Studies of backscattered electrons in scanning electron microscopy using Monte Carlo simulations

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The electron backscattering coefficient (BSC) is the fraction of primary beam electrons which emerge from the sample's top surface after a series of elastic and inelastic collisions with the specimen's atoms. The elastic reflection coefficient (ERC) consists of those electrons that underwent only elastic scattering. The BSC is important when working with signals that depend on the energy loss and deposition in the specimen, such as x-ray microanalysis and EBIC (electron beam induced current) in semiconducting devices. The ERC is used in surface analysis techniques, such as EPES (elastic-peak electron spectroscopy).

The BSC for a bulk material is usually given as an integrated value, at times, as function of the incident beam energy. The ERC shows in addition an angular distribution. Further parameters that affect measured and calculated values of these parameters are the beam tilt angle, specimen composition, surface condition, and the characteristics of reflected electrons detectors.

Monte Carlo simulation (MCS) of electron trajectories has become a common method for calculating electron scattering parameters. The basic idea in the simulation is to calculate trajectories for a large number of electrons, using a combination of physical models and fits to experimental data that can be derived from the simulations. Aspects of the simulation process include specimen definition based on its composition and geometry, elastic scattering and inelastic scattering considerations, and detector properties. In many cases, such as in multilayer specimens, this type of simulation is the only method available.

The composition of multicomponent specimens can be dealt in MCS either by assuming some form of averaged values for the material parameters, or by tabulating scattering parameters for the range of electron energies of interest. Dapor and Miotello[1] tabulate the inelastic and elastic cross sections for various oxides for beam energies <10 keV. They find that calculated BSC values were close to experimental within 5–15% in the above energy range, and that the values and their beam energy dependence are similar to that of a compound material whose average atomic

number is ~ 10. Berger and Niedrig[2] report that the BSC angular distribution and the integrated BSC from W-Cu were similar to that of a single component with a mean atomic value calculated using a quadratic weighted (using atomic concentration) average of the atomic numbers.

Detector characteristics effects in the calculation of BSC have been studied by Rosenberg *et al.*[3] It is clear from this work that these play a major role in values obtained for the BSCs, and therefore the wide spread in reported experimental reports for this parameter, as given in the tabulations by Joy,[4] and the graphical presentation of these by Napchan[5] is not surprising.

With increased detection sensitivity and definition, and the selection of suitable elastic and inelastic scattering, it might be possible to increase the quality of available backscattered electron data and perhaps increase the experimental resolution to a few atomic layers range, as calculated by Kwei *et al.*[6] for reflected electrons from Cu at 400 eV primary beam voltage.

References

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