APPLICATION OF ELECTRON ENERGY-LOSS SPECTROSCOPY IN MATERIAL SCIENCES

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Equipment for the analysis of energy distribution of electrons after transmitting samples has become more or more standard unit in modern transmission electron microscopes (TEM). This can be integrated in the column of the TEM (called in-column filter) or installed beneath the TEM column below the view screen.

Besides the well-known structural information provided by TEM with a spatial resolution adequate to distinguish each phase individually, electron energy-loss spectroscopy (EELS) provides a series of information, for instance, the distribution of light elements, sample thickness, crystallographic structure, bond character and electronic structure. The combination of electron energy-loss spectroscopy with TEM makes spatially resolved studies possible and structure-property relationships can be explored in greater detail with this source of spatially resolved information. This is an excellent advantage of EELS/TEM compared with conventional X-ray spectroscopy.

The low-loss region (< 50 eV) of an EELS-spectrum is dominated by the contribution of the collective oscillation of valence electrons and of the excitation of outer-shell electrons. The single scattering distribution obtained from the low-loss region provides a thickness independent result and can be used in the first step of a Kramers-Kronig analysis of the spectrum to derive the complex dielectric response of the studied materials. For semi-conducting materials, recently it is reported that EELS can be used to measure the band gap of the sample if the necessary energy-resolution can be obtained. However, the possible Čerenkov radiation emitted by electrons lost energy has to be considered for the band gap determination.

Core loss spectra (energy loss > 50 eV) of EELS are most commonly used in application of EELS. The isolation of spectral intensities that scale with atomic concentration makes quantitative analysis at nanometer scale (on nanoparticle or at interface boundaries) possible. Fine structure at the core edges provides electronic and structural information. The energy-loss near-edge structure (ELNES) reflects the density of un-occupied electronic states in a band structure. Characteristic feature in core excitation regions of the spectrum can be used extensively for phase identification in material science (finger print). For metal oxides, the oxidation states of anions and the coordination of constituent atoms can be determined by comparison of ELNES with these of known sample or with the spectra of density-functional theory calculations.

Recently, it is shown that the combination of new spectrometer with monochromised field emitter TEM gives access to the same information as the synchrotron. This opens the exciting possibility to study the electronic structure of materials with the same physical method either in a surface-sensitive (XAS) or a bulk sensitive (EELS) mode with complete geometric structure information (electron diffraction, high-resolution imaging) and nanometer lateral resolution.

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