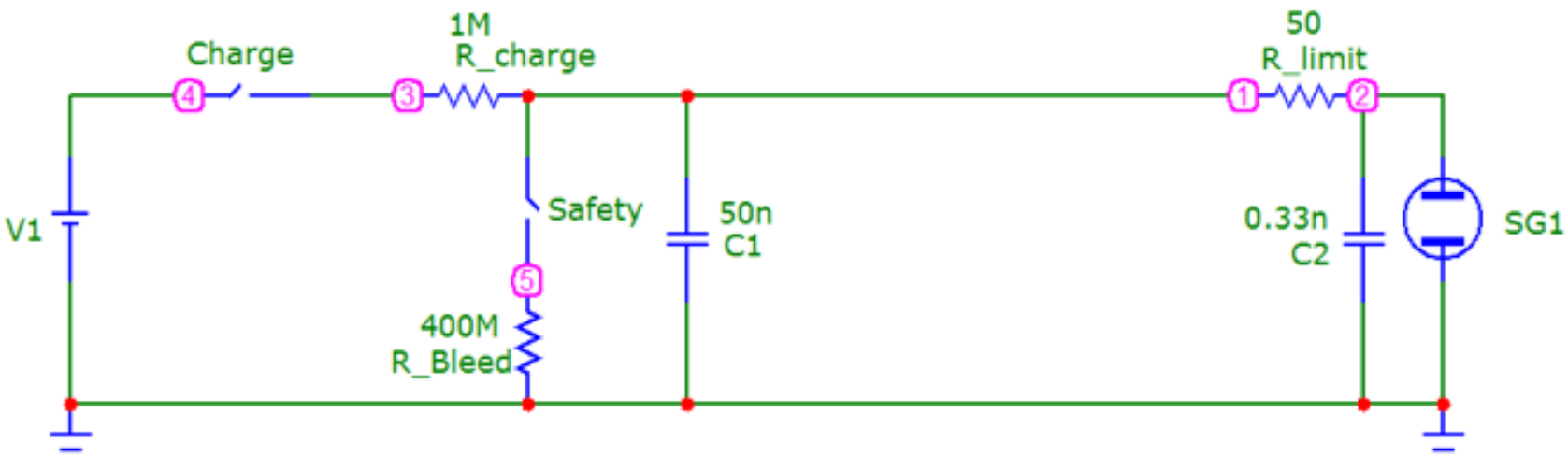


Acoustic emission for a DC set preBD event

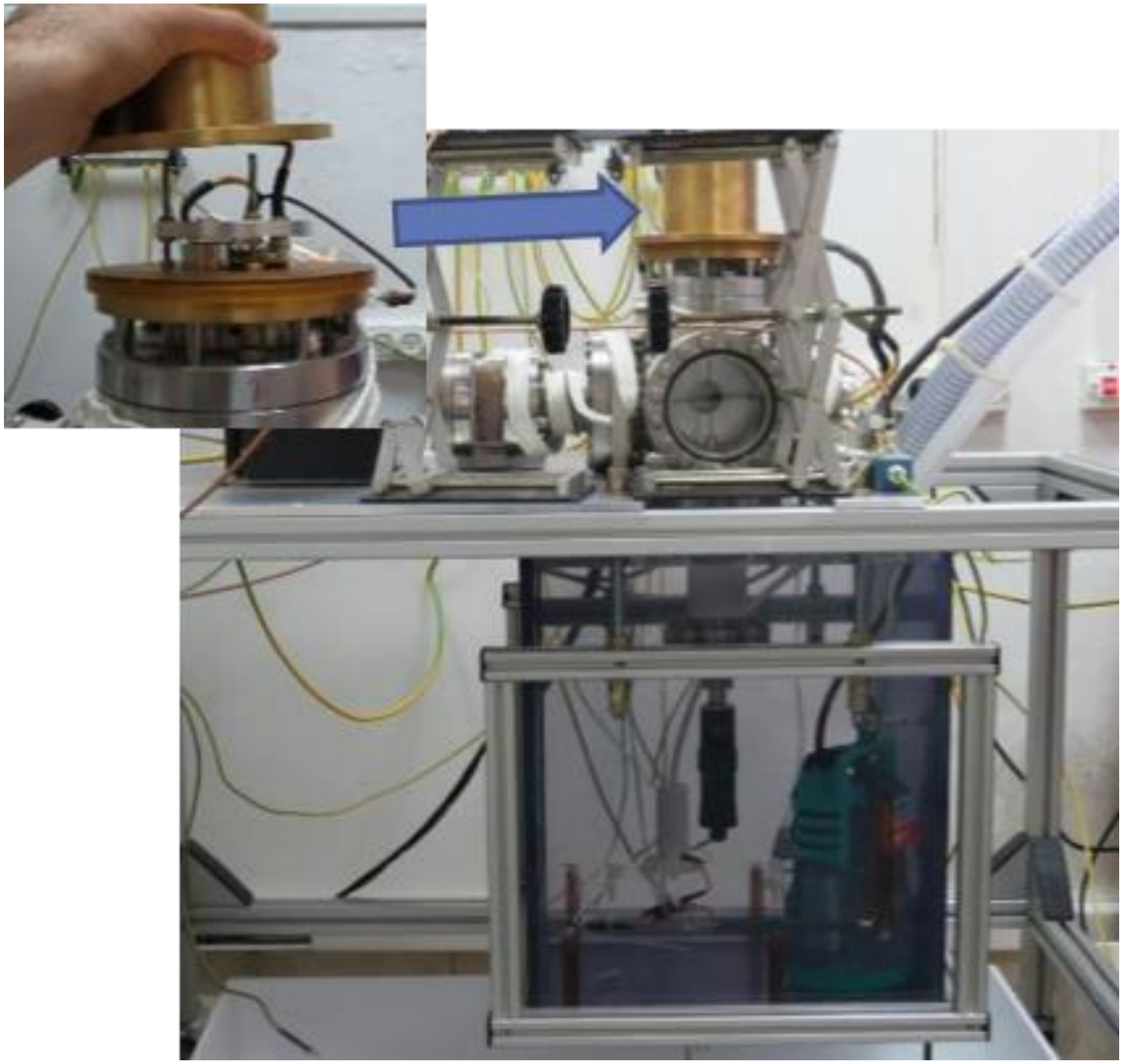
- Aim - detect pre BD signals unique to dislocations.
- Hope to correlate field emission and acoustic signal
- Current state: re-establishing electric system resolving safety issues.



Value	Parameter
20kV	Max Volt.
5.6J	Total Energy



AE and FE



Future experiments

- Dark current - FE.
  - nano-sec time resolution - Improve ability to identify source of FE variation
  - Possible high res dark currents from RF test stands.
- Variation with field, close to BD…
- Modify drive conditions - Temperature (go low)
- Sample kinetics: Average BD rate as a function of filed ramp rate