Backscattered Electrons

1. Backscattered electron emission

When a beam of electrons is projected onto the surface of a solid sample, many of the incident electrons will be scattered inside of the sample, resulting in repeated collisions with the atomic core and electrons that compose the sample, until they lose their energy inside the sample. Some of the incident electrons, however, will be emitted from the sample surface into vacuum before losing all of their energy. These are called backscattered electrons. Monte Carlo simulation can model this process where incident electrons, after being projected onto the sample surface, will lose the energy inside the sample, or will be emitted as backscattered electrons into a vacuum. Figure 1 is an example of Monte Carlo simulation where 100 electrons having a kinetic energy of 15 kV are vertically incident onto the surface of an iron (Fe) sample.

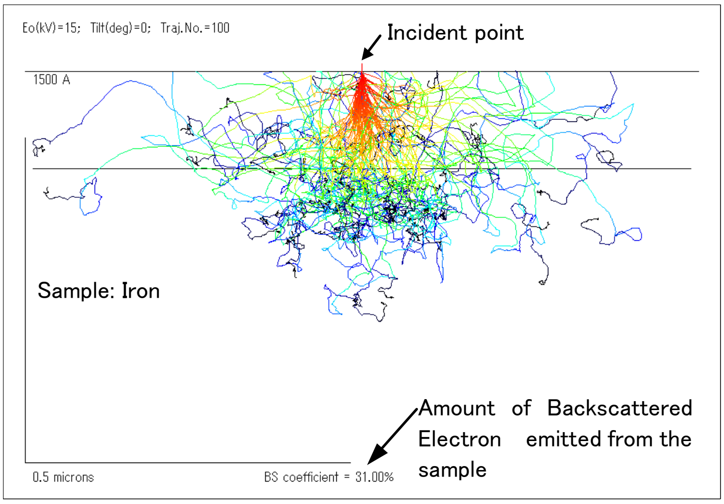

Figure 1
Example of Monte Carlo simulation (100 electrons with a kinetic energy of 15 kV are vertically incident to iron)

2. Backscattered electron energy

The energy level of backscattered electrons ranges widely since some electrons are re-emitted into vacuum immediately after they reach the sample with no energy loss while others lose their energy to varying degrees in the scattering inside the sample. Figure 2 shows an energy distribution of emitted electrons.

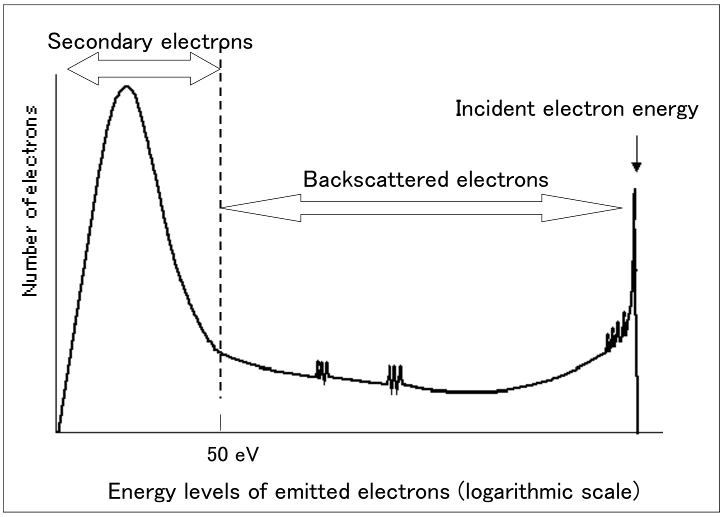

Figure 2
Energy distribution of emitted electrons

3. Information acquired with backscattered electrons

(1) Compositional differences

The volume of backscattered electron emission is determined by the materials that compose a sample (average atomic number). As Figure 3 shows, the higher the atomic number, the larger the emission volume. If the sample surface has differences in composition, backscattered electron emission will acquire the contrast (compositional contrast) determined by the average atomic number of a component. Thus, backscattered electron imaging before elemental analysis with EDS allows the operator to estimate the location of high atomic number materials on the sample. Note that the scale is non linear, making small differences in mean atomic nuclei easier to detect at lower atomic numbers.

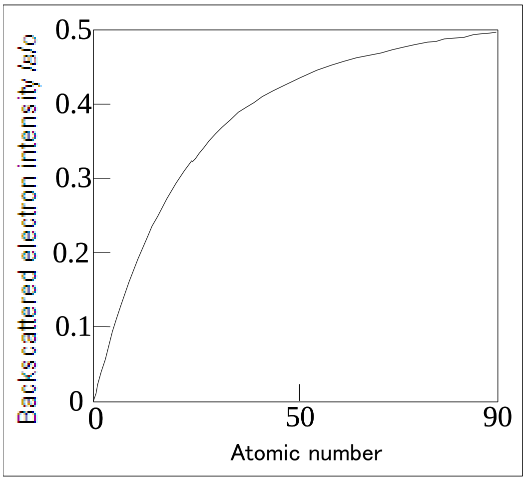

Figure 3
Atomic number vs. backscattered electron intensity (emission rate)

(2) Topography

As Figure 4 shows, backscattered electrons are highly directional; they are emitted in the direction of specular reflection with reference to the incident angle on the sample surface. As a result, backscattered electron emission can detect subtle topographical differences that cannot be identified in secondary electron imaging. Thus, backscattered electron emission can be used for samples polished for analysis to detect subtle differences in depth and to determine the levels of hardness of different areas. This effect is greatly enhanced as the incident electron voltage is reduced.

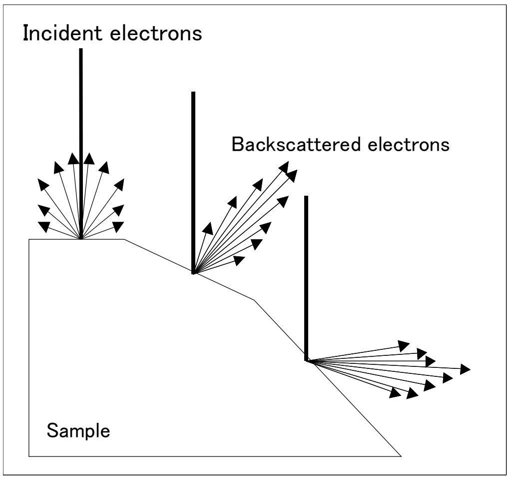

Figure 4
Backscattered electron emission angles

(3) Crystal orientation

Backscattered electron emission from a solid crystal sample is significantly affected by the incident angle of electrons with reference to the crystal orientation. Backscattered electron emission from a multi crystal sample of the same composition, where each crystal has a different tilt angle, will product a different contrast per crystal (channeling contrast). Thus, backscattered electron emission is effective for observation of crystal grains of multi crystal samples.