Development of Advanced Methodologies for Using EBSD Characterization with Non-Planar Samples

Postdoctoral Research Position in Materials Science

CEA, Saclay, France

Context

Electron Back-Scattered Diffraction (EBSD) in Scanning Electron Microscopy (SEM) is essential for characterizing crystalline materials at the mesoscopic scale. Recent advancements — such as fast EBSD cameras with high signal-to-noise ratios and robust orientation indexing methods like "Dictionary-Indexing" [1] — have expanded its applications. In spite of such remarkable progress, enabling studies under extreme conditions both *in situ* and *post mortem* remains unsolved, although it would bring an extremely valuable information.

Indeed, traditional EBSD analysis assumes flat sample surfaces, and samples with surface relief present significant challenges. Variations in surface topography alter the electron beam's incidence angle and the distances to the EBSD detector, leading to degraded map quality (see Fig. 1) due to reduced signal-to-noise ratios, shadowing effects, and contrast inversion on EBSD detector.

These limitations impact many materials science applications involving non-planar surfaces. For example, EBSD analysis of fractured surfaces can provide valuable information but is currently impossible to perform with commercial tools. Similarly, studying crystal orientation evolution during mechanical or thermal stress is complicated by unaccounted surface roughness. Accurate data are crucial for modeling and predicting deformation and rupture mechanisms of materials under various stresses. This issue applies to all samples with non-planar geometries, such as tubular structures and thin-film surfaces.

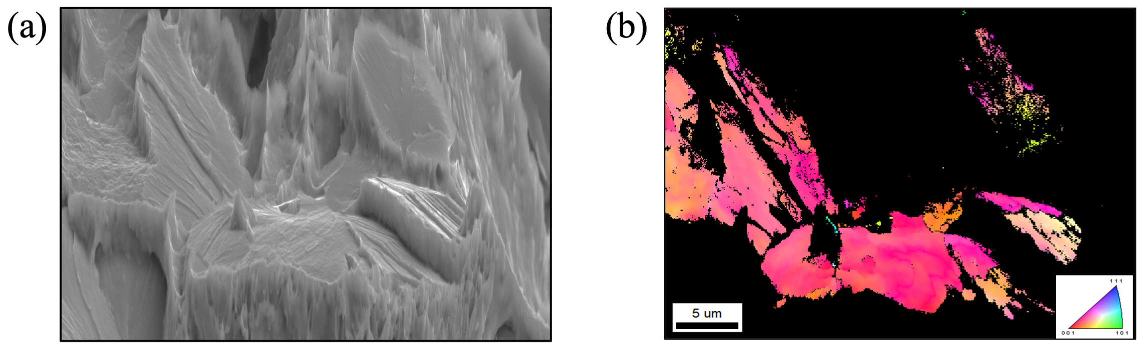

Figure 1: (a) SEM image of the surface of a fractured sample (b) Partially indexed EBSD map of the same surface.

Project Description

The aim is to develop a robust, automated EBSD analysis method for materials with varying surface relief. Previous studies have coupled EBSD data with 3D surface reconstructions from SEM images [2] [3] or AFM surfaces [4]. While effective for moderate topographies, these methods are difficult to automate due to complex data alignment. A more promising approach directly exploits EBSD information, simplifying alignment, but it has only been tested on samples with minimal relief [5].

Key Challenges Include:

(i) Establishing a theoretical model for orientation correction that accounts for all geometric parameters affecting EBSD orientations on non-planar samples.

(ii) Optimizing experimental acquisition conditions (EBSD detector position and orientation, sample tilt, and orientation) to maximize data quality and quantity.

(iii) Adapting post-processing of experimental patterns with topography-related artifacts.

(iv) Evaluating, adapting and optimizing existing topographic reconstruction approaches in SEM [5] [6] [7].

(v) Validating the method's accuracy on known surface topographies, which could be machined by focused ion beam (FIB) (see Fig. 2).

(vi) Applying the methodology to real-world case studies: EBSD analysis on fractographies and during *in situ* mechanical and/or thermal loading tests.

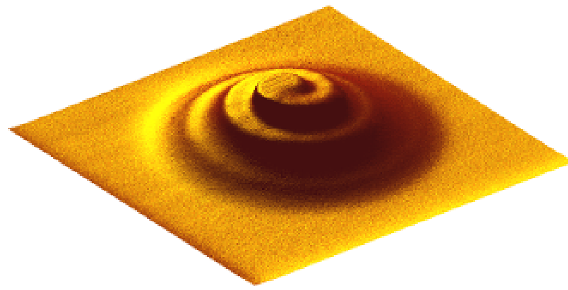

Figure 2: 3D model of sample with a known surface topography that will be used for validation

This project is part of a collaborative effort involving several esteemed laboratories (LMPS, LMS, PIMM, Centre des Matériaux, CEA, ONERA) each bringing specialized expertise to the table. These collaborations ensure access to a broad range of expertise and state-of-the-art equipment, fostering an environment conducive to innovative research and development in EBSD methodologies.

Position Details

- **Duration**: 10 months (with the possibility of extension).
- **Location**: French Alternative Energies and Atomic Energy Commission (CEA), Saclay, France.
- **Start Date**: As soon as possible.

Candidate Profile

We are seeking a highly motivated Postdoctoral Researcher with a strong background in computational methods, with applications in materials science, physics, or related fields. The ideal candidate will possess:

- Proficiency in **numerical modeling** and the **development of algorithms for** complex problem-solving.
- Familiarity with **image processing** and pattern recognition methods.
- Strong **programming skills** (e.g., Python or similar language).
- Excellent communication and teamwork abilities.

Application Procedure

Interested candidates should send the following documents:

- A detailed CV including a list of publications.
- A cover letter outlining your research experience and motivation for this position.
- Contact information for at least two references.

Please send your application material to clement.lafond@cea.fr.

References

[1] M. De Graef. A dictionary indexing approach for EBSD. *IOP Conference Series: Materials Science and Engineering*, 891(1):012009, jul 2020.

[2] P. Mohseni, J.K. Solberg, M. Karlsen, O.M. Akselsen, and E. Østby. Application of combined EBSD and 3D-SEM technique on crystallographic facet analysis of steel at low temperature. *Journal of Microscopy*, 251(1):45–56, 2013.

[3] M. Tsuboi, A. Shibata, D. Terada, and N. Tsuji. Crystallographic characterization of cleavage plane in low-carbon martensitic steel. *Materials Today: Proceedings*, 2:S655–S658, 2015. International Conference on Martensitic Transformations, ICOMAT-2014.

[4] Yongzhe Wang, Marcel Winhold, Mingguang Kong, Matiullah Khan, Pinar Frank, Christian H. Schwalb, and Yi Zeng. Investigation on the habit plane of martensitic transformation in zirconia coatings. *Journal of the Australian Ceramic Society*, 56(1):257–264, Mar 2020.

[5] M. Chapman, P.G. Callahan, and M. De Graef. Determination of sample surface topography using electron back-scatter diffraction patterns. *Scripta Materialia*, 120:23–26, 2016.

[6] Jan Neggers, Eva Héripré, Marc Bonnet, Denis Boivin, Alexandre Tanguy, Simon Hallais, Fabrice Gaslain, Elodie Rouesne, and Stéphane Roux. Principal image decomposition for multi-detector backscatter electron topography reconstruction. *Ultramicroscopy*, 227:113200, 2021.

[7] Jan Neggers, Eva Héripré, Marc Bonnet, Simon Hallais, and Stéphane Roux. A generic topography reconstruction method based on multi-detector backscattered electron images. *Strain*, 58(5):e12416, 2022.