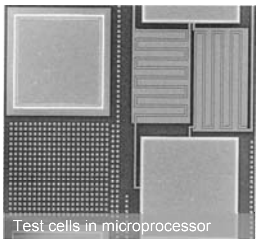
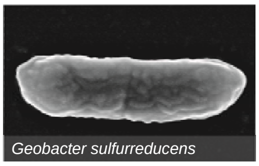
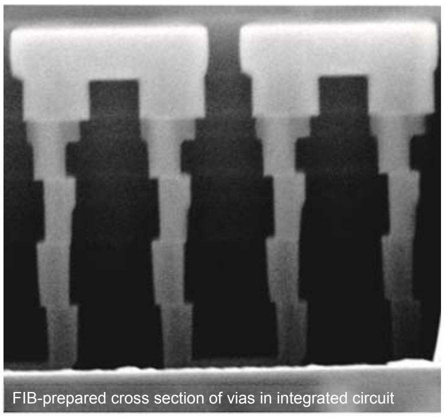

Test cells in microprocessor


Geobacter sulfurreducens


FIB milling in a ZnO nanowire


FIB-prepared cross section of vias in integrated circuit

Scanning Electron Microscopy Focused Ion Beam (SEM-FIB)

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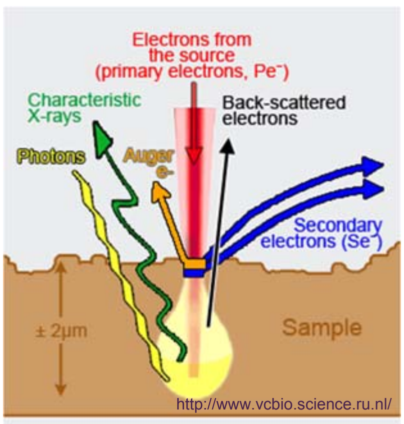


SEM Principle

SEM is a powerful technique capable of producing images with resolution ≈1 nm. High-energy electrons are thermionically emitted from a tungsten or lanthanum hexaboride cathode or, alternatively, generated via field emission, being then accelerated towards an anode. A condenser system composed by electromagnetic lenses focuses the electron beam into a fine probe (1-5 nm) that impinges on the specimen. The objective lens determines the resolution attainable by the microscope. The beam passes through pairs of scanning coils deflecting the beam horizontally and vertically over the sample surface. When the primary electron beam is focused on the material the electrons lose energy by recurrent scattering and absorption within a teardrop-shaped volume of the specimen. This interaction results in multiple effects such as secondary electrons (topographic information), backscattered electrons (atomic number contrast) and X-rays (elemental analysis).

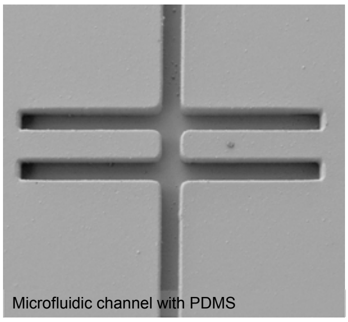
FIB Principle

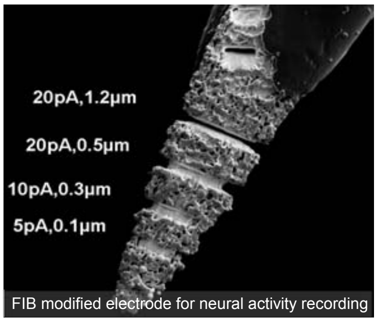
FIB uses a primary beam of ions rather than electrons to interact with the sample. Ions are larger, heavier and have different polarity compared with electrons, bringing different imaging capabilities (e.g., grain orientation contrast, chemical contrast) and controlled nanoscale etching. Modern dual-beam systems have SEM and FIB columns for enhanced nanoanalysis/nanofabrication capabilities. With a gas injector system (GIS) nanoscale deposition and selective etching are achievable, decomposing a precursor gas in volatile and non-volatile species by the electron or ion beam.

Applications

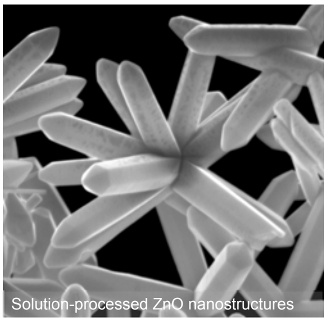
Morphological, structural, elemental and electrical analysis of micro-nanostructured samples from different fields: material science, microelectronics, geology, biology, chemistry, cultural heritage, pharmaceutics, forensic science.

