High Angle Backscattered Electrons and Low Angle Backscattered Electrons

Backscattered electrons emitted from a sample can be captured at angles that are closer to the direction of incident electrons (high takeoff angle) or are farther from the incident electrons (low takeoff angle) by changing the position of the backscattered electron detector. The former is called high angle backscattered electrons, while the latter low angle backscattered electrons. Each provides different types of information.

[High angle backscattered electron emission]

- Detects compositional differences (Z contrast); the higher the accelerating voltage, the more information on the inner structure of a sample is available.
- Shows crystal orientation (channeling contrast) from crystalline samples.
- Has poorest spatial resolution.

[Low angle backscattered electron emission]

- Shows topography; little information on compositional differences or on the inner structure of samples.
- Shows crystal orientation (channeling contrast) from crystalline samples.
- Has highest spatial resolution

Backscattered electron emission accounts for different types of information acquired from a sample by changing the angle of the collection. Figure 1 shows the intensity levels of backscattered electrons emitted from a sample. As the figure demonstrates, backscattered electrons have the maximum intensity in the direction of specular reflection with reference to incident electrons. Backscattered electrons emission by vertical irradiation features a broad angle distribution, penetrates into the sample, and has a large energy loss. On the other hand, backscattered electron emission by oblique irradiation features a narrow, sharp angle distribution, acquires information from the sample surface, and has a small energy loss. The backscattered electron emission can be represented by cos θ of the incident angle.

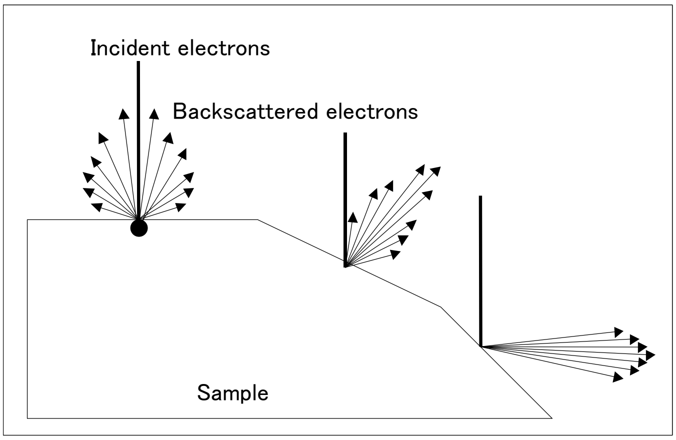

Figure 1. Backscattered electron emission angles

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High angle backscattered electrons are those emitted in the direction closer to incident electrons. They are less sensitive to the inclination of the sample surface, and penetrate into and spread within the sample. They also demonstrate the strong relationship between the atomic number and backscattered electron emission (contrast due to compositional differences), and show crystal orientation (channeling contrast) of crystalline samples.

On the other hand, low angle backscattered electrons mostly have a narrow, sharp intensity distribution. Since their takeoff angle is small, and the signal intensity is easily affected by a slight change in the direction of backscattered electron emission, in short, they are extremely sensitive to subtle changes in localized topography of the sample surface. Since most of the information is from the sample surface, the resulting image will highly reflect this topography. In crystalline samples, these backscattered electrons show crystal orientation (channeling contrast) from the area close to the surface with no energy loss.

Figure 2 shows different locations of a backscattered electron detector in order to capture those emitted in the direction close to incident electrons and those emitted closer to a sample.

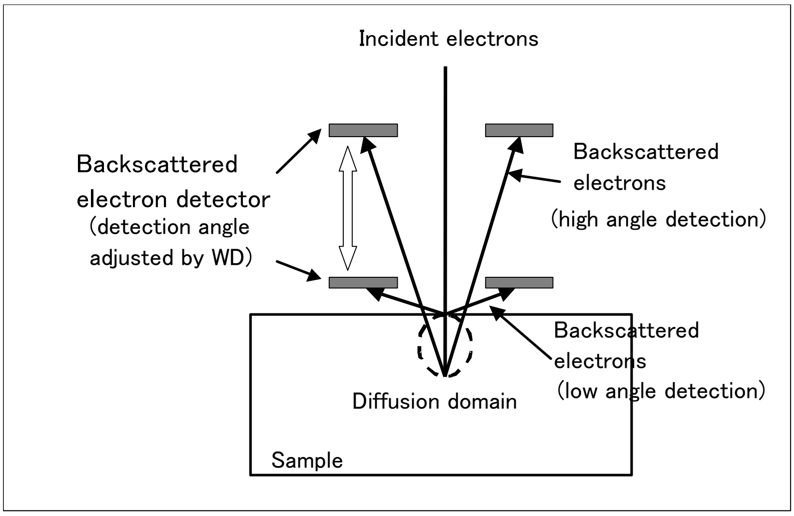

Figure 2. Detector positions and angles

Figure 3 shows backscattered electron images acquired at different detection angles. A semiconductor pair detector was used for capturing backscattered electrons, and the detection angle was switched between high and low by changing the distance between the sample and detector. The sample was a cross section of solder on a NiP substrate. The cross section, prepared by an ultra microtome, features a rugged surface resulting from cut marks and chattering during the sample preparation process. The low angle backscattered electron image shows the surface roughness in addition to the contrast of lead (Pb) and tin due to their compositional differences and the channeling contrast of crystals. However, the images demonstrate that as the detection angle was increased, the topography was replaced with composition and channeling contrast.

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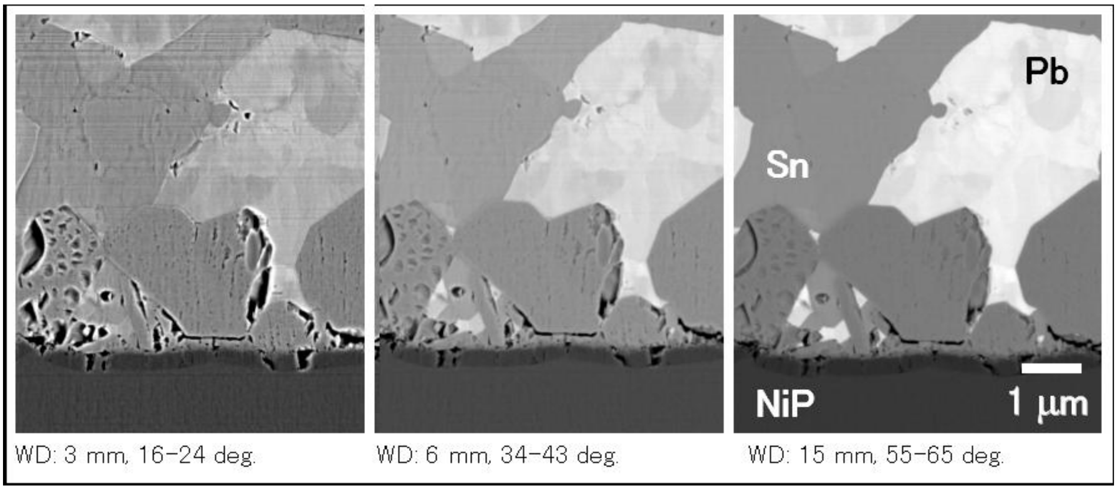

Figure 3. Backscattered electron images acquired at different detection angles
Accelerating voltage: 5 kV; sample: cross section of solder on NiP substrate
Angles in the figure represent backscattered electron solid angles of detection.

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