17.2.2.1 Electron scattering spectroscopies

The secondary electron signal produced by a primary electron beam impinging on a surface consists of several contributions. These are: coherent and incoherent elastically scattered electrons, inelastically scattered electrons, electrons from primary ionization and Auger electrons.

The coherent and incoherent elastically scattered electrons are the basis of *electron diffraction* (*LEED*) and *scanning electron microscopy* (*SEM*), respectively. The electrons from primary ionization and inelastically scattered electrons are detected and analyzed in the Electron Scattering Spectroscopies. The analysis of the Auger electrons is considered in a later section.

Spectroscopy based on the analysis of the electrons from ionization is *Ionization Spectroscopy* and that based on the analysis of inelastically scattered electrons is *Energy Loss Spectroscopy*.

The very obvious dissimilarities between these electron induced spectroscopies and the corresponding photon induced spectroscopies arise from the fact that photons can only take part in one resonant absorption process but electrons can take part in many non-resonant scattering processes.

The principle of electron-energy-loss spectroscopy is that a primary electron beam of fixed energy is incident on a surface and its energy distribution after interaction with the sample is recorded. The difference in energy between primary and measured electrons corresponds to the energy loss.

High resolution electron energy loss spectroscopy (HREELS, HEELS)

Incident: fixed energy electrons (1-50 eV). Beam diameter: 1-3 mm. Angle of incidence: 45-85°.

Detected: scattered primary electrons. Energy loss from 0.02 eV to several eV. Angle of exit: near specular.

Spectrum: Electron current vs. electron energy loss.

Electron energy loss spectroscopy (EELS, ELS)

Incident: Fixed energy electrons (50-200 eV). Beam diameter: 1-5 mm. Angle of incidence: 30-50°.

Detected: scattered primary electrons, energy losses from 0.005 eV to several hundred eV.

Angle of exit: near specular.

Spectrum: Electron current vs. electron energy loss.

Extended electron energy loss fine structure (EELFS, EXELFS)

Incident: Fixed energy electrons, 10-80 keV. Beam diameter: 0.3 nm. Angle of incidence: normal to surface.

Detected: Scattered incident electrons, energy loss for ionization, 200-4000 eV. Angle of exit: 45°.

Spectrum: Backscattered electron current or its first or second derivative with respect to incident electron energy (energy loss function vs. incident electron energy).

Ionization spectroscopy (IS)

In ionization spectroscopy (IS) a core electron is excited to the Fermi level. The technique is also known as *Ionization Loss Spectroscopy* (*ILS*) or *Core-Level Characteristic Loss Spectroscopy* (*CLS*). The core electron excitation produces a weak edge (step) in the distribution of backscattered electrons as a function of incident electron energy when the loss energy is equal to the binding energy of the core electron. These weak ionization edges have to be distinguished from the more intense Auger electrons. This is achieved by using the fact that the intensity of electrons scattered after core ionization processes depends on the primary electron energy but the Auger electron signal does not.

Incident: Variable energy electrons (250-1000 eV). Beam diameter: 3 mm. Angle of incidence: 0° or 45°.

Spectrum: Second derivative of backscattered electron current with respect to incident electron energy (energy loss function) vs. incident electron energy.

Electron transmission spectroscopy (ETS)

The technique is used for studying thin films (1-10 nm) of organic materials with low energy electrons.

Incident: Variable energy electrons, (0-15 eV); beam diameter: 3 mm; Angle of incidence: normal to surface.

Detected: Transmitted scattered electrons (0-15 eV). Angle of exit: normal to surface.

Spectrum: First derivative of transmitted electron current with respect to incident electron energy vs. incident electron energy.