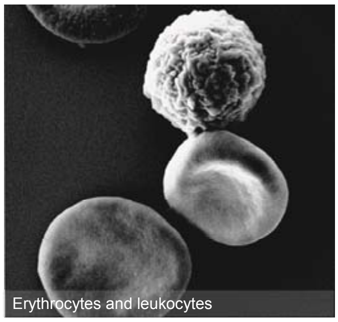
Nanofabrication (deposition/etching) and nanomanipulation.


Microfluidic channel with PDMS



FIB modified electrode for neural activity recording


Solution-processed ZnO nanostructures


Erythrocytes and leukocytes

Technical specifications

Zeiss Auriga CrossBeam system

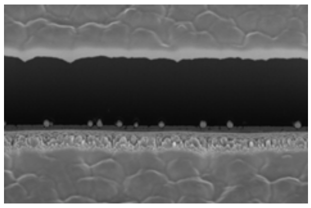
- SEM column for high resolution images even at low accelerating voltage (1 nm @ 15 keV, 1.9 nm at 1 keV)
- FIB column for imaging/milling: Ga liquid metal ion source (LMIS), resolution <7 nm @ 30 keV, accelerating voltage 1-30 keV, probe current 1 pA-50 nA.
- Imaging with different detectors (InLens SE and BSE, OutLens SE)
- GIS for C, Pt and SiO_2 deposition and XeF_2 for Si selective etching
- Local charge compensation system to reduce charging effects in non-conductive samples
- Load-lock chamber for fast loading of samples and reduced contamination levels

Additional features

- EDS for elemental analysis: Oxford XMax 150
- EBSD for crystallographic analysis, Oxford HKL Advance, Nordlys II-S
- Heating stage for in-situ imaging up to 1050 °C
- 4 Kleindiek nanotechnik nanomanipulators for electrical measurements and sample manipulation (e.g., TEM lamella preparation). 4 Triaxial connectors for external semiconductor parameter analyzer (SPA)
- Nanolithography using electrons or ions, milling of imported bitmaps or CAD files. Electrostatic beam blanker

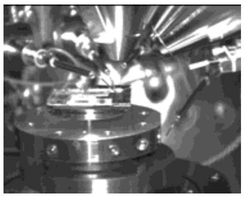
Solar cell cross section

FIB milling enables precise/fast cross section preparation for SEM observation. Process started with SEM- and FIB-assisted deposition of sacrificial C or Pt layer. Then FIB milling is performed, initially with high ion current (100s pA-10s nA), then with low ion current (10s pA) for cross-section polishing. Image shows a nc-Si:H solar cell with Au nano-colloids incorporated in the plasmonic back reflector.



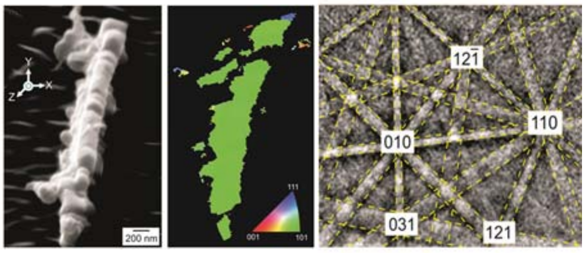
Nanofabrication/characterization of nanowire transistors

SEM- and FIB-assisted deposition of Pt source-drain electrodes on top of a ZnO nanowire. FIB-assisted selective etching of SiO2 to access highly-doped Si wafer. Tungsten tips positioned on contact pads using nanomanipulators, for in-situ electrical characterization.



Electron Backscatter Diffraction (EBSD)

Very powerful tool for microstructural characterization, including crystal orientation, grain size, global and local texture, recrystallization, strain analysis, phase identification and transformations. Images show a Cu_2O nanowire and corresponding orientation map with the Kikuchi pattern obtained by EBSD analysis.



Energy Dispersive X-ray Spectroscopy (EDXS)

Interaction of primary electron beam with sample produces X-rays that provide qualitative and semi-quantitative elemental analysis.

TiO_2 / Cu_2O heterojunction and FTO layer in a solar cell after FIB milling: EDS spectrum and corresponding maps of Cu, Ti and Sn.