SEM In-situ Field Emission Experiments for Breakdown Study

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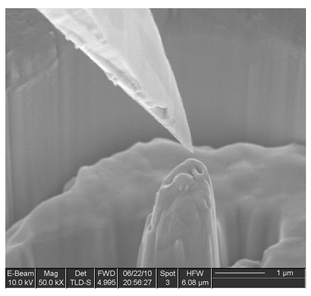


Basic Idea

Reproduce high gradient electric field conditions in micro meter range

1 GV/m = 1 kV/µm

Scanning Electron Microscopes (SEM) open an opportunity to investigate local processes during breakdown

Requirements and Advantages

Precise gap measurement between the anode and the cathode is required for precise electric field gradient determination

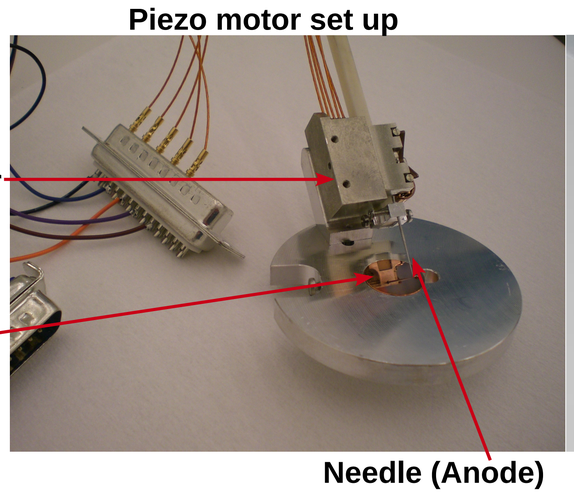
- ➡ Piezo motor with micro-step control
- ➡ Coupled images of micro meter range from different angles

Controlled surface features to investigate the surface condition dependence

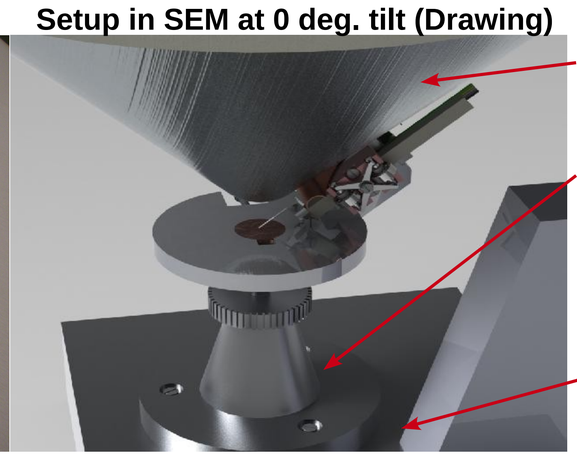
- ➡ Focused Ion Beam (FIB) combined with SEM

Precise gap measurement: determine the distance between the needle top and the surface

Piezo motor set up



Setup in SEM at 0 deg. tilt (Drawing)



Experimental setup

- The piezo motor (Piezo LEGS® Linear 10N Non Magnetic Vacuum) is mounted on the sample stage at 40 degrees to avoid contact with the electron column
- A tungsten needle is attached to the rod of piezo motor (electrically isolated from the chassis)
- Positive bias voltage is put on the needle (anode)
- Cu sample: 1.2 mm diameter, 0.5 mm thickness (cathode)

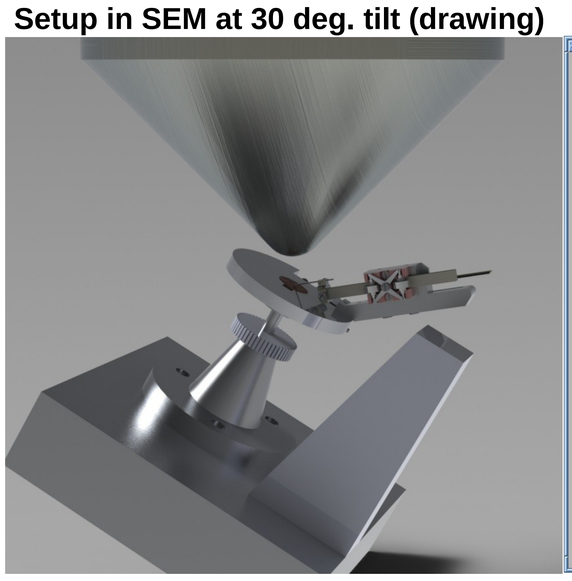
Micro step control

- The micro-stepping driver PMD 90 provided by PiezoMotor (Uppsala, Sweden, www.piezomotor.com) enables us to move the anode needle closer to the Cu surface with nm resolution.

