BIO Web of Conferences **129**, 05019 (2024) https://doi.org/10.1051/bioconf/202412905019
EMC 2024

Optimizing Backscattered Electron Detection in SEM: Diode Layout and Collection Efficiency

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Scanning electron microscopes (SEMs) with their variety of attachments designed for surface observation and analysis stand as a key instrument in research institutes and quality testing facilities worldwide. The essence of the SEM is to induce the emission of various electron products from the specimen, among which backscattered electrons (BSEs) play a pivotal role. These BSEs emerging from the specimen carry information of composition and structure and play an important role in material and life science. Therefore, while most SEMs are equipped with a standard BSE detector, optimizing the measurement process of BSEs becomes crucial when considering the wide range of measurements into account and pushing the limits for aiming the maximum performance. In addition to the detection efficiency of the detector, the geometry of the set-up also plays a decisive role. We therefore address the question of how the layout of the detector affects the specific geometries present in SEM setups [1].

In SEM in general, ensuring clear visualization of specimen features relies on several factors, including beam current, pixel dwell time, working distance, and detector efficiency. Below a certain minimum contrast threshold, specimen details may become indistinguishable. However, for certain specimens or setups it may not always be feasible to increase beam currents, adjust beam energy, or change the working distance to enhance contrast. In such cases, maximizing the collection of electrons (here BSEs), becomes essential for obtaining satisfactory results. Achieving this involves optimizing the diode layout, thus emphasizing the importance of selecting suitable detectors aligned with specific measurement requirements for effectively optimizing SEM imaging parameters [2]. But despite the important role of BSE collection efficiency across scientific and industrial domains, the literature addressing this aspect remains relatively sparse, posing a significant challenge for comprehensive research in this field.

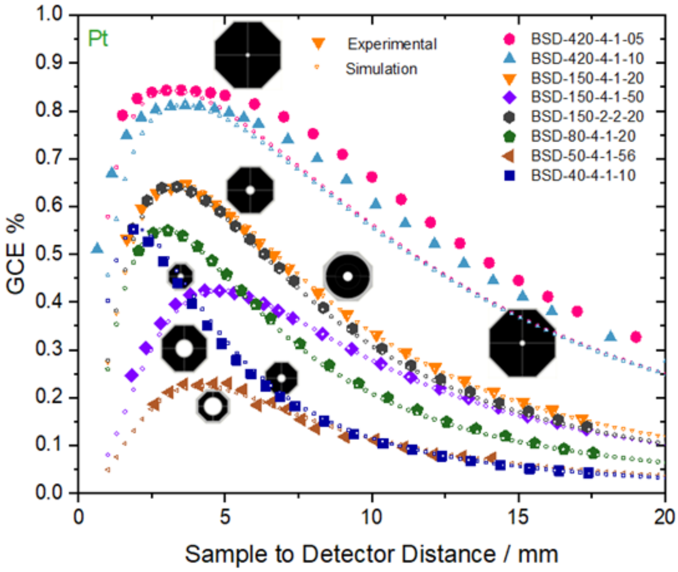
We conduct experiments measuring the backscattered electron collection at various working distances to determine the optimal conditions for each type of diode. To provide a quantitative assessment, we introduce the Geometric Collection Efficiency (GCE), defined as the ratio of BSE impinging on the active area of the diode to the total number of BSE leaving the sample. We present GCE values for different diode layouts across varying working distances. These results are supported by simulations of GCE based on the cosine distribution of BSE and the setup geometry.

Our study aims to illuminate a crucial aspect influencing the performance and accuracy of Back-scattered electron Detector (BSD). We seek to quantitatively understand the collection efficiency of backscattered electrons across a diverse range of BSD. Employing BSD with varying active areas ranging from 40 to 420 mm^2 and hole diameters ranging from 1 to 5.6 mm. Moreover, these findings enable the identification of the most suitable diode layout for specific measuring geometries. Typically, the diode aperture should be sufficiently small to minimize backscattered electron (BSE) loss at shorter working distances, while the outer diameter of the diode must be large enough to capture a greater proportion of BSE at larger working distances. However, this general approach must be adapted to fit within an existing setup, where the hole size additionally impacts the field of view, and the outer diameter may obscure or interfere with other detectors within the SEM. Therefore, it is imperative to determine the optimal diode layout considering both geometric collection efficiency and mechanical constraints of the setup. Subsequently, we will showcase images from various applications, spanning from low working distance (WD) and low keV scenarios to high-current applications accompanied by parallel energy-dispersive X-ray spectroscopy (EDX) measurements at higher WDs.

In conclusion, our investigation utilizes various BSD with distinct geometries to assess their suitability for diverse applications in SEM. Through systematic evaluation of detector performance under varying experimental parameters, we aim to offer insights into selecting the most appropriate detector for specific imaging tasks or analytical objectives.

Fig. 1. Comparing simulated and experimental Geometric Collection Efficiency (GCE) values for diverse Backscattered Electron (BSE) chips with different geometrical configurations. The analysis reveals a close agreement, providing insights into the performance and accuracy of each chip.

Graphic:



Keywords:

Scanning Electron Microscope,Backscattered Electrons,Detector Efficiency

Reference:

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