

Local state analysis by STEM-EELS equipped with a nanotip-FEG

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Electron energy-loss spectroscopy (EELS) combined with an aberration corrected scanning transmission electron microscope (STEM) enable to perform local analysis with an atomic resolution owing to a sub-angstrom electron probe with a high probe current [1]. In order to enhance a performance of STEM-EELS analysis, we developed a bright electron source, a nanotip, consisting of a nano-protrusion on a tip apex of W<111> emitter [2]. In the present work, we demonstrate capabilities of a nanotip cold-field emission gun (FEG) mounted on a Cs-corrected STEM and its application to EELS analysis.

The newly developed 200 kV Cs-corrected STEM/TEM equipped with a nanotip-FEG is based on JEM-2200FS, in which the omega type of energy filter is incorporated in the microscope column. The spherical aberration corrector for illumination lens system consists of the hexapole and transfer lenses, which produces an incident electron probe of 0.1 nm or less in diameter with an illumination semi-angle of 23 mrad. A double tank system was adopted to improve the stability of high voltage, which promises the stability of +/- 0.05 eV/min measured from the drift of zero-loss peak.

The emission from the nanotip is confined to a small area near the anode hole. Total emission current from the nanotip is typically about 2 μ A at an extraction voltage of 1.6 kV that is fairly low compared to that of the normal emission. These results indicate that the electrons are emitted from a protrusion formed at the 111 pole of tip apex.

As an application to STEM-EELS analysis, we will show local state analysis using the spatially resolved EELS measured from a BaTiO₃ (BTO) thin film grown on SrTiO₃ substrate. In the vicinity of the interface, the strained structure and a misfit dislocation are observed in the BTO region. The imaginary part of dielectric function (ϵ_2 spectrum) deduced from valence electron excitation spectrum shows the change of electronic structure due to the strain structure near the interface, which is confirmed by a first principles band structure calculation. From the energy-loss near-edge structure of Ti L_{2,3}-edge, the crystal-field strength measured from the separation between t_{2g} and e_g peaks is also slightly different, which indicates that the local electronic structure should be changed at the strained and defect regions.

References

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