FP7 R&D plans for DC-breakdown measurements inside a Scanning Electron Microscope

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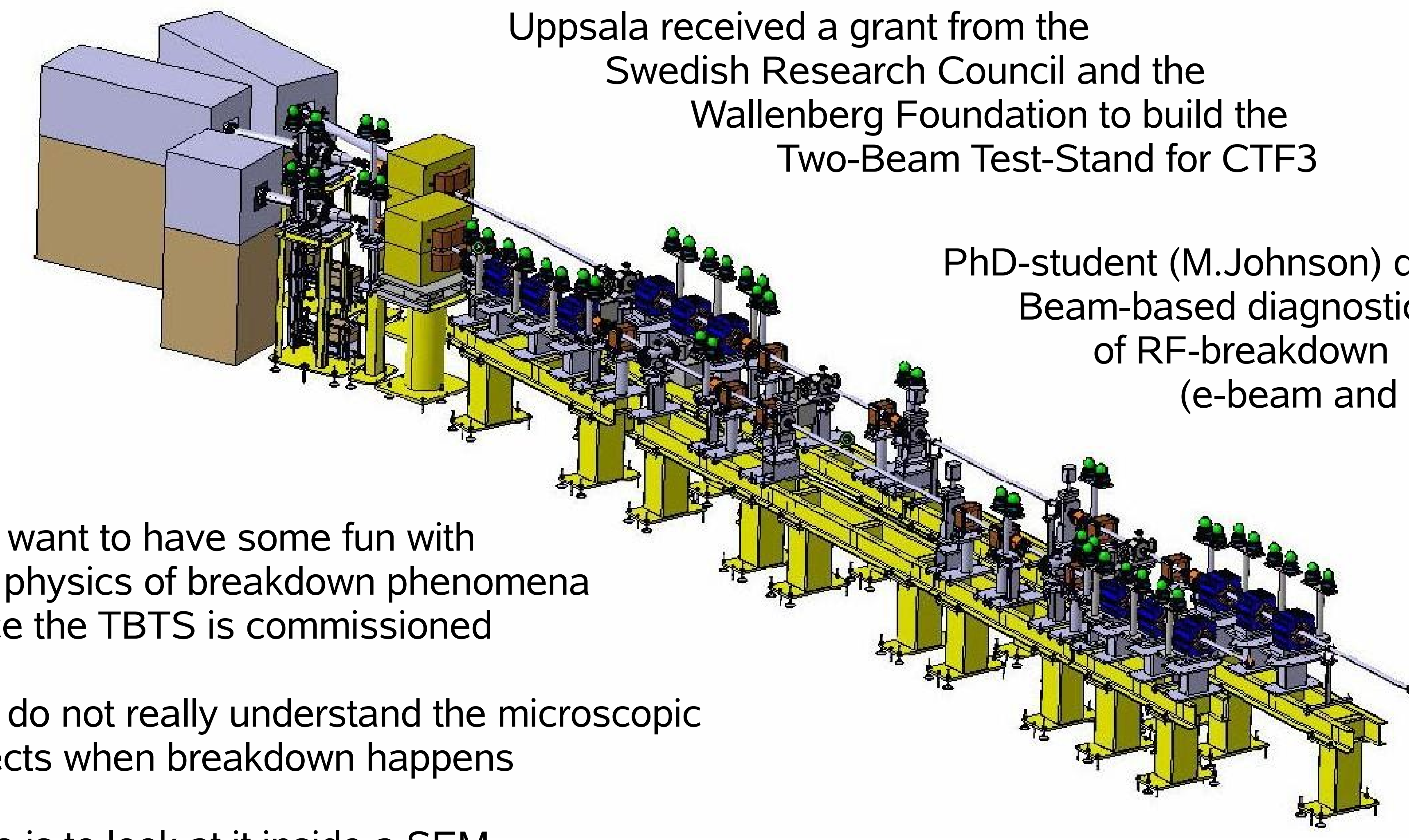
Why are we interested?



Uppsala received a grant from the Swedish Research Council and the Wallenberg Foundation to build the Two-Beam Test-Stand for CTF3

