doi:10.1017/S1431927617001581
Microsc. Microanal. 23 (Suppl 1), 2017
© Microscopy Society of America 2017

Accurate Diffraction Peak Identification for Scanning Electron Nanodiffraction Based on Automated Image Processing and Feature Detection

Renliang Yuan[1,2*], Yifei Meng[1,2*], Jiong Zhang[3] and Jian-Min Zuo[1,2]

[1.] Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois, USA
[2.] Fredrick Seitz Materials Research Laboratory, University of Illinois at Urbana-Champaign, Urbana, Illinois, USA
[3.] Intel Corp., Hillsboro, Oregon, USA
*First two authors contributed equally to this work.

Transmission electron diffraction (TED) has been widely used to characterize nanocrystalline materials due to its high sensitivity to local structure and ability to focus electron beam to nm or sub-nm size [1-5]. By controlling the built-in TEM deflection coils with a DigitalMicrograph® script, we can scan the nano-beam across desired sample area and acquire a series of diffraction patterns over a region of interest. This technique is called scanning electron nanodiffraction (SEND) [6,7]. Recently, 3D-SEND is developed as a new SEND-based technique to determine 3D morphologies and orientations of grains in nanocrystalline materials, which can work with chemically homogeneous samples with grains of different orientation [8], as well as chemically inhomogeneous samples.

The big dataset for 3D-SEND (~1,000 patterns for one angle and ~30,000 patterns in total for an example) requires a fast and robust algorithm to identify the diffraction peak positions. Previously, a template matching process is utilized to find the diffraction peaks [9]. A cross correlation map is calculated for each diffraction pattern with a spot template, where local maxima are determined to be the position of the diffraction spots. This technique works well for most of the experimental data, but may also cause discernable error when diffraction spots vary in size or are irregular in shape (see Fig. 1(a)).

Here we propose a new algorithm to identify peak position in SEND data. Seeing the diffraction spots as circles with different radii, we employ the edge detection method in computer vision by applying a edge filter to the original diffraction pattern [10]. After edges are detected, a circular Hough transform (CHT) is carried out by creating an accumulator matrix and determining the center of the circle by a "voting" process [11]. An example of this detection process is shown in Figs. 1(a-c). This technique still is not perfect due to the fact that circles may not be successfully detected when the spot intensity is too low. Thresholding and binarizing the original diffraction pattern before performing the edge detection improves the result. An example in which all diffraction peaks, both strong and weak or irregular, are detected can be seen in Figs. (d-f). Various filters and modification to the process have been tried to find the best condition for accurate peak identification, which will be reported here [12].

References:

[1] Cowley, J.M., "Electron Diffraction Techniques." 1993: International Union of Crystallography.
[2] Zuo, J.M. and Spence, J.C.H., "Advanced Transmission Electron Microscopy". 2017: Springer.
[3] Zuo, J.M. et al, Science, 2003. **300**(5624): p. 1419-1421.
[4] Zuo, J.M. et al. Microscopy Research and Technique, 2004. **64**(5-6): p. 347-355.

https://doi.org/10.1017/S1431927617001581 Published online by Cambridge University Press

[5] Zuo, J.M. and J.C.H. Spence, "Advanced Transmission Electron Microscopy: Imaging and Diffraction in Nanoscience." 2016: Springer.
[6] Tao, J. et al, Physical Review Letters, 2009. **103**: p. 097202.
[7] Kim, K.H. et al, Micron, 2015. **71**: p. 39-45.
[8] Meng, Y. and Zuo, J.M., ICUrJ, 2016. **3**: p. 300-308.
[9] Zuo, J.M. et al, Ultramicroscopy, 2014. **136**: p. 50-60.
[10] Canny, J.F., IEEE Transactions on Pattern Analysis and Machine Intelligence, 1986. **8**(6): p. 679-698.
[11] Duda, R.O. and P. E. Hart, Comm. ACM, 1972. **15**: p. 11–15.
[12] This work is supported by a grant from Semiconductor Research Corporation.

