Transmission Electron Microscopy

Short technology description
Transmission electron microscopy (TEM) enables characterization of powders and thin films (which can be prepared in a target preparation from bulk materials) by direct imaging with up to atomic resolution. The image information can be locally correlated with spectroscopic techniques (EELS/EFTEM and EDX) to provide semi-quantitative elemental composition/maps with up to subnanometer resolution. All of these techniques can also be performed during in-situ heating or tensile testing of the material.

For complex three-dimensional structures, electron tomography can be used to generate a 3D representation of the material with a spatial resolution of 1–2 nm, which can be used to quantitatively measure e.g. particle distributions, surface areas and faceting.

Special features
- FEI Titan 80–300 (aberration corrected TEM)
- Resolution:
  - 0.08 nm information limit TEM
  - 0.14 nm resolution in STEM
  - 0.7 eV energy resolution EELS
- Techniques: BF-TEM, aber. cor. HRTEM, HAADF-STEM, HRSTEM, EFTEM, EELS, EDX, Electron diffraction, Lorentz imaging, (S)TEM tomography, Low-dose techniques, Cryo imaging
- In-situ heating holder (up to 900 °C)
- In-situ straining holder

Limitations/constraints
- Sample has to be a solid at LN2 and stable under vacuum conditions
- Maximum sample thickness: 10–2000 nm (depending on resolution and technique)
- Except in tomography, the TEM always provides an image/analysis of the projected structure of a sample
- Depending on the chemical composition, the sample might be sensitive to the electron beam
- H, He und Li can not be detected by analytical techniques

Design rules
- Thin films or nano powders can be directly imaged. All other materials need to be prepared for the TEM analysis
- Target preparation by FIB lift-out (field of view typically 25 x 10 µm)
- Classical preparation by cutting, grinding, argon ion milling or microtomy

Material class

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<th>Silicon</th>
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<tr>
<th>Glass</th>
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Typical structures and designs

BF-TEM image of Co/CoO core/shell particles with a diameter of ~30 nm

HRTEM image of Co/CoO particles showing the atomic arrangement in the single crystalline Co core and the polycrystalline CoO shell

EFTEM image of oxygen distribution in Co/CoO particles and local EELS spectrum of a CoO shell

Multivariate analysis of Co and O EFTEM maps revealing Co und CoOx distribution

Volume rendering of 3D tomographic imaging of Co/CoO particles

Atomic resolution TEM image of a partial dislocation in nanocrystalline palladium