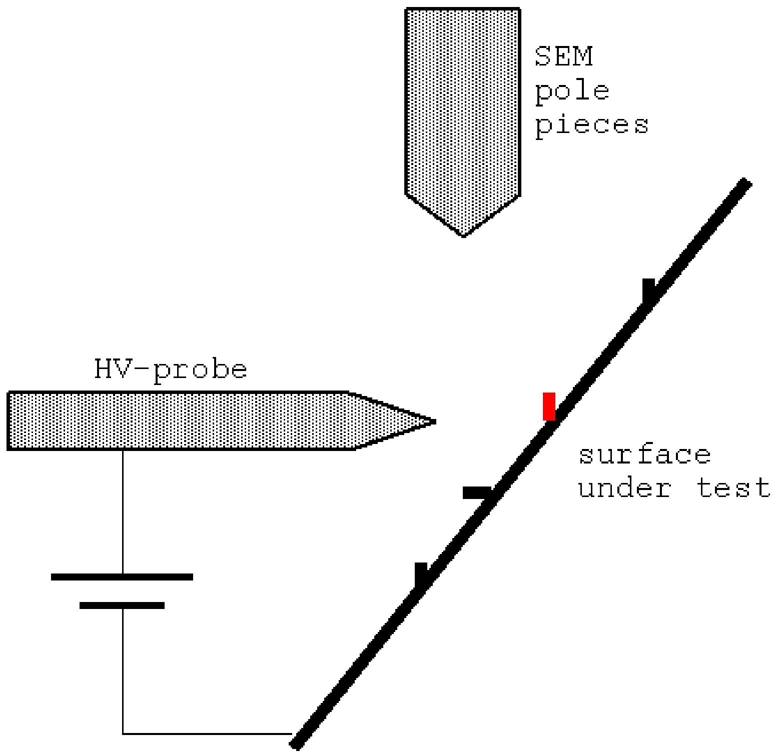
PhD-student (M.Johnson) does Beam-based diagnostics of RF-breakdown (e-beam and ions)

We want to have some fun with the physics of breakdown phenomena once the TBTS is commissioned

We do not really understand the microscopic effects when breakdown happens

Idea is to look at it inside a SEM

Vision and Plan



- DC-breakdown test inside SEM
- Select interesting surface structures
- 200 V/µm = 200 MV/m
- See the same spot before/after
  - Fowler-Nordheim (I-V) plots
- Lots of diagnostics
  - secondary electrons and ions
  - fast diodes
  - spectrometer
  - X-rays for element diagnosis
- Cut out surface slices with FIB
- Post-analysis in TEM

Comparison to other work

- Normally
  - breakdown studies are done in a 'global' spirit, covering macroscopic areas
  - and then do post-mortem surface analysis
  - more statistical or averaged results
  - in different vaccum systems
- We want to do breakdown studies
  - on microscopic scale
  - careful analysis of individual events
  - heavily equipped with diagnostics
  - in the same vacuum system

Questions to address

- Influence of surface topography
- What role does surface oxide layer play?
- Which materials constitute the plasma?
- How is the surface affected? Does it get softer, because the breakdown anneals the material?
- What are the time scales involved?
- Classification of breakdown (is there: ions, light, spectral lines,...)
- Does the chemistry change during breakdown?
- When does processing good, and when does it harm?
- Can one observe the processing curve even with single processed spots?

Microscopic Breakdown

- Is the picture developed for superconducting cavities applicable? (J. Knobloch thesis, 1997)
  - field emission current heats and desorbs gas
  - field emission current ionizes gas
  - and generates plasma of which electron disappear
  - 'naked ions' increase surface field
  - and generate a runaway process...
  - where the ions eventually do Coulomb-explosion

