Type of presentation: Plenary

IFSM-PL-1780 Some surprises in electron diffraction physics and imaging.

Spence J. C.[1]

[1]Physics Department, ASU, Tempe , Az. USA. 85282, and LBNL USA.

Email of the presenting author: spence@asu.edu

The multiple scattering theory on which modern electron microscopy (EM) is based had been fairly well worked out by about 1960, following work by Bethe, Sturkey, Heidenreich, Hirsch, Howie, Whelan, Cowley and Moodie and others. Nevertheless many surprises remained in the ensuing 50 years. For me the most important of these have been i) The finding that multiple energy-loss effects can be removed from EELS spectra, using earlier work on cosmic ray showers. ii) The richness of the "point-projection" geometry, championed by Gabor in 1949. In turn this has produced Ptychography, the theory of STEM lattice imaging for crystals and low-voltage field-emission point-projection imaging. It is remarkable that coherent overlapping convergent beam orders provide a solution to the phase problem, an atomic-resolution "shadow image", Talbot self-imaging, and in-line holography. iii) The discovery of "forbidden" termination reflections and their value for imaging surfaces and sub-surface dislocations and kinks. Their monolayer sensitivity is remarkable. iv) The detection of coherent bremstrahlung tunable X-ray emission lines in STEM EDX. It is remarkable that these lines can be indexed, and are absent when reflections are forbidden by symmetry. v) The explanation for dynamically forbidden reflections, which cancel due to symmetry-related paths for all thickness. vi) The usefulness of electron channelling effects (Alchemi) on EDX for locating foreign atoms in several fields (turbine blades, mineralogy), previously an academic curiosity. vii) The achievement of aberration correction. viii) The success of our TEM CCD camera, whose impact on cryo-em tomography we never anticipated. ix) The surprising sensitivity of low-angle scattering to atomic bonding, with the zero-order scattering the most sensitive quantity known. x) The finding that sufficiently short pulses of radiation can outrun radiation damage, thus breaking the nexus between damage, resolution and particle size if a large number of particles can be packed into a near delta-function pulse. xi) The information extracted from ELS spectra, with its unrivalled spatial resolution.

The changing agenda of EM over this half-century, from the study of bulk defects such as dislocations, and atomic resolution imaging of interfaces, to nanoscience, cryo-electron and in-situ microscopy (liquid cells, catalysis) has been fascinating to watch. Recent developments - atomic resolution imaging with characteristic X-rays, direct injection detectors, sub-Angstrom resolution, high-resolution imaging in 3D, fast diffraction and imaging - continue to surprise. References in: High Resolution Electron Microscopy (Spence, 4th ed. 2014) and Electron Microdiffraction (Spence & Zuo, 1992).

Acknowledgement: To many colleagues and friends over half a century in many countries, and to the US funding agencies and Arizona State University.