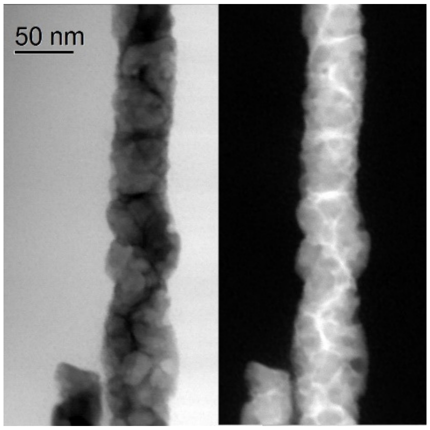
Scanning Transmission Electron Microscope (STEM)

(JEOL JEM-ARM200CF,)
The STEM combines features of both the TEM and SEM to produce transmission images obtained with a scanning probe. Magnification is changed by changing the area scanned on the specimen and post specimen lenses are not strictly needed in a STEM. In STEM mode, the final image resolution depends on use of a high brightness source to produce a small focused probe with high current density. The ARM200CF has a cold field emission source and is fitted with a probe aberration corrector.

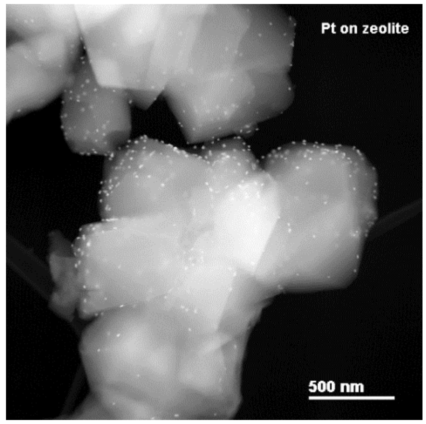
The first scanning electron microscope image ever obtained was a STEM image in 1938. Von Ardenne had realized that the transmitted electrons would not need to be refocused to form a high-resolution image, merely detected, and so the resolution of a STEM would not be degraded by chromatic aberration as was the case in TEM. Unfortunately the improvement in resolution, compared to TEM, was soon overtaken by TEM development. The STEM resolution is determined by the brightness of the electron source and with thermal sources is limited to a more than 20nm. Renewed interest in dedicated STEM started with the development of stable high brightness field emission sources in the late 1960s, which needed ultra-high vacuum. Commercial dedicated STEMs (VG Microscopes) have been available since 1974. STEM attachments to TEMs have been available since the 1970's, but it is only with the introduction of field emission source TEMs in the 1990s that the performance of the TEM/STEMs has reached the level of the dedicated instruments. With field emission sources the minimum probe size is now determined by the spherical aberration of the microscopes objective lens and not the brightness of the electron source. The JEM-ARM200CF, which replaced a JEOL JEM-2010F, was delivered in July 2011 with a CEOS probe aberration corrector this improves imaging resolution from the 0.135nm which was attainable in the JEM-2010F down to below 0.078nm.

Images in the STEM are produced while scanning the beam over the specimen. Electrons transmitted through the specimen can be detected on a detector on the axis of the microscope (bright field detector (BF)), or on an annular detector sensing electrons scattered through a range of angles (annular dark field detector (ADF) or annular bright field (ABF)). Detectors can also be fitted to look at secondary and backscattered electrons, as in a SEM, although our instrument does not have that detector.

