Physics 7320  
Laboratory 2: Effect of Accelerating Voltage and Secondary vs. Backscattered  
Electron Signal Processing  

Introduction:  
This is a two part lab. The first section examines effects of accelerating voltage. The  
second part examines topographic and Z-contrast using secondary and backscattered  
electron signals.  

Specimens:  
1. Polished mineral specimen containing the following: quartz (SiO$_2$), silver (Ag) and  
sulfur minerals - sphalerite (ZnS), galena (PbS), and chalcopyrite (CuFeS$_2$). One side  
is coated with carbon, the other with platinum.  
2. Semiconductor component  

![Figure 1. Polished mineral specimen overview showing surface coatings (left) with carbon on left and platinum on the right and secondary electron images (mid, right) of polished mineral (middle) and semiconductor (right).](image)

Objectives:  
1. Determine differences between secondary (SE) and backscattered (BSE)  
electrons.  
2. Effect of accelerating voltage (keV) on SE vs. BSE signal  
3. Topographic contrast by SE and BSE at different keVs  

Imaging:  
1. Obtain 8 well-focused/stigmated images of Specimen 1 using secondary electrons at various accelerating voltages.  
2. Obtain 8 well-focused and stigmatmed images of Specimen 2: Semiconductor at increasing accelerating voltages  
   • One set of 4 images will show secondary electron signal images at increasing accelerating voltage.  
   • The other set of 4 images will show backscattered electron signal images at increasing accelerating voltage.
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Questions to be answered:

1. What is a secondary electron? Please describe at least two different mechanisms by which a secondary electron is generated when the SEM’s primary electron beam interacts with your sample?

2. What type of detector is used to detect a secondary electron? Please describe how the signal detected by this detector can be varied.

3. Please discuss the differences in contrast that is seen in the secondary electron image of the polished mineral specimen. What causes this difference in contrast? Are only secondary electrons being detected?

4. In reviewing your images of the semiconductor at increasing accelerating voltages, look at the fine detail in the secondary electron images. What do you notice? Why do you think this is occurring?

5. Use Monte Carlo simulations to support your observations to answers given in question 4.

6. On the polished mineral specimen, describe an experiment where the thickness of the coatings (carbon & platinum) could be determined. Please include relevant equations that would predict your experimental results and speculation on what would be seen in the resulting images. For conveying your answer, a Monte Carlo simulation may be helpful.

7. What is a backscattered electron? How is a backscattered electron generated?

8. Describe the process of elastically scattering an electron. Please write the equation that describes the probability of elastic scattering.

9. Describe the effect of accelerating voltage on the signals displayed in backscattered electron images.

10. How does elemental composition affect BSE-signal generation? How does topography affect BSE-signal generation?

11. Speculate on the composition of the semiconductor based on BSE signals and include an image/images where these areas are labeled.
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Part 1. Polished mineral specimen
This section will demonstrate differences in accelerating voltage on secondary electron signal.

1. Set the following operating conditions
   - Accelerating Voltage........Variable
   - Emission Current..............10 µAmp
   - Mode...........................Normal
   - Working distance.............12 mm
   - Condenser lens...............5
   - Detector.......................Mixed

2. Using overview figure on the right (generated using SE), find an area on the specimen that contains 3 phases (bright, medium and dark)

3. Obtain a focused, well-stigmated image at an accelerating voltage of 10 kV. Label with your LastName_Mineral_ 10kV

4. Staying at 10 kV, take an image with only the lower SE detector " under the “Column Setup” (Figure 2) and take an image. Next, switch to the upper SE detector and take an image. Label with your LastName_Mineral_(lower/upper)_10kV
   ****Note: may need to adjust brightness and contrast

5. Staying at 10 kV, enable “Specimen Bias Voltage” under the “Column Setup” (Figure 2). Take 3 images, with various SE detector settings (Mix, upper and lower). Label each with your
   LastName_Mineral_(mix/lower/upper)Bias_10kV
   **** Note: Specimen Bias applies a voltage of -15 V to the specimen.

6. Obtain a focused, well-stigmated image at an accelerating voltage of 20kV and 30 kV. Label with your LastName_Mineral_ (20/30)kV.
   **** Note: Each time you change kV - focus, alignments, and stigmation must be redone
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Part 2. Semiconductor

This section will demonstrate topographic (secondary electrons) and Z contrast (backscattered electrons).

1. Insert Backscatter Detector (Figure 3), on back left of instrument, screw detector fully into the column.

2. Set following operating conditions:
   - Accelerating Voltage........Variable
   - Emission Current..............20 µAmp
   - Mode.........................Normal
   - Working distance.............8 mm
   - Condenser lens...............5
   - Detector.......................Upper (no bias voltage)

3. Starting at 30 kV, center the numbers on the semiconductor sample in low mag mode. Switch to high mag mode, and adjust sample to 8 mm working distance using the Z-height adjustment knob. Perform focus, alignments, stigmation, & brightness/contrast.

4. Enable “Split Screen” Mode.

5. Open the “Signal Select” window and choose “SE” for the right side and “BSE” on the left. Adjust brightness/contrast.

   ****Note, the left split screen can be adjusted with hand-panel controls, right side need to be adjusted with the slider bars

6. Obtain 8 focused, well-stigmated images of the same area (ex. the numbers) using both secondary electron and backscatter detectors at the following accelerating voltages: 5 kV, 10 kV, 20 kV & 30 kV.

   ****Note: Each time you change accelerating voltage, focus, alignments, stigmation, & brightness/contrast must be redone.

7. Retract backscatter detector fully by unscrewing BEFORE venting and removing sample.