

How to get the Best of Electron Microscopy with Monte Carlo Simulations

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This paper will present how Monte Carlo simulations can be used in advance to determine the best experimental conditions for performing x-ray microanalysis and electrons backscattered imaging in a field emission scanning electron microscope. The Monte Carlo free software, Casino [1] and Win X-Ray [2] will be presented. These programs can be used to perform quantitative x-ray microanalysis as well as to find optimum conditions to analyse and image various types of materials. The utility of Monte Carlo simulations to characterize non homogeneous materials in the SEM will also be covered. Finally, Monte Carlo simulations for the effect of the skirt on X-Ray microanalysis in the environmental scanning electron microscope (ESEM) or the variable pressure scanning electron microscope (VP-SEM) will be discussed. Casino simulates electron scattering for homogeneous and heterogeneous materials consisting of horizontal or vertical layers and x-ray emission for characteristic lines only. Win X-Ray computes the full X-ray spectrum emitted from a homogeneous bulk specimen and measured with an energy dispersive spectrometer (EDS) x-ray detector in a SEM. These two Monte Carlo programs can be downloaded at <http://www.montecarlo modeling.mcgill.ca/> .

As an example, CASINO was used to simulate the variation of the BSE coefficient, η , and of the boron K_{α} line on a line scan for a Fe specimen having a 10 nm layer of boron for various electron beam energy (E_0) with a beam diameter of 10 nm and with 5000 electron trajectories simulated. Figure [1] shows the variation of η with the beam position. Clearly, the boron layer should be visible at all E_0 . Figure [2] shows the computed contrast as a function of E_0 using the line scans of figure [1]. The contrast decreases with E_0 owing to the increase of the interaction volume. Figure [3] shows simulated x-ray line of the boron K_{α} line. Figure [4] shows the variation of the intensity of the boron K_{α} line when the beam is located at the center of the boron layer as a function of E_0 for two cases, same beam current and the real situation of the brightness proportional to E_0 . In this later real case, 20 keV would be the condition that would maximize the B K_{α} line count rate.

References

1. P. Hovington, D. Drouin and R. Gauvin (1997), "Casino: A New Era of Monte Carlo Code in C Language for Electron Beam Interaction, Part I: Description of the Program", Scanning, Vol.19, pp. 1-14.
2. R. Gauvin, E. Lifshin, H. Demers, P. Horny and H. Campbell (2003), "Win X-ray, a new Monte Carlo Program that Computes X-ray Spectrum for X-ray Microanalysis in the Scanning Electron Microscope", Submitted to Microscopy & Microanalysis.

Figure [1] Variation of the BSE coefficient with the beam position. 10 nm B vertical layer in Fe.

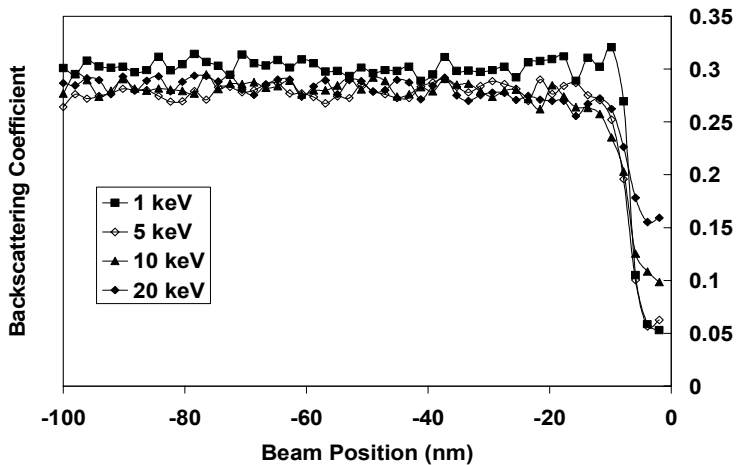


Figure [2] Variation of the contrast versus E_0 computed from the data of figure [1].

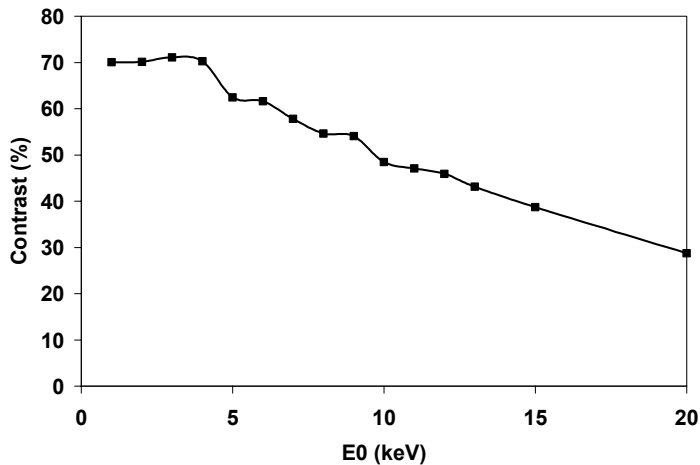


Figure [3] Variation of the B K_{α} line with the beam position. 10 nm B vertical layer in Fe.

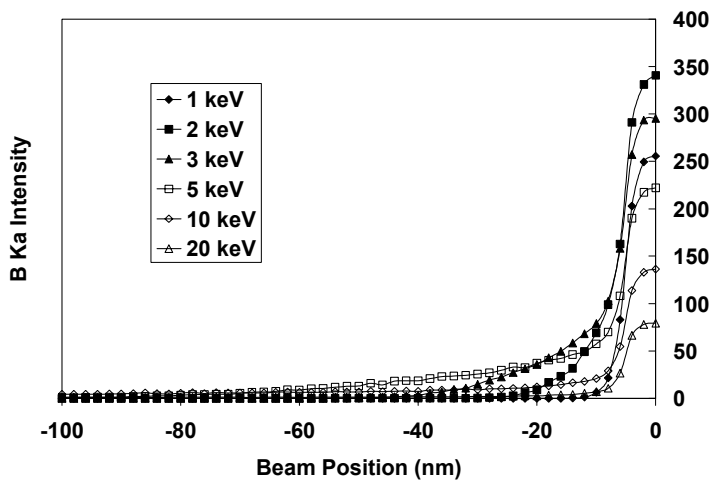


Figure [4] variation of the intensity of the B K_{α} line when the beam is located at the center of the layer as a function of E_0 .

