17.2.4 Auger electron spectroscopies (AES)

Auger Electron Spectroscopy measures the energy distribution spectrum of the electrons ('Auger electrons') emitted following the primary ionization of a core energy level. This ionization can result from internal conversion in a radioactive element or from X-ray photoionization, high energy electron ionization or positive ion ionization (in particular, protons).

Electron-excited Auger electron spectroscopy (EAES)

Electron Excited (or *Induced* or *Initiated*) *Auger Electron Spectroscopy* (*EEAES* or *EIAES* or *EAES*) is the most common form of Auger Electron spectroscopy and, if the ionizing source is not obvious from the context, then this technique is assumed by default. Thus electron excited AES is often referred to simply as AES.

Incident: Fixed energy electrons (100 eV - 10 keV); beam diameter 0.1-1 mm; angle of incidence: 0-70°.

Detected: Secondary Auger electrons (20-2000 eV); angle of exit: polar angle: 0-70°, azimuthal: not critical.

Spectrum: First or second derivative of secondary electron current, with respect to the analyzer energy vs. analyzer energy.

Scanning Auger microscopy (SAM)

A focused electron beam of small diameter is scanned across a surface to produce Auger electrons from a defined area (high lateral resolution AES).

Incident: Fixed energy electrons (2-15 keV); beam diameter:
0.3-5 μm (thermionic sources), 300-30 nm (cold cathode sources); angle of incidence: electron beam is scanned across surface.

Detected: Secondary Auger electrons (selected electron energy within the range 200-2000 eV); angle of exit: 0-60° (not critical).

Spectrum: Presented as a map of surface distribution of a particular element X and Y axes: position, Z axis intensity of first derivative of Auger electron current.

Angle resolved Auger electron spectroscopy (ARAES)

If the Auger electrons, produced as a result of electron ionization of a core level, are

collected as a function of their emission angle with respect to the surface the technique is referred to as *Angle-Resolved Auger Electron Spectroscopy* (*ARAES*) or *Angular-Dependent Auger Spectroscopy* (*ADAS*).

Incident: Fixed energy electrons (500-2000 eV); beam diameter: 0.1-0.5 mm; angle of incidence: 0-70° (must be specified).

Detected: Secondary Auger electrons (20-2000 eV); angle of exit: polar angle: 0-70°, azimuthal angle: 0-360°.

Spectrum: First or second derivative of secondary electron current, with respect to the analyzer energy at specified angle vs. analyzer energy (Auger electron energy).

Spin-polarized Auger electron spectroscopy (SPAES)

In SPAES the core hole is produced by electron bombardment with beams up to 3000 V striking the surface at a grazing incidence of $\approx 20°$. The secondary electron signal is collected normal to the surface by a Mott detector (of high efficiency with a central electric field for acceleration and focusing) and an electron energy analyzer of constant energy resolution and angular acceptance. A permanent magnet is required to magnetically saturate the sample by aligning the spins parallel to the emitting surface. The polarization due to the spin-orbit coupling in the scattering process can be averaged out by reversing the magnetization direction.

Incident: Fixed energy electrons (1000-3000 eV); beam diameter: 0.1-0.5 mm; angle of incidence: grazing ($\approx 20°$.)

Detected: Secondary Auger electrons (100-2000 eV); angle of exit: normal to surface.

Spectrum: Secondary electron current vs. analyzer energy (Auger electron energy).

Ion-excited Auger electron spectroscopy (IAES)

If the core hole is produced by high energy ion collisions the technique is called *Ion-* (*Excited* or *Induced* or *Initiated*) *Auger Electron Spectroscopy* (*IAES*). Usually heavy ions are employed but *Proton-Excited AES* (*PAES*) has also been used.

Incident: Fixed energy ion (1 keV-10 keV); beam diameter: 0.5-2 mm; angle of incidence: 20-60°.

Detected: Secondary Auger electrons (100-2000 eV); angle of exit: 20-90°.

Spectrum: Secondary electron current or its first derivative with respect to analyzer energy vs. analyzer energy (Auger electron energy).

Nuclear Auger electron (emission) spectroscopy (AES, AEES)

In the neighbourhood of an excited or radioactive nucleus the field of the nuclear multipole will act on the core electrons and in some cases the excited nucleus can decay to its ground state by transferring energy to the core electron. This process is called *internal conversion*. This energy usually exceeds the ionization energy and thus a core hole is formed and Auger electron emission may occur. Nuclear Auger electrons may also be produced by *orbital electron capture*. These processes do not really constitute a surface electron spectroscopy but are of some importance in considering radiation damage in solids.

Detected: Secondary Auger electrons (20-2000 eV).

Spectrum: the same as for IAES.

X-ray excited Auger electron spectroscopy (XAES)

Because of the limited flux density of X-ray sources they are seldomly employed in Auger electron spectrometers. The importance of the X-ray excited Auger electron spectrum is that it accompanies the photoelectron emission spectrum produced in an X-ray Photoelectron Spectrometer. *X-ray* (or *Photon*)-*Excited* (or *Induced* or *Initiated*) *Auger Electron Spectroscopy* (*XAES* or *XEAES*) are synonymous terms.

Incident: Fixed energy photons (1-10 keV); flux: low; beam diameter: 1-3 mm; angle of incidence: 70-85°.

Detected: Auger electrons (50-2000 eV); angle of exit: polar: 10-80°; azimuthal: not critical.

Spectrum: the same as for IAES.