Photoshop for Scanning Electron Micrographs

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Company Background

Prof. Mistry's research is about building next-generation batteries and other futuristic electrochemical energy systems. The development of such devices is limited by an incomplete understanding of how material behavior translates to device-scale performance. To address this key scientific knowledge gap, his research group synergistically combines controlled experiments, physics-based theory, and machine learning techniques.

Description of the Work to be Done

Scanning Electron Microscopy (SEM) is a workhorse technique imaging material features spanning nanometers to microns[1,2]. For a given sample, a typical SEM station captures the images with three different modalities: secondary electron (SE), back-scattered electron (BSE), and energy dispersive spectrum (EDS). Exemplar images are shown in Figure 1.

The goal of this field session project is *to develop an image processing app that combines images of these three modalities and performs a variety of operations on them to generate different types of composite images* (i.e., a Photoshop but for SEM images), for example,

- **False color BSE**. A BSE image assigns grayscale values depending on material composition; this information can be used to assign false colors to various parts of the images, for example, the spherical blobs in Figure 1(a) can be colored blue.
- **False depth SE**. An SE image assigns grayscale values depending on the surface morphology; this information can be used to create a terrain-like 3D visualization of the imaged surface.
- **Composite EDS**. Various EDS images can be stitched together to generate a single composite EDS image with multiple user-defined colors for specific elements.
- **Statistics of Geometrical Features**. Geometrical features such as the spherical blobs in Figure 1(b) can be analyzed to quantify their number density and size distribution statistics.

Being able to analyze SEM images of different modalities and generate such composite images will be quite valuable to Prof. Mistry's research.

App Design for User Experience

Ideally, a user should be able to upload various raw SEM images, and select from a variety of image processing options to guide image manipulation, and should not have to explicitly

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code any steps. The app output should be a few selected image file formats (.png and .jpg) and data files for the geometrical statistics.

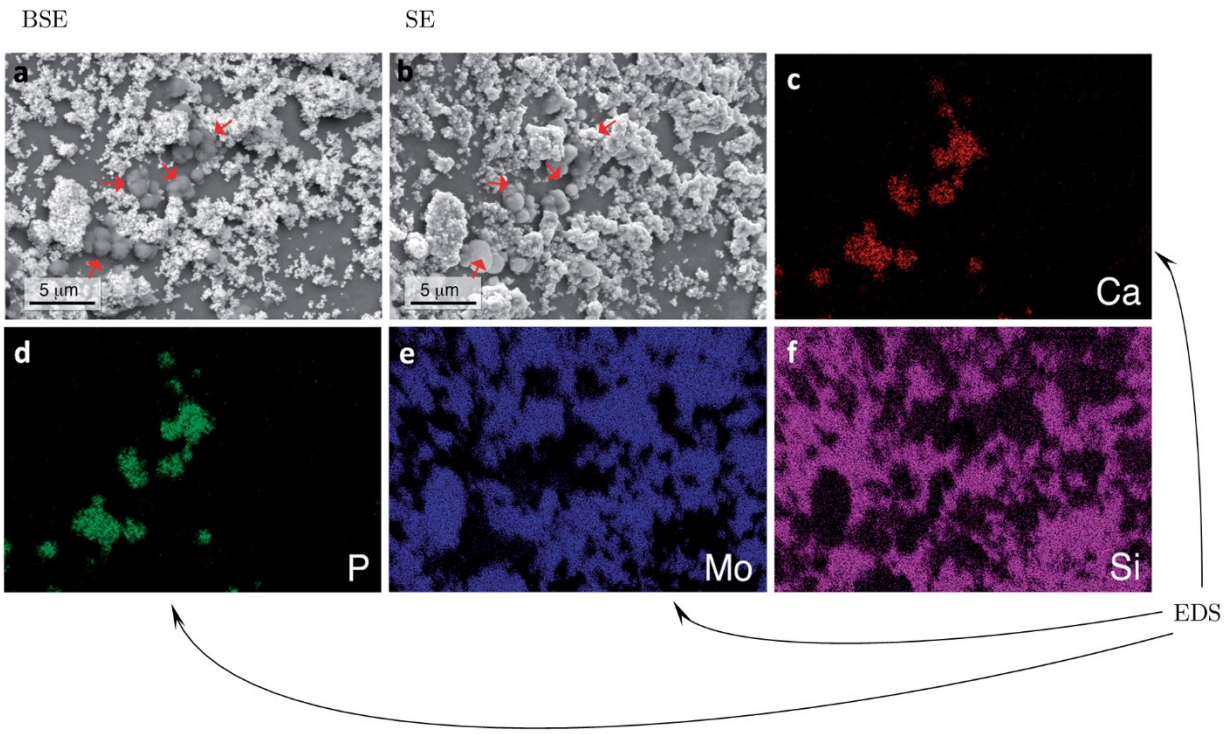

Figure 1. Exemplar SEM images of the same sample from Ron et al. (2014) Nanoscale 6, 5251[2]. (a) BES image (b) SE image (c) – (f) EDS maps respectively identifying Ca, P, Mo and Si elements for the same material sample.

Any Desired Skills for the Students

- python programming,
- image processing,
- geometrical analysis,
- 2D and 3D visualization, and
- GUI development.

Preferred Team Size

3 – 4 students

Potential Internship at the End of the Course

Please reach out to Prof. Mistry if you are interested in using your computer science skills to solve problems relevant to battery and electrochemistry research.

Some of the potential opportunities are independent study, SURF (Summer Undergraduate Research Fellowship), and a CS project-based Masters (https://cs.mines.edu/msdegree/).

If the app built for this project does the intended task, it will contribute to a future research publication from the group, and the students from this team will be invited to be co-authors for the study.

Location

Anywhere except for the regular in-person check-ins @Mines

Non-disclosure Agreement (NDA)

Depending on the end result, there may be a scope of marketable software. While any information revealed to other Mines students or professors is not considered public disclosure, please refrain from discussing the specific details of the project with anyone outside Mines.

Intellectual Property Rights

We will jointly hold the Intellectual Property Rights.

References

(1) De Castro, O.; Audinot, J.-N.; Hoang, H. Q.; Coulbary, C.; Bouton, O.; Barrahma, R.; Ost, A.; Stoffels, C.; Jiao, C.; Dutka, M.; Geryk, M.; Wirtz, T. Magnetic Sector Secondary Ion Mass Spectrometry on FIB-SEM Instruments for Nanoscale Chemical Imaging. *Anal. Chem.* **2022**, *94* (30), 10754–10763. https://doi.org/10.1021/acs.analchem.2c01410.

(2) Ron, R.; Zbaida, D.; Kafka, I. Z.; Rosentsveig, R.; Leibovitch, I.; Tenne, R. Attenuation of Encrustation by Self-Assembled Inorganic Fullerene-like Nanoparticles. *Nanoscale* **2014**, *6* (10), 5251–5259. https://doi.org/10.1039/C3NR06231G.