Helium detection by elastic scattering in EELS

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With the advent of high quality monochromation for electron sources in EM, the range of energies available to the EELS spectroscopist has been extended deep into the infra-red region. Amongst the events potentially detectable using suitably monochromated beams are the elastic interactions, which for light target atoms and relatively high scattering angles can transfer (elastically) several tens of meV from the incident electron to the atom in question. At least two attempts have already been made to apply this approach to the detection of carbon. The first was a proof of principle demonstration [1] and the second applied the idea to the possible detection of different isotopes through the difference in energy transfer for varying mass target atoms [2].

Here we will present calculations showing the potential of this approach for the detection of helium trapped in bubbles in metals. Although the total elastic cross-sections are lower than their inelastic counterparts for very light atoms, the potential advantage of this approach lies in the fact that the signal will not be superposed on the very intense plasmon resonance of the metal matrix, as is usually the case when attempting to detect inelastic helium signals at around 21eV.

Indeed the key to a successful experiment will be the selection of a range of collection angles (and consequently of energy losses) over which the helium signal should be present in isolation, with no overwhelming background from the zero-loss tail, or from diffraction spots from the metal matrix. The optimisation of all relevant microscope parameters will be examined. High incident energy (200kV) for example increases the energy transfer for a given angular range, making the signal potentially easier to distinguish, but reduces the total elastic cross-section. The calculations reveal that small ranges at low angles give an intense signal but which isprobably too close to the ZLP to be detected, even with excellent monochromation. Wider ranges give a weaker, more diffuse, but ultimately more easily detectable signal - see figure.

The calculations will be complemented with the results of our first attempts to detect helium experimentally using the Nion Hermes monochromated STEM recently installed at the LPS. The high quality monochromation furnished by this instrument is uniquely complemented by a cold stage, enabling experiments at around LN_2 temperatures, which should significantly reduce the thermal energy spread of the elastic signal, rendering its detection easier.

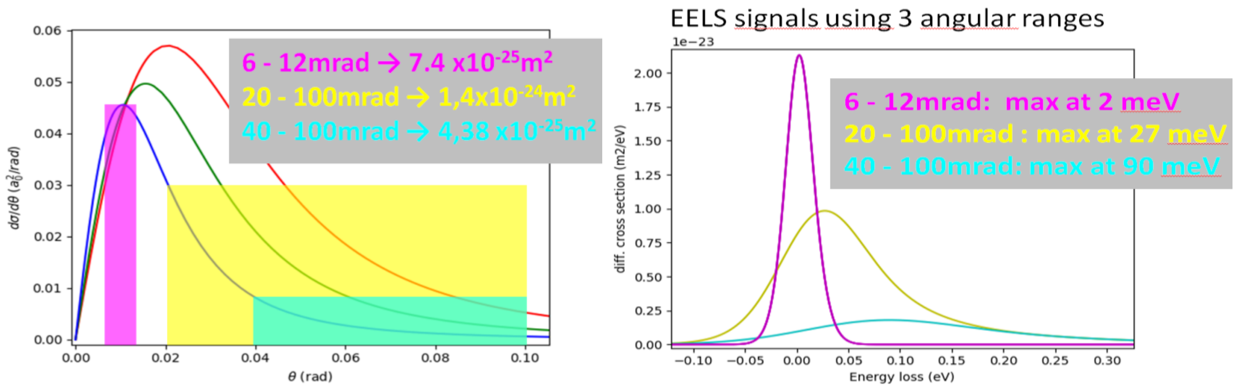

Fig. 1. *left*: Annularly integrated elastic scattering cross-sections at 60, 100 and 200kV and the values at 200kV integrated over 3 angular ranges, *right*: the corresponding energy-loss signals for the 3 angular ranges, assuming a temperature of 75K.

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[2] G. Argentero, C. Mangler, J. Kotakoski, F. R. Eder, J. C. Meyer, Ultramicroscopy **151** 23-30 (2015)

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