An overview of HREBSD techniques for measuring local stress and dislocation density in crystalline materials

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Abstract

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1. Introduction

Electron backscatter diffraction (EBSD) is a common diffraction technique associated with scanning electron microscopes (SEMs) used to spatially map crystallographic orientation and phase. EBSD, and other diffraction techniques in an SEM, works at a convenient intermediate length scale between transmission electron microscopy (TEM) diffraction and X-ray diffraction (XRD) techniques, having enough resolution to resolve most microstructural features but also the ability to collect statistically relevant data with comparatively little sample preparation. However, conventional, Hough-based indexing of EBSD patterns has an accuracy of around 0.5°, a limited ability to distinguish between similar phases and no capability to explicitly measure elastic strains. A number of techniques have been developed to extract additional information from EBSD patterns, and the purpose of this paper is to summarize one of these: high resolution EBSD (HREBSD), a technique that involves image correlation on diffraction patterns for superior orientation precision as well as elasticstrain information. Although this review will cover a broad range of work, HREBSD is presented here in the context of OpenXY, an open-source HREBSD software package. This work will start by giving an overview of the history of HREBSD and contextualize it with other prominent EBSD techniques. Then an overview of the mathematics of HREBSD, including error estimates and dislocation analysis will follow. Finally, a number of cross-validation studies and applications will be discussed.

DO WE WANT ONE OF THOSE PAPERS PER YEAR CHARTS? I'VE GOT NOTHING ON IMPACT HERE.

2. Background

The first dynamical electron diffraction patterns formed by diffuse scattering were reported by Nishikawa and Kikuchi [1] from work in a TEM, and dynamical diffraction patterns formed by diffuse scattering of an electron beam, including EBSD patterns, are referred to as Kikuchi patterns. Shortly after, the first example of Kikuchi diffraction with a glancing incidence angle, i.e. EBSD, was reported [2]. Kikuchi diffraction patterns are characterized by excess and defect lines associated with crystallographic planes as opposed to spots from kinematical diffraction techniques, as well as bands of increased intensity between the lines. For a summary of much of the early work on Kikuchi diffraction, see [3].

EARLY DETECTORS

INDEXING AND FEATURE ANALYSIS

TROOST AND WILKINSON

3. Nomenclature

Lines versus bands.

So many types of Kikuchi diffraction. But not ECP?

HREBSD, where does it end?

Pattern center versus detector distance.

F, β, ω, ε, etc.

Stress, strain and elastic strain.

TKD

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4. Method

4.1. Mathematics of the projection of a deformed material

4.2. Local shift measurements with cross-correlation

4.3. Least squares fit of measured shifts

4.4. Pattern remapping

4.5. DIC-based approaches

4.6. Reference pattern selection

4.7. Simulated reference patterns

5. Error and Mitigation

5.1. Gaussian error

5.2. Pattern center error

5.3. Interaction volume size and shape

5.4. Traction free assumption

5.5. Neglecting Bragg's Law

5.6. The "MV" effect

5.7. Large misorientations

6. Dislocation analysis

6.1. Derivative calculation

6.2. The Nye tensor - α

6.3. "Splitting"

6.4. Step size sensitivity

6.5. Groma-Wilkinson

7. Cross-validation studies

7.1. HREBSD and ECCI

7.2. HREBSD and TEM

7.3. HREBSD and X-ray techniques

8. Applications

8.1. Crystal plasticity models

8.2. Lattice parameter variation

8.3. Stresses in microelectronics

8.4. In situ testing and nanoindentation

9. Summary

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Data Availability

The data used in this study will be made available upon request.

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