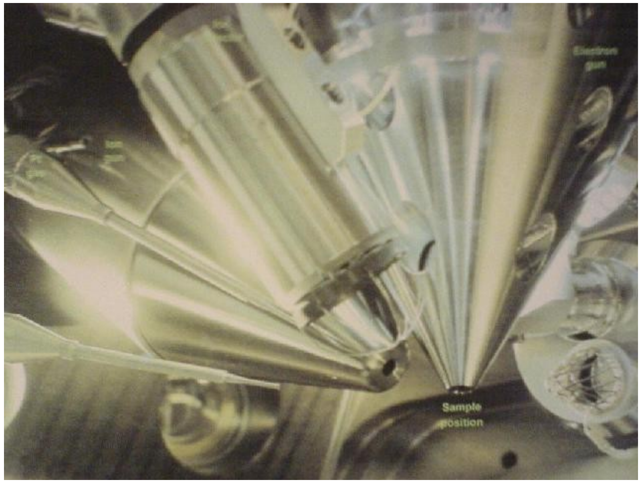
Infrastructure in Uppsala

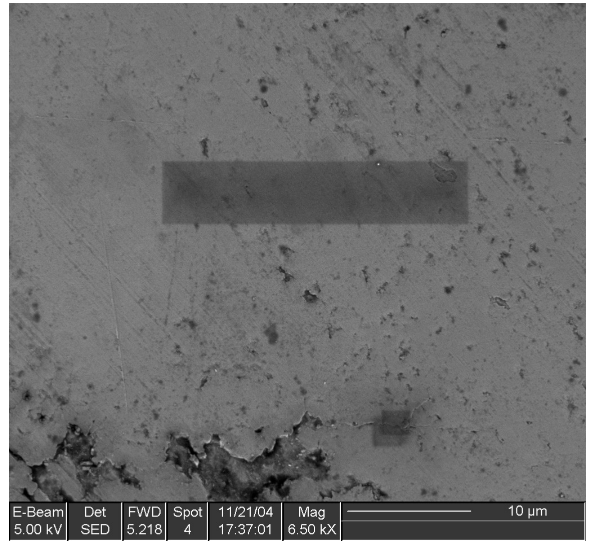
- Ångström Laboratory at Uppsala University
  - Micro-structure lab (msl.angstrom.uu.se)
    - 1 FIB, 4 SEM, 2 TEM, 1 AFM
    - 2000 m^2 clean room with process and analysis lab
  - Electron microscopy
  - High-voltage
  - Surface physics
  - CAI: Center for Accelerator and Instrument Development (www.cai.uu.se)

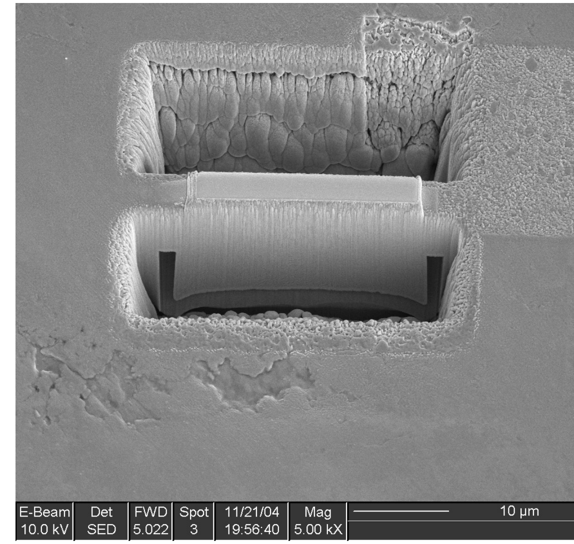
The FIB SEM (FEI Strata DB 235)

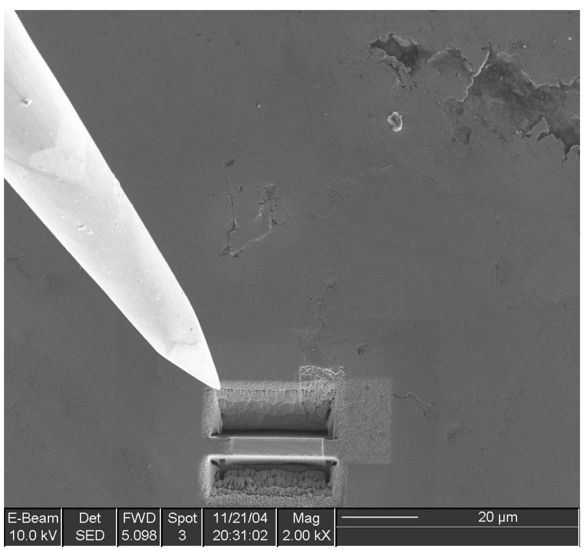
- Vertical SEM
- Diagonal manipulator
- Ion beam in the back
- EDX (big cylinder)
- about cube-foot space
- available flanges
- positioning knobs

