Re-inventing the SEM - electrons, protons, and ions

Scanning microscopy now dates back three quarters of a century, so it seems appropriate to ask whether this technology is now as advanced as it will ever get, or are there still novel modes of operation or new technologies which could give the instrument a second lease on life? This presentation will suggest that much that is new and exciting can still be anticipated.

A key enabling step will be the use of scanning microscopes that employ particle (proton or ion) beams rather than electrons. It will be shown that this could result in instruments which demonstrate resolution that is not limited by either fundamental constraints or optical aberrations giving performance which could be comfortably sub-angstrom without any requirement for aberration correctors. A problem with the conventional SEM is that its depth of field falls to just a few nanometers when the tool is optimized to the conditions used for high resolution. This restriction is also absent for ion beam systems as these can deliver depths of field 50 to 100x larger than existing SEMs at equivalent magnifications resulting in images that are both more useful and easier to interpret reliably. Compared to the situation for electrons the interactions of protons and ions are both stronger and more complex in nature, resulting in less beam penetration but higher signal levels and richer information content. For example, while crystallographic contrast in the SEM typically results in just a few percent variation of the backscattered signal, for an ion beam of comparable energy the contrast can approach 40% of the ion induced secondary electron yield so permitting high resolution imaging of grain contrast and crystallographic defects even in bulk samples.

On problem with proton and ion beams is that - because of their low velocity - they cannot excite fluorescent X-rays. Chemical microanalysis, which is a key component of current SEM use, is therefore not presently possible other than possibly by exploiting the Rutherford Backscattering of the incident beam. The RBS images provides high in contrast and resolution, and is specific to the chemistry of the top two or three surface layers. However indentifying elemental compositions is not yet feasible in this mode because of the absence of optimized detectors. Removal of this limitation would remove the final remaining obstacle to the renaissance of the scanning microscope.