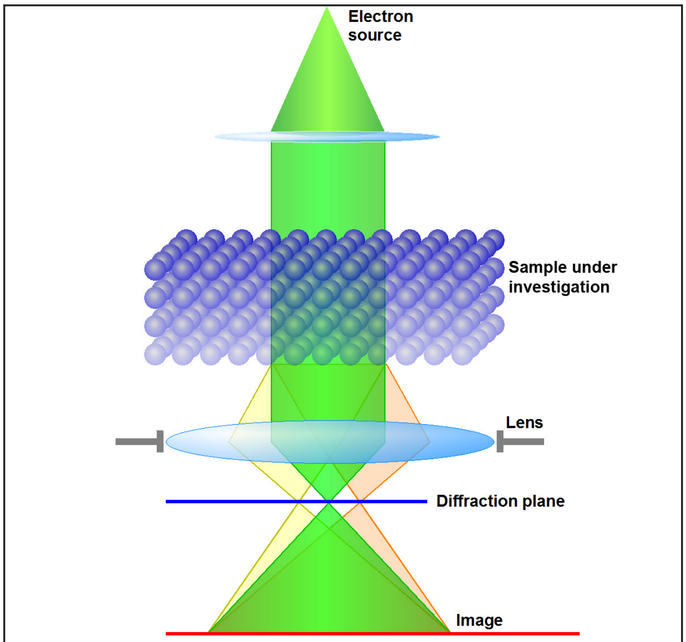
TRANSMISSION ELECTRON MICROSCOPE (TEM)

Binnig and Rohrer Nanotechnology Center

WHAT IS A TEM?

The TEM is an ultra high-resolution electron microscope that can image atomic structures in very thin (100 nm or less) solid-state samples. The TEM operates on the same principle as an optical microscope, but uses a beam of electrons instead of light. The electrons are transmitted through the sample and interact with it. After passing through the lenses, the electrons are detected by various detectors or a fluorescent screen.

The intensity variations are translated into a picture with various contrasts, containing direct information about the nanoscopic sample. In scanning TEM mode (STEM), an extremely focused beam scans across the sample, and the image is built from the direct interaction of the sample with the beam.



Operation principle of a TEM, Image courtesy of R. Erni, EMPA

THE TEM AT THE NANOTECHNOLOGY CENTER

The TEM installed in a “noise-free” lab at the Binnig and Rohrer Nanotechnology Center is a **JEOL ARM200F** model.

Operated jointly by IBM Research – Zurich and EMPA, the Swiss Federal Laboratories for Materials Science and Technology, this unique atomic-resolution TEM complements the microscopy capabilities in Switzerland. Its installation in a “noise-free” lab makes it the first of its kind in Europe.

WHY DOES IT NEED TO BE INSTALLED IN A “NOISE-FREE“ LAB?

The TEM is capable of achieving sub-angstrom ($<10^{-10}$ m) resolution. At this scale, any perturbation has disastrous effects on the operational stability of the instrument. Perturbations can include electromagnetic fields, temperature drifts as well as acoustic vibrations.

Installing the microscope in a “noise-free” lab provides the best environment for operation beyond the guaranteed specifications and with excellent long-term stability. To achieve a perfect isolation from perturbations, the instrument is operated remotely.

WHY DO WE NEED AN ATOMIC RESOLUTION TEM?

Projects in nano- and molecular science inherently involve phenomena that take place at the atomic scale. The characterization of samples is always a combination of the structural and/or chemical properties of the materials. Therefore a tool is needed to image these features.

WHY AN ARM200F MICROSCOPE?

Like any optical element, electromagnetic lenses suffer from aberrations (i.e. when passing through a lens, not all electrons converge into a single point). Aberration correction (Cs) has become a standard for high-end instruments.

The TEM at the Binnig and Rohrer Nanotechnology Center is equipped with a cold field-emission gun as its electron source and two Cs correctors to compensate for the spherical aberrations in the TEM and scanning TEM modes. It is one of the very first instruments in Europe to be operated with this unique combination.

This TEM enables the investigation of materials and nanostructures at the atomic scale, i.e. with a resolution of 0.09 nm.

It also provides the capability to perform faster analyses and to visualize atoms at high (200 kV) as well as at low voltages (80 kV). The latter is extremely relevant when sensitive materials, such as graphene or crystalline interfaces, are being investigated.

The use of a cold field-electron gun, which guarantees an energy dispersion lower than 0.3 eV, allows the analytical capabilities to be exploited fully as it combines energy-dispersive X-ray spectrometry and electron energy-loss spectrometry.

With this unique instrument it is possible to obtain detailed information on the atomic positions, chemistry, composition and electronic properties of sample surfaces with subnanometer lateral resolution.

Conventional TEM image from an active silicon photonic device.
Courtesy of R. Erni, EMPA

Closeup of the $BaTiO_3$ epitaxial layer.
Courtesy of R. Erni, EMPA

Image performed with Cs-corrected STEM: The high resolution permits the Sr and Ti atoms as well as the oxygen sites to be imaged with very good contrast and no aberrations or artifacts.
Courtesy of N. Endo, JEOL GmbH

TEM images of nanostructures at different resolutions down to the individual atoms.

Jointly operated with EMPA

Materials Science & Technology