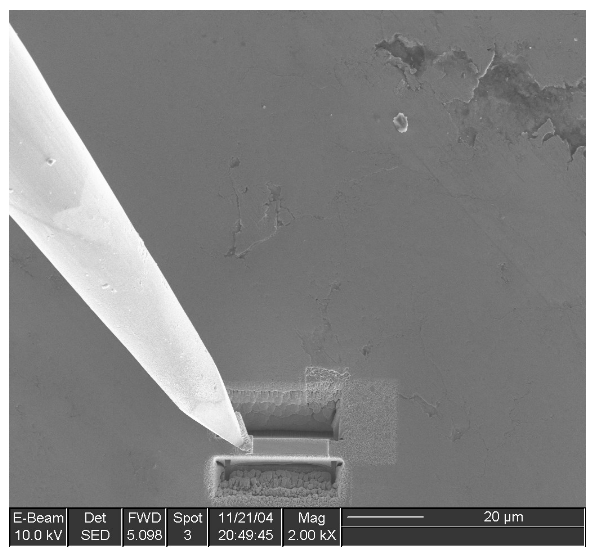
TEM sample preparation in FIB

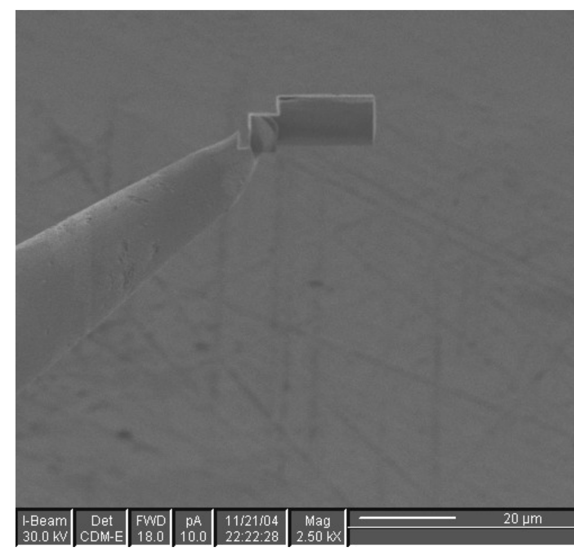






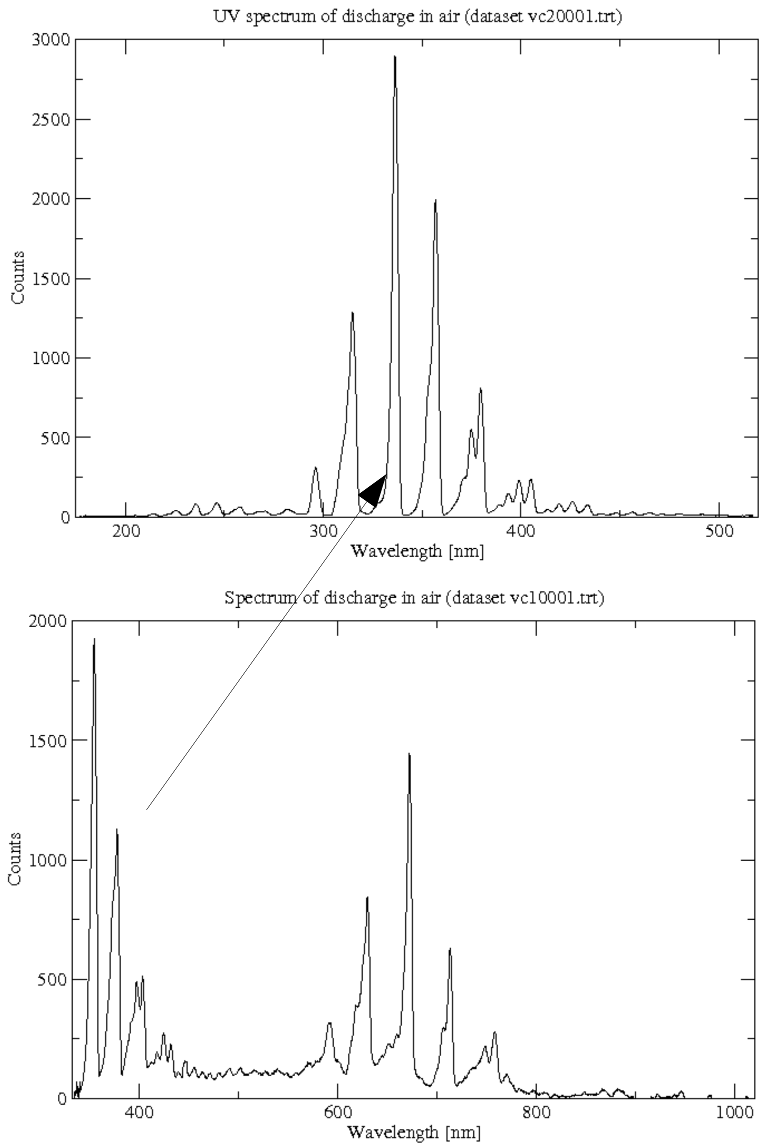






Pictures are shown courtesy of E. Coronel Uppsala University

Preliminaries: Spectra in Air



- Borrowed Ocean Optics spectrometer (S2000 UV+VIS)
- Continuous 20 kV discharge in air at the HV department
- UV: 0.2 eV spacing ≈ O_2
- No success of identification yet, despite searches in Pearse and Herzberg
- Triggering worked, but not used in the presented pictures
- Even triggering on light (LDR)
- too long integration time

Technical Issues

- Put high-voltage (< kV) on the manipulator in FIB (asked manufacturer, probably ok)
  - Could use extra remote-controlled XY-motion stage inside the FIB as backup solution
- Elektrostatic forces on the thin needle will bend it which will affect pin-positioning accuracy
- Timing and triggering
- Controlling the energy in breakdown

Conclusion

- Want to participate in the later physics program of the TBTS after commisioning
- Understand what happens during breakdown on a microscopic scale
- We have a powerful infrastructure at home in Ångström laboratory at Uppsala University which constitutes a strong multi-disciplinary infrastructure
- Help and collaborations are certainly welcome