Experiment Brief

eaSI 4D STEM

Title

NBED strain measurements enhanced via energy-filtered 4D STEM

Gatan Instrument Used

eaSI™ is an exclusive technology from Gatan that delivers the most **efficient** and **effective** workflow for advanced STEM experiments. eaSI leverages the **GIF Continuum**® system upgraded with the **STEMx**® system to enable energy-filtered 4D STEM studies.

Background

A better understanding of materials' behavior under tension or compression is vital for various engineering fields. For instance, in many common silicon devices, strain engineering is used to tailor their electronic properties for different applications. Similarly, in the case of metallics, understanding and then predicting the material behavior under deformation requires strain measurement. One of the standard strain mapping (scanning transmission electron microscopy (STEM) methods is nanobeam electron diffraction (NBED) [1, 2]. In this technique, the electron probe is scanned over a two-dimensional (2D) array on the specimen, while a 2D electron diffraction pattern is recorded at each probe position, hence the name 4D STEM. Strain is then calculated by measuring changes to the positions of the diffraction disks compared to a reference diffraction pattern acquired from an unstrained area of the sample. NBED strain mapping depends greatly on how precise the position of the diffraction disks is measured.

Materials and Methods

First, two diffraction images were collected from a Si sample on a Stela® camera (that utilizes DECTRIS hybrid-pixel technology) at the end of a GIF Continuum system upgraded with STEMx: One unfiltered (without an energy selecting slit) and one filtered (with a 10 eV energy selecting slit on the ZLP). As shown in the line profile in Figure 1, disk edges are much sharper in the filtered diffraction pattern compared with the unfiltered pattern. Sharper edges in the diffraction disks increase the precision with which the position of the diffraction disk can be measured, and hence a more precise strain map is generated when energy filtering is used. Next, using the STEMx system, we collected two 4D STEM datasets (unfiltered and energy-filtered) and calculated the strain: Strain maps from the energy-filtered 4D STEM data showed a 20% improvement in the standard deviation compared to unfiltered maps [3].

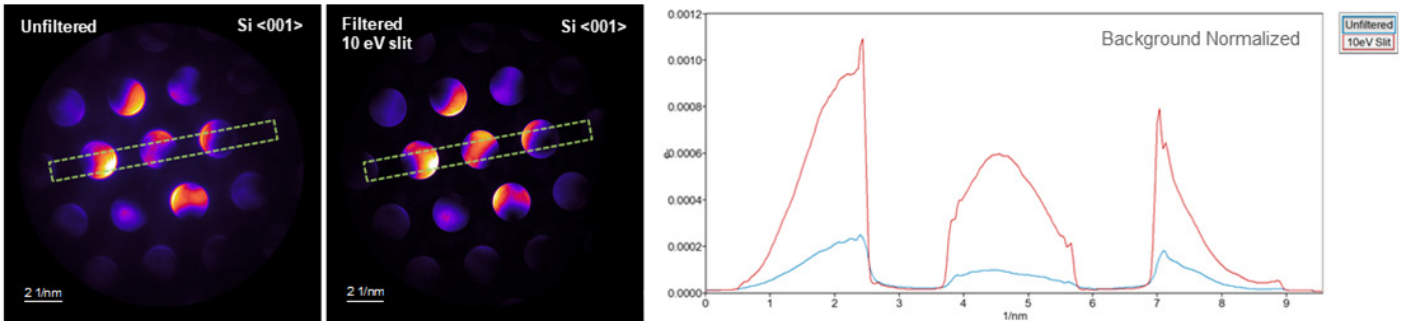

Figure 1. Diffraction disks in the energy-filtered patterns have sharper edges, as shown in the profile lines on the right, resulting in more precise strain map calculations from NBED.

Summary

A simple experiment using a Si sample was designed to study the benefits of using a GIF Continuum for NBED strain mapping. Upgrading the GIF Continuum with a STEMx system allows recording 4D STEM datasets in energy-filtered mode. In this mode, inelastically scattered electrons are eliminated, and diffraction disks are recorded with sharper edges. This means disk positions can be measured more precisely, resulting in at least a 20% improvement in the precision of strain mapping results.

Credit(s)

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[1] M.J. Hytch, A. Minor, MRS Bulletin, 39, 139 (2014).
[2] V. B. Ozdol, C. Gammer, X.G. Jin, P.Ercius, J. Ciston, C. Ophus, and A. Minor, Applied Physics Letters, 106, 253107 (2019).
[3] A. Pakzad, P. Longo, Microscopy and Microanalysis, 24, 168 (2018)

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