The 3 SEM Signals You Need to Know to Optimize Your SEM Analysis

A Scanning Electron Microscope (SEM) is a powerful magnification tool that utilizes a focused beam of electrons to obtain information. SEMs produce high-resolution, three-dimensional images and provide topographical, morphological, and compositional data. SEMs are invaluable in various industries and applications, such as material science, failure analysis, microelectronics, semiconductors, medical devices, general manufacturing, etc. Below we will explore three SEM signals and how we can use them to optimize SEM analysis.

Backscattered Electrons (BSE)

Backscattered electrons (BSE) are high-energy electrons from the primary beam of SEM. When the primary beam interacts with the atoms of the sample, BSEs are scattered elastically off the nucleus and returned towards the beam's origin. As BSEs are of high energy, they travel deep into the sample, between tens and hundreds of nanometers. Due to interaction with the nucleus, different elements scatter different amounts of BSEs, e.g., elements with higher atomic numbers scatter higher amounts. This behavior allows the collection of compositional information in the sample

Attributes of Backscattered Electrons (BSE):

- Originate from the primary beam
- Result of elastic scattering events
- High energy
- Provide compositional information
- Depth between 10's to 100's of nanometers
- Minimally affected by charging of surface/environment

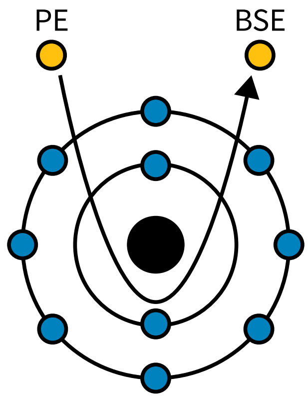

Figure 1: *Backscattered electron (BSE) is scattered elastically off the nucleus after primary electron (PE) interacts with the atom of the sample.*

Secondary Electrons (SE)

Unlike BSEs, secondary electrons (SE) are low-energy electrons emitted from the surface or the near-surface regions of the sample. When the primary SEM beam hits the sample, a portion of the beam electrons excite electrons of sample particles. SEs scatter more broadly with less energy than BSEs. Due to the low energy, only the SEs created in the top few nanometers can escape the sample to be detected - allowing for the collection of topological information. Edges or ridges in the sample produce an increased amount of collectible SEs, appearing brighter on resulting images and allowing for increased surface understanding.

Attributes of Secondary Electrons (SE):

- Result of inelastic scattering events
- Low energy <50eV
- Depth of only a few nanometers
- Contain topographic information
- Affected by charging of surface or environment

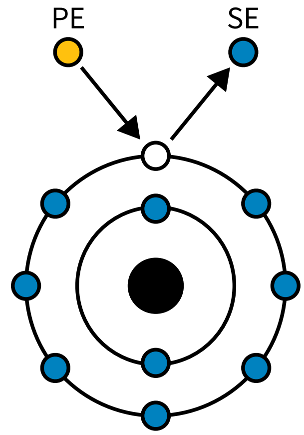

Figure 2: *Secondary electron (SE) is emitted from the surface or the near-surface region of the sample when primary electron (PE) hits the sample.*

X-Ray Emissions

During the SEM process, characteristic X-rays are emitted from the sample. We can use energy-dispersive X-ray spectroscopes (EDS or EDX) to detect characteristic X-rays for further elemental composition characterization. When a primary beam electron knocks out an inner shell electron, it produces a gap, and an electron from a higher shell of the atom drops down to fill the void. This electron drop frees up energy emitted from the atom as an X-ray. The energy patterns of characteristic X-rays are dependent on the energy level differences between electron shells in the atom, which are unique to each atomic species. This signal can escape from deep within the material, allowing for compositional surveys between 100's of nanometers to microns deep.

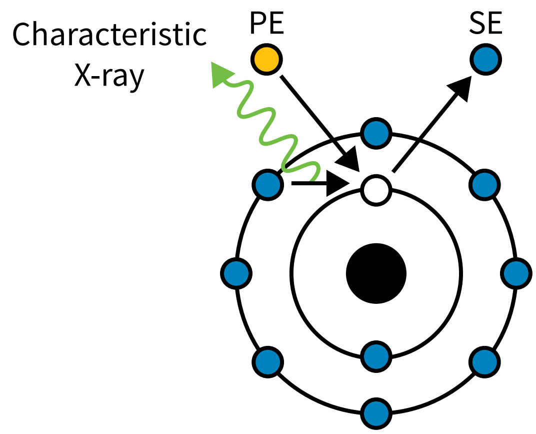

Figure 3: Characteristic X-ray is emitted from the sample when a primary electron (PE) knocks out an inner shell electron.

Attributes of X-Ray Emissions:

- Produced during electron ejection
- Higher depth than both BSE and SE – 100's of nanometers to microns deep
- Characteristic X-rays 100's eV up to 10's of KeV
- Compositional/elemental information

Tips for Optimization

1. Understand the information needed

Different methods collect different information, so understanding what type of information you are looking for can help narrow your optimization steps. If the goal is to understand the surface topology of the sample, making modifications to optimize SE collection will be helpful. Whereas if the goal is to understand the sample composition, optimizing BSE collection or X-ray detection will be more beneficial.

2. Instrument Modifications

- **Primary Beam Voltage**

  Changing the voltage of the primary beam can alter signals. A higher voltage can increase penetration depth while reducing surface data.

- **Electric Fields**

  Applying a repelling force to the sample stage can encourage SEs to work their way up through the column to the detector, increasing the collection of SEs. The charged stage can also help BSEs, but not as effectively. With the charge encouragement, the instrument's working distance can be reduced, consequently improving the resolution of the data.

Applying charge biases to the detectors can filter signals to improve the clarity from a single type of signal. A negative bias to the column will repel SEs, filtering out cleaner BSE signals. On the other hand, a positive bias can be applied to the SE detectors, pulling increased signals and allowing for more detailed topological information.

- **Detector selection**

  There are various detectors available, and each detector collects different signals and produces images with varied depths, contrasts, and information. Understanding the needs for the sample will help identify the detectors and modes that are best suited for the task, and expert selection and combination of detectors can help produce optimized experimentation.

SEM is an essential technique across many fields. Knowing your project needs and optimizing SEM analysis towards your goals helps solve product development problems effectively. If you have a challenge you want to overcome, a problem you want to solve, or a guideline you need to meet, Covalent Metrology is here to help. With advanced technology and industry experts, Covalent Metrology provides in-depth data and analysis you can trust.

Covalent Metrology's Instruments

Covalent Metrology uses new, cutting-edge instrumentation from Thermo Scientific to deliver high-quality SEM data with rapid turnaround times. Our Helios 5 DualBeam provides excellent resolution for enhanced measurement and visualization – with specialized features particularly beneficial to clients characterizing devices or complex nanostructures. Our Scios DualBeam has comparable ultra-high resolution with immense adaptability to accommodate challenging materials: including samples previously untenable on an electron microscope.

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