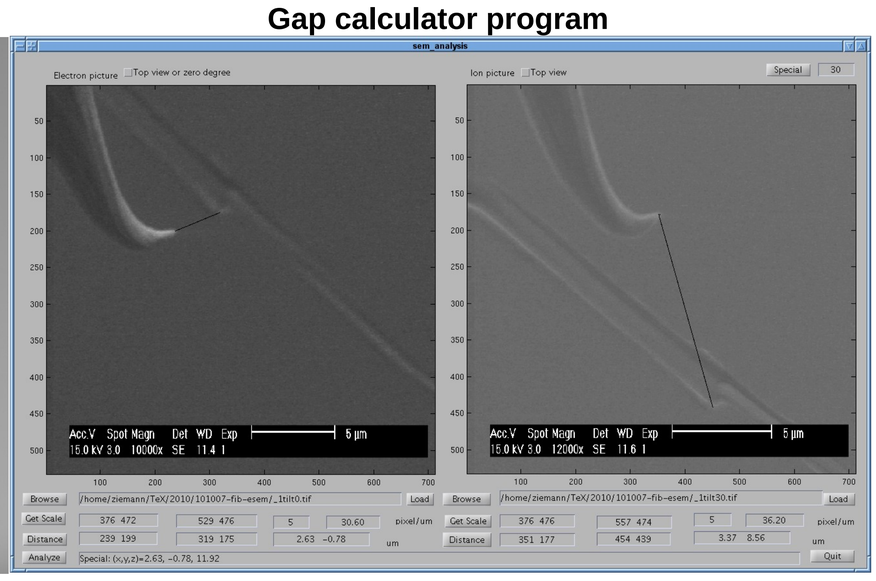
Gap calculation

- By tilting whole sample stage with respect to the electron column, one can take SEM images of different angles. With the two views from different angles, one can calculate the gap between the needle top (anode)and the Cu surface (cathode).

Setup in SEM at 30 deg. tilt (drawing)



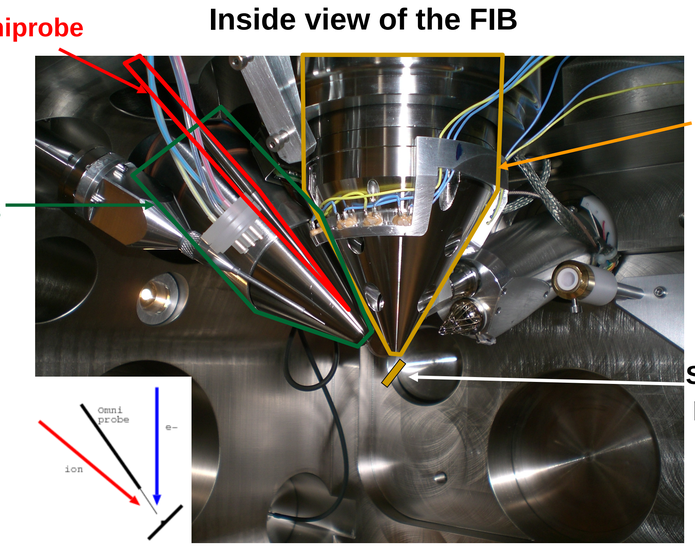
Gap calculator program

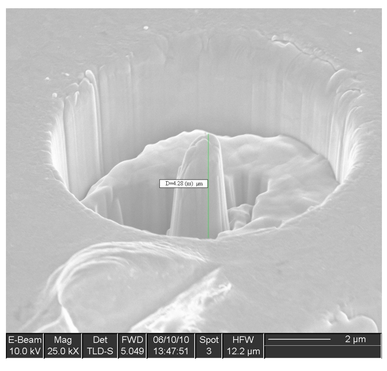


Combining our advantages of the precise gap measurements and the creation of artificial surface corrugations, we can investigate geometrical dependence of breakdown. As a in-situ experiments it is also possible to observe the evolution of surface condition under high gradient electric field.

Create surface corrugations by Focused Ion Beam

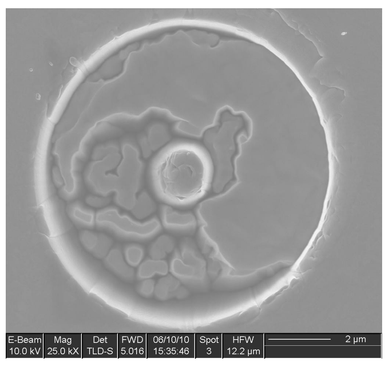
Inside view of the FIB





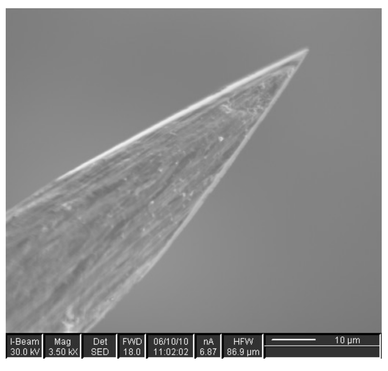
3D structure

By controlling gallium ion beam size and intensity, one can ”mill” a surface of samples with nm resoution and create surface corrugations, pillars and tips.



Images from two different angles

The image of the sample can be observed both by SEM and FIB, simultaneously. FIB beam line is at an angle of 52 degrees to the SEM beam line.



Sharpen up the needle

Tungsten needle connected to the omniprobe manipulator can also be sharpen up by FIB.

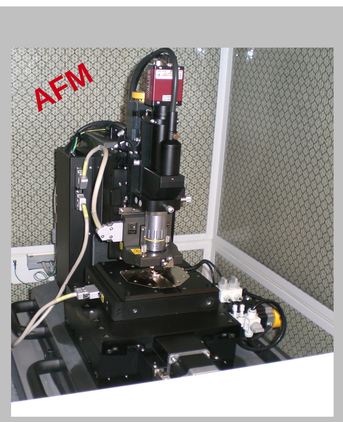
Ångström laboratory

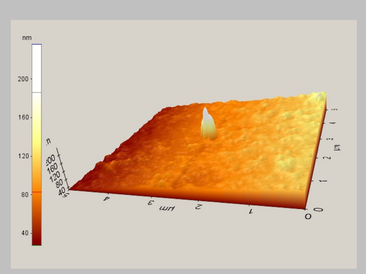
We have several electron microscopes in the Microstructure Laboratory in Uppsala
4 SEM, 2 TEM, 1 AFM, 1 FIB

http://www.myfab.se/AringngstroumlmMSL.aspx

Philips XL30 ESEM FEG

FEI Strata DB235





Atomic Force Microscopy (AFM)

- Surface analysis and characterisation on nano-scale
- Real number of surface roughness