GATAN

AMETEK

Experiment Brief

Stela Hybrid-Pixel Camera

Title

Electron diffraction for chirality identification in spintronics

Gatan Instrument Used

The Stela™ hybrid-pixel camera enables uncompromised diffraction imaging at low-beam energies. Stela uses the DECTRIS hybrid-pixel technology to reveal hard-to-detect diffraction details with the highest signal-to-noise ratio via electron counting. Additionally, it captures low- and high-intensity diffraction peaks in a single frame leveraging its high-dynamic-range sensor.

Background

The field of spintronics has been drawing a great deal of attention in recent years because of its potential in applications such as data storage, telecommunications, and information processing [1]. Among spintronics, non-centrosymmetrics (NCS) show switchable spin split electronic band dispersions with external stimuli. $NaCu_5S_3$ (space group $P6_322$) is one such NCS: a stable ferri-chiral compound that has been shown theoretically to display chirality-dependent spin splitting in the electronic structure. On the other hand, experimental chirality determination using electron microscopy has proven quite challenging, as detection of chirality (a three-dimensional structural feature) in a simple two-dimensional transmission electron microscope projection is not possible.

Materials and Methods

Based on the violation of Friedel's law in chiral crystals, diffraction intensities observed from two enantiomers using convergent beam electron diffraction (CBED) will differ [2]. Hence, chiral identification is possible using the intensity asymmetry in Bijvoet pairs of reflections on the correctly chosen zone axis. Such intensity differences can be very subtle, difficult to detect and require an electron detector with a high signal-to-noise ratio and dynamic range. The Stela camera was used to collect CBED patterns from synthesized $NaCu_5S_3$ crystals in a JEOL Grand ARM operated at 80 kV. No beam stop was required. The 512 x 512 pixels CBED pattern was collected in the camera's high-dynamic range (HDR) mode using a total exposure time of 0.5 s (pixel size of 0.092 nm^{-1}). Thus, central beam (without saturation) and FOLZ discs were collected in a single frame.

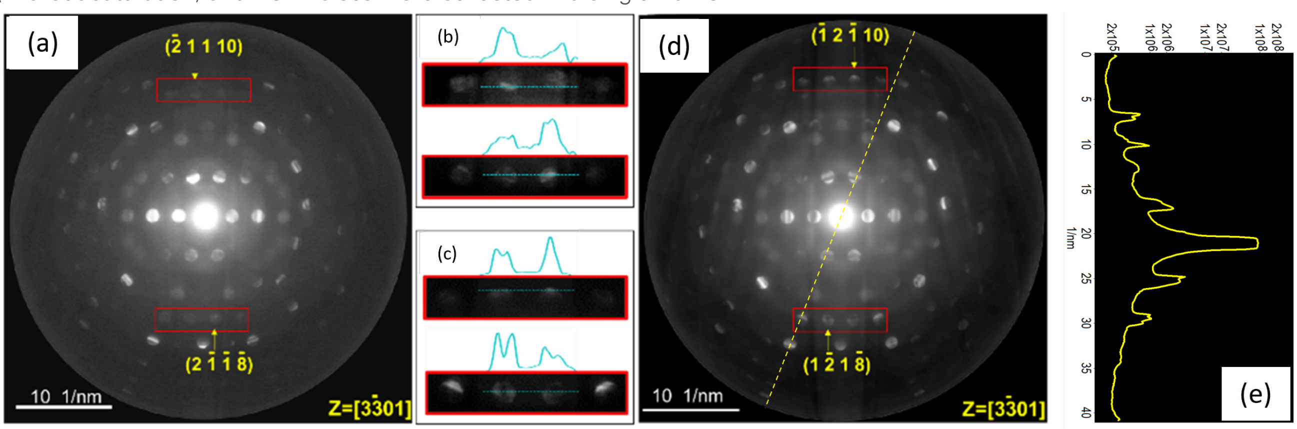

Figure 1. Experimental CBED patterns of (a) FEC-1 and (d) FEC-2 $NaCu_5S_3$ along [3301] zone axis, showing the asymmetric intensity distribution of FOLZ reflections in two enantiomers. (b) and (c) high-magnified and contrast-enhanced images of critical discs in the red-marked box in (a) and (d): the intensity profile of critical discs shows the asymmetric brightness. (e) intensity profile along the dashed yellow line in (d): no saturation (32 bit) at the central beam location (log scale).

Summary

A study of chirality in spintronics was possible by leveraging the Stela hybrid-pixel camera's high-quality diffraction imaging capability to capture subtle difference/intensity asymmetry between Bijvoet pairs in CBED patterns.

Credit(s)

A special thanks to Northwestern University Chi Zhang, Ken Poeppelmeier, Vinayak P. Dravid, and Roberto dos Reis. This work made use of the EPIC facility of Northwestern University's NUANCE Center, which has received support from the SHyNE Resource (NSF ECCS-2025633), the IIN, and Northwestern's MRSEC program (NSF DMR-1720139).

[1] W. W. Chow and S. Reitzenstein, Quantum-Optical Influences in Optoelectronics—An Introduction, Applied Physics Reviews 5, 041302 (2018).

[2] J. M. Bijvoet, A. F. Peerdeman, and A. J. van BOMMEL, Determination of the Absolute Configuration of Optically Active Compounds by Means of X-Rays, Nature 168, 271 (1951).

EB-Stela-CBED-FL1-CA-NOV21