17.2.2.2 Electron-induced photon emission spectroscopies

The photon emission spectra produced by primary electron beams impinging on a surface consist of contributions from two distinct mechanisms.

The first of these is decay of the excited core-state by X-ray emission following transitions of valence or core electrons from occupied states to the unoccupied core state.

If core-core transitions are involved the technique is *X-ray Emission Spectroscopy* (*XES*) or *Energy-Dispersive* (*X-ray Analysis*) *Spectroscopy* (*EDS*) and if valence-core transitions are involved the technique is *Valence Band X-ray Emission Spectroscopy* (*VBXES*) or *Soft X-ray Emission Spectroscopy* (*SXES*). If these regions are combined for the purpose of elemental analysis this technique is known as *Electron Probe Micro Analysis* (*EPMA*). See section 17.3.

The second mechanism involves transitions from the free-electron-like states of the incoming electrons, as they are accelerated by the potential inside the surface, to unoccupied states of the surface above its Fermi level with the consequent emission of Bremsstrahlung radiation.

Inverse photoemission spectroscopy (IPS)

Incident: Variable energy electrons (10-20 eV). Beam diameter: 1 mm. Angle of incidence: varied from 0-30°.

Detected: fixed energy photons (6-10 eV). Flux at detector: from several hundred counts per second to a few counts per second. Angle of exit: usually 45° (not critical).

Spectrum: Photon flux (isochromat intensity) vs. incident electron energy (usually presented as electron energy above Fermi level).

Bremsstrahlung isochromat spectroscopy (BIS)

This technique is used, in conjunction with XPS, to provide the one-electron density of states of f and d levels of transition metals and rare-earth metals. The XPS spectrum gives the filled part of the density of states and the BIS spectrum, if the initial and final states are matched, gives the unoccupied part of the density of states.

Note that the recent technique of momentum-resolved Bremsstrahlung spectroscopy is a low energy inverse photoemission spectroscopy not an X-ray Isochromat Spectroscopy.

Incident: Variable energy electrons (1-2 keV).

Detected: fixed energy photons (usually an isochromat energy corresponding to a characteristic X-ray line used in XPS is chosen within the range 1-2 keV).

Spectrum: Photon flux (isochromat intensity) vs. incident electron energy.

Momentum-resolved Bremsstrahlung Spectroscopy (BS)

This is an *Inverse Photoemission Spectroscopy* not an X-ray Bremsstrahlung Isochromat Spectroscopy. The confusion in nomenclature is unfortunate.

Incident: Variable energy electrons (10-20 eV, i.e., few tenths of an eV to ca. 10 eV above Fermi level). Beam diameter: 3 mm. Angle of incidence: 0-60°.

Detected: photons (10-40 eV)

Spectrum: Intensity of parallel component of photon wavevector vs. incident electron energy relative to Fermi level.