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Optimization of Spectral Data Acquisition for Electron Microscopy

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Abstract
This contribution explores the optimization of Energy-Dispersive Spectroscopy (EDS) measurement point placement in Scanning Electron Microscopy (SEM) utilizing Backscattered Electron (BSE) images. Existing methods for elemental analysis often face a tradeoff between precision and speed, relying on point placement strategies that can slow down data acquisition. To address this, the proposed the proposed method introduces an segmentation-based technique designed to enhance the process of selecting measurement points. Through testing and comparison with traditional approaches, the proposed technique demonstrates improved performance, yielding clearer and more reliable elemental information. Figure 7 Figure 10 This method holds potential for applications in automated mineralogy and materials science, where accurate compositional analysis is essential.

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1. Introduction

Scanning Electron Microscopy (SEM) is a key tool in materials science for capturing detailed images of sample surfaces. Backscattered Electrons (BSE) are high-energy electrons that bounce off a sample, creating images that highlight differences in composition and surface features based on atomic number. [1]. Figure 3 Heavier elements yield more BSEs, appearing brighter, which makes BSE imaging ideal for distinguishing phases in complex samples. Energy-Dispersive Spectroscopy (EDS), a complementary technique, identifies and quantifies elements by analyzing X-rays emitted when the sample is bombarded with electrons [2]. Figure 1 The strategic placement of EDS measurement points on BSE images is critical to obtaining accurate and representative elemental data, as poor placement can result in mixed or unreliable spectra.

1.1 Motivation

The reasonable placement of EDS measurement points in SEM is vital for achieving reliable elemental analysis, a necessity in fields such as mineralogy, metallurgy, and materials science. Inaccurate placement can lead to data that misrepresents a sample's composition. Current automated mineralogy systems, such as TESCAN's TIMA (TESCAN Integrated Mineral Analyzer), face challenges in optimizing point placement, particularly for samples with complex or crystalline structures. This contribution, developed in collaboration with TESCAN, aims to enhance the efficiency and accuracy of EDS analysis by optimizing point placement, thereby improving decision-making in industrial processes and deepening the scientific understanding of material properties .

2. Problem Definition

This contribution focuses on optimizing the placement of EDS measurement points on BSE images to maximize the accuracy and representativeness of elemental data. The core challenge is to develop a method that positions points in locations yielding clear, unambiguous EDS spectra, avoiding regions like material boundaries or low-signal areas that compromise data quality. A successful solution should be adaptable to diverse sample types, computationally efficient, and capable of minimizing redundant measurements. The solution's effectiveness will be evaluated by representativeness of the sample's elemental composition, and the method's practical applicability in automated mineralogy systems.

2.1 Existing Solutions

Current methods for EDS point placement, such as those implemented in the TESCAN TIMA system, typically rely on segmenting BSE images to identify regions of interest, followed by placing measurement points on a regular grid within these segments. Figure 5 This approach offers systematic coverage and is relatively straightforward to implement, making it suitable for high-throughput mineral analysis. However, it has notable limitations:

- Regular grid placement may not align with the structural properties of certain samples, such as crystalline materials, where lattice-specific placement could decrease data quality.
- To sensitive segmentation parameter can result in inaccurate region identification, leading to suboptimal point placement.
- Points positioned near segment boundaries may capture mixed signals from adjacent materials, reducing the accuracy of elemental analysis.

These drawbacks highlight the need for a more adaptive and precise approach to EDS point placement.

2.2 Proposed Solution

This contribution proposes an segmentation-based technique to enhance EDS point placement. Figure 4 Figure 6

The method processes a BSE image by converting it into segments using a threshold, reducing segment borders and small transitional segments identified as boundary regions, distributing points across segments based on parameter k, and adaptively spreading points within each segment to create an optimized mask of EDS measurement points. Figure 2 Unlike traditional methods, the proposed approach incorporates several key improvements:

- Exclusion of segment edges and transitional regions to prevent mixed spectra, ensuring points are placed in areas with consistent material properties.
- Adaptive, non-grid-based point placement within segments, tailored to the sample's morphology and composition for more representative sampling.
- Variable parameters integration for fine-tuning the method, allowing dynamic adjustment of parameters such as point density and segmentation threshold. Figure 9

This method aims to deliver higher-quality elemental data by addressing the shortcomings of grid-based placement and improving adaptability to complex samples.

2.3 Contributions

The proposed method has been tested and demonstrates significant improvements over existing approaches, delivering clearer and more reliable EDS spectra.By enhancing the precision of elemental analysis, this work advances the capabilities of automated mineralogy systems, with potential applications in mineral processing, materials characterization, and scientific research. The collaboration with TESCAN ensures that the method is designed with practical integration into commercial SEM systems in mind, amplifying its impact.

3. Conclusions

This work developed a segmentation-based method to optimize EDS point placement on BSE images in SEM, enhancing elemental analysis efficiency and accuracy . By excluding edges, using adaptive point placement, and dynamically allocating points, it delivers clearer, more representative spectra.

The key take-home messages are as follows:

- The proposed method improves spectra quality by avoiding mixed signals from material boundaries.
- Adaptive and dynamic point placement offers better representativeness, tailoring measurements to the sample's unique morphology and composition.
- Collaboration with TESCAN ensures practical applicability, paving the way for integration into automated mineralogy systems.

If additional time were available, future efforts could focus on refining the algorithm and expanding its capabilities. Specifically, further optimization of dynamic allocation of points per segment, guided by factors such as BSE intensity, could enhance coverage while minimizing redundancy. Additionally, incorporating dynamic allocation of EDS measurement counts could improve the efficiency of data collection by prioritizing regions with higher analytical value [3].

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