Condensed Matter Physics Institute Seminar

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Ultra-high resolution analysis of nanostructures with SEM and SEM-EDX at lower beam voltages

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For many years SEM performance in both imaging and microanalysis was limited by restrictive understanding of beam-specimen interactions and a correspondingly conservative and unambitious approach to optical design and operating procedures. A re-examination of the relevant physics and pressing needs in key applications led to new initiatives in proof-of-principle instrument design and revitalisation of operating practices for more wide spread kit. To date and to <0.4nm each advance in the optics has led to increased information in images and in spatially resolved elemental analysis now down to <1nm in surface thin film sensitivity. The basic advantage of the SEM is the bulk specimen form after minimal preparation or none but always much simpler, quicker, less invasive and more contextual than thin foils for STEM. Minimising turn round time and effort, and reducing barriers to new experiments, is important in academic research as well as in industry. The complementary multi-spectral signals of the SEM are also available in expanded form in the derivative STEM.

We now have an SEM probe size limited <0.4nm image resolution at 1,000,000x but more importantly 1nm at 1kV and 150-300,000x, either directly or by retardation, so that even electrically non-conducting specimens can be imaged without the need for a potentially invasive conductive coating. More generally imaging at lower voltages can be more informative and surface sensitive, especially for lighter and softer materials.

The bulk specimen volume analysed chemically by EDX, itself with recent developments also greatly improved in sensitivity, is strongly dependent on the incident beam voltage E with the range $R = F(E^{5/3})$, or 10x between 20kV and 5kV, providing $E >> E_x$. With other factors included the analysed volume V is even more strongly influenced by E, with $V = F(E^n)$ with $4<n<5$ and this is the basis for the modern semiconductor defect review tool. Demonstrated analysis of surface SiO_2 particles down to <20nm in diameter is a long way from the long assumed limits of >1um for analysis of bulk specimens. There is corresponding application impact including in high speed high resolution chemical mapping. The basis of quantitative analysis is re-structured and simplified with more emphasis on Z(E), which is standard physics, and less on the more complex A and F. The SEM at lower beam voltages has become a powerful cross-section, plan view, surface analysis and particle defect review tool for complex geometries and diverse interfaces.