Summary

Many special techniques have been developed in electron microscopy. Electron tomography is used to get access to the 3rd dimension, and obtain information about the 3D structure of the samples.

Electron holography uses the interference of a reference beam and a transmitted beam. It gives information about the phase shift of the electron wave after traveling thru the sample. It is very sensitive to magnetic or electric fields as well as strain fields in the sample.

Lorentz microscopy is used to image magnetic domain walls. The objective lens is switched, thus avoiding the strong magnetic field on the sample.

In-situ experiments are very tricky experiments, often developed in few specialized labs. Some are relatively easy like using a heating or cooling sample holder. Some are more tricky like traction holder. Holders have been developed for applying controlled magnetic fields, making electrical measurements, applying traction or nano-indentation. Reactions cells allow to look at chemical reaction. Sometimes, the electron beam can be used to induce reactions or movements of atoms.

The 4D electron microscope project at CalTech is the development of a fully operational TEM with pulsed electron source for time resolved experiments.
Electron Tomography

Basic idea: recover the 3D structure of the object investigated
Developed for life sciences
Useful for materials sciences (but additional difficulties)

Different algorithms for backprojection
Electron tomography


Figure 3. An axial projection of a 30 nm thick specimen and five successive 3 nm thick slices through a tomogram of silica-supported [Ru3P3] nanoparticles (red), mesoporous silica (white).

Figure 2. a) BF images, taken at three defocus values, of nanoparticle-filled mesoporous silica. b) A comparison of BF (left) and HAADF (right) images of identical areas of catalyst: nanoparticles of [Ru3P3] invisible in BF are clearly seen in the HAADF image.
Electron tomography

Final resolution depends on:
- number of projections
- Missing wedge
- noise
- accuracy of tilt angles
- drift (correction)
- focus (corrections)

Issues for biological samples:
- beam damage (dose control)
- contrast

Issues for materials science samples:
- diffraction contrasts (HAADF STEM)

Needs well controlled automatic procedures for acquisition and processing

Other ...
Cathodoluminescens (SEM)

(time resolved) cathodoluminescens in the SEM

LABORATORY OF QUANTUM OPTOELECTRONICS - EPFL

High spatial resolution picosecond cathodoluminescence of InGaN quantum wells


Cathodoluminescens (STEM)

Project P. Stadelmann
In-Situ experiments

- Heating
- Cooling
- Magnetic field
- Reaction cell
- Electrical measurements
- Traction / indentation
- Growth, recrystallisation, Movements of atoms etc.

- But also:
  - Lorentz microscopy
  - Holography

In situ nucleation of carbon nanotubes by the injection of carbon atoms into metal particles

Jannik Meyer, UC Berkley. Now in Ulm

Electronic properties of individual carbon nanotubes

Jannik Meyer, UC Berkley. Now in Ulm
Ultrafast electron microscopy

http://www.ust.caltech.edu/index.html

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CalTech

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