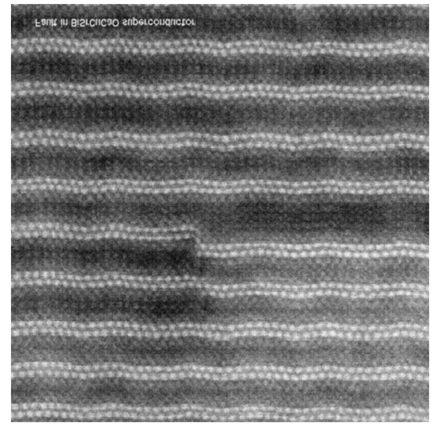
The main applications of a STEM are high spatial resolution imaging and microanalysis. X-ray spatial resolution of less than 0.13nm is possible with sufficient beam current to collect statistically significant XEDS spectra in 100 seconds. The scanned probe also allows for collection of X-ray maps and line scans at atomic resolution. Imaging with a resolution equivalent to the minimum probe size is possible using electrons scattered through high angles onto the ADF detector (high angle annular dark field (HAADF)), or missing from the ABF detector. The intensity of the signal on the HAADF detector is proportional to the average atomic number under the probe, and in correctly oriented crystalline samples, it is possible to get Z contrast images at atomic resolution. ABF images can show locations of light element columns down as low as hydrogen. Chemical and electronic information at a resolution slightly larger than the minimum imaging resolution is possible using EELS.



Bright Field (left) and High Angle Dark Field (right) images of an erbium coated germanium nanowire. (JEOL JEM-2010F)

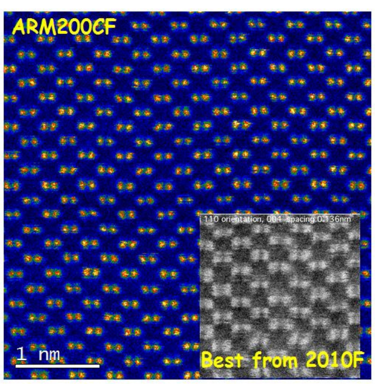


Z-contrast High Angle Dark Field image of platinum catalyst (brights spots) on a zeolite support. (JEOL JEM-2010F)

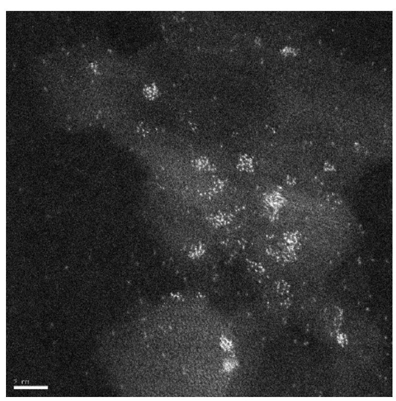


Z-contrast Atomic Resolution High Angle Dark Field image of a stacking fault in a BSCCO superconductor. Ba atoms are the brightest, Sr are the next brightest and the Cu and Ca give similar contrast. (JEOL JEM-2010F)

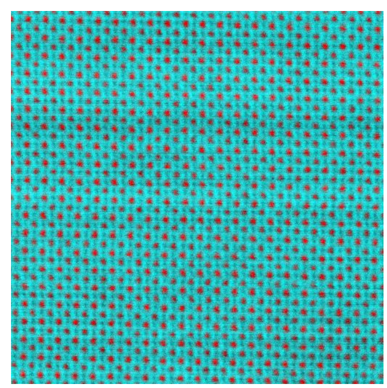
The JEOL JEM-ARM200CF is fitted with five STEM detectors to allow imaging under a wide range of conditions. There are three JEOL detectors (High Angle Annular Dark Field (HAADF), Low Angle Annular Dark Field (LADF) and Bright Field/ Annular Bright Field (BF/ABF)) and two Gatan detectors (Bright Field/ Annular Dark Field detector (BF/ADF) which allows either the BF or ADF to be selected). Examples of the images obtained from this microscope are shown below.



The improvement in imaging resolution in the ARM200CF is seen in this comparison of Si 110 high angle dark field atomic resolution images acquired from the ARM200CF (main picture) and 2010F (inset)



Z-contrast High Angle Dark Field image of platinum atoms on an alumina support. (JEOL JEM-ARM200CF)



Composite high angle dark field and annular bright field images of SrTiO3 (Red - HADF showing location of Sr and Ti, Blue - ABF showing location of O) (JEOL JEM-ARM200CF)