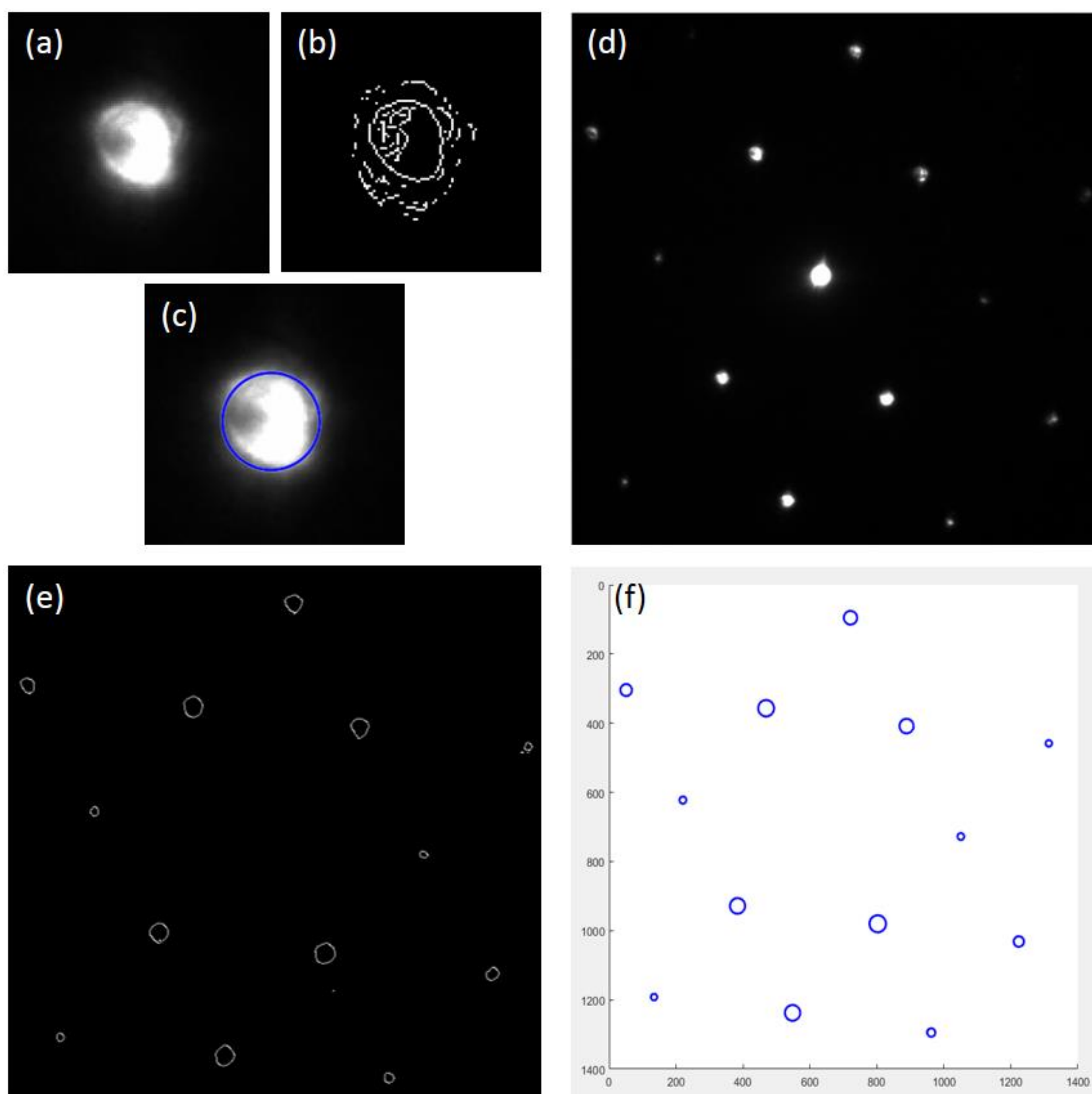

Figure 1. (a) Typical irregular shaped diffraction spot. (b) Edges detected using Sobel filter from (a). (c) Blue circle denotes the circle detected after circular Hough transform. (d) Typical diffraction pattern of Si in [110] zone axis. (e) Edges detected from (d) after image binarization. (f) Diffraction peaks detected from (d).

https://doi.org/10.1017/S1431927617001581 Published online by Cambridge University Press