A toroidal spectrometer for signal detection in scanning ion/electron microscopes

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This paper presents a toroidal spectrometer detection system for scanning ion/electron microscopes. At present, the detection systems of the Scanning Electron Microscope (SEM), Scanning Helium Ion Microscope (SHIM) or Focused Ion Beam (FIB) are not generally designed to capture the energy spectrum of the ions/electrons scattered from the sample, from which their respective output signals are formed. However, the energy spectra of these particles contain valuable information about the sample under study. The shape of the emitted secondary electron spectrum is related to the sample's work function[1], while the form of the backscattered ion/electron spectrum changes significantly with atomic number[2]. Combining this kind of information with a scanning ion/electron microscope's normal imaging mode of operation, would obviously make it a much more powerful analytical tool for nano-scale inspection.

The research work reported here is based upon using a second-order focusing toroidal spectrometer design, predicted to have a relatively high level of transmission for a given energy resolution[3]. The spectrometer is predicted to have a base relative energy resolution of 0.131% for an emission angular spread of ± 10º, corresponding to a transmittance of around 34% for scattered ions/electrons emitted from the sample at any given energy (assuming a cosine polar angular distribution). This energy resolution is typically an order of magnitude better than the base resolution of the widely used Cylindrical Mirror Analyzer (CMA) for the same entrance angular spread[4]. The toroidal spectrometer is also predicted to have a parallel mode of energy spectrum acquisition, whose energy range exceeds ± 15% of the pass energy.

Fig. 1 depicts simulated trajectory paths through the toroidal spectrometer for different emission angles. The central ray enters the spectrometer at an angle of 45º with respect to the horizontal axis and has a small rotationally symmetric pre-focusing electrostatic lens. Preliminary experimental backscattered energy spectra for three different materials were obtained from a proto-type toroidal spectrometer incorporated into a conventional JEOL 5600 SEM as an add-on attachment, shown in Fig. 2. The experimental results correlate well with Monte-Carlo simulations. Further results and details will be presented at the conference.

References

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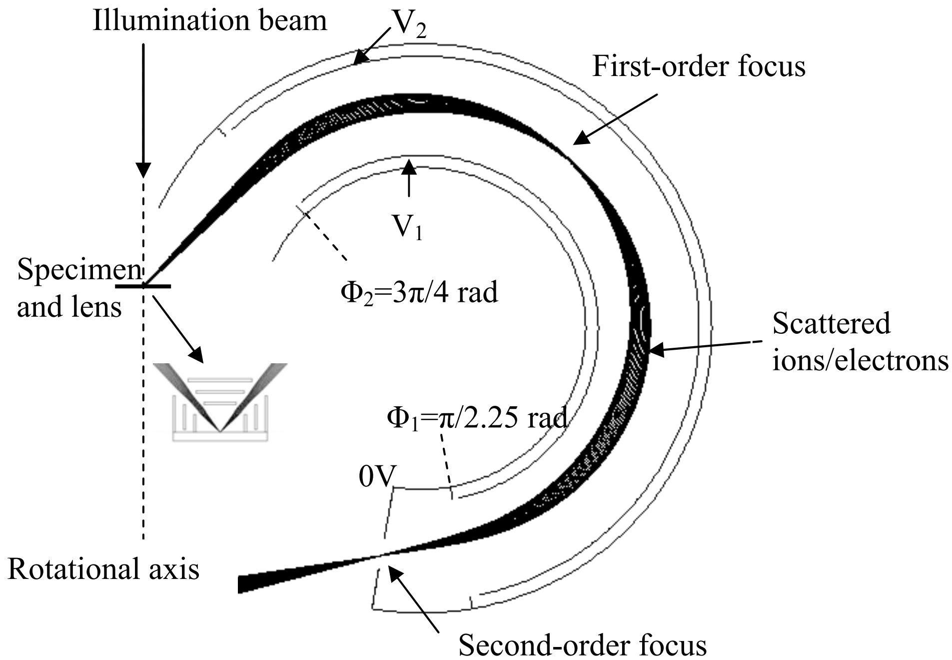

Fig 1: Simulated ray paths through the spectrometer. The central ray enters in at 45^{o} and 21 trajectories are plotted over uniform steps for an input angular spread from -175 mrad to +175 mrad (-10^{o} to $+10^{o}$)

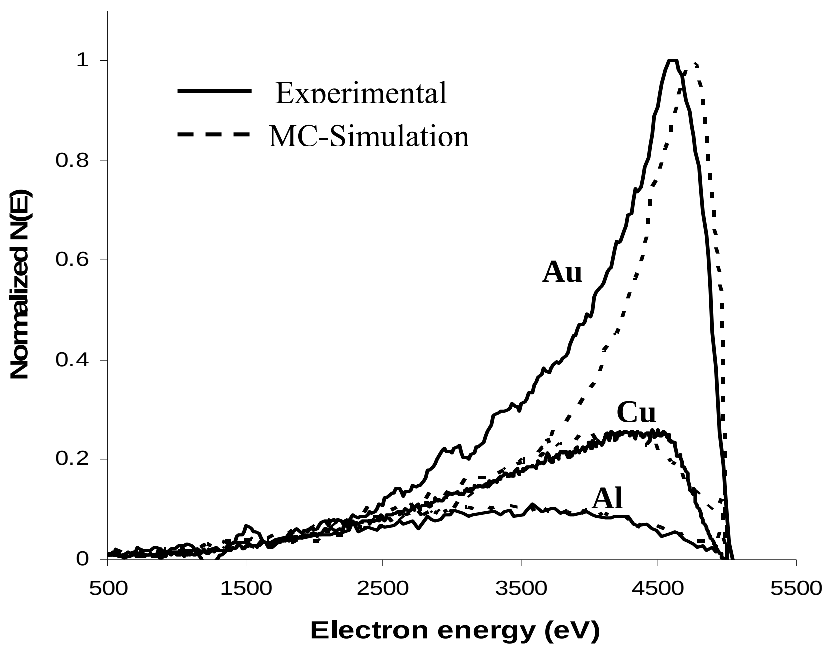

Fig 2. Experimental and Monte-Carlo (MC) simulation for the backscattered electron spectra of gold, copper and aluminum. Each experimental spectrum is normalized to its corresponding MC-simulation.