The use of Correlation Coefficient maps to enhance visibility of internal structure for nanocrystalline thin foils

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DOI: 10.1002/9783527808465.EMC2016.6564
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Keywords: Transmission electron microscopy (TEM), electron diffraction, correlation coefficient map, automated crystal orientation mapping (ACOM)

Orientation and phase are routinely determined with the automated ACOM tool developed for Transmission Electron Microscopes [1]. With this attachment, the beam is scanned over the area of interest and all the diffraction patterns are collected and kept in memory for further off-line analysis. The present work concerns a novel approach that makes use of the memorized data to compute a structural image of the sample through a straightforward post-processing algorithm that consists in weighting the similarities between the neighbor diffraction patterns [2].

The successive diffraction patterns acquired within a given crystal are anticipated to be nearly identical, while an abrupt change is expected when the beam is crossing a grain or a phase boundary. Plotting the value of a correlation coefficient that compares the intensities of every pixels of the neighbor diffraction patterns produces a contrasted picture in which all structural features that modify the local diffracting conditions are highlighted.

Fig. 1 gives a typical example where grain boundaries for a polycrystalline sample are retrieved. Of particular interest is the fact that the grain boundary contrasts are directly related to the boundary inclination. Indeed, the sharp changes in diffraction patterns expected for boundaries parallel to the electron beam are associated to a strong contrast. A weak and extended contrast indicates qualitatively a gradual modification of the diffracting signal as expected for inclined boundaries. Quantitative evaluation needs different processing [3].

The correlation coefficient is sensitive to any structural component that modifies the diffracting conditions. This is valid for dislocations, too. Two of them appear in the upper grain in figure 1.
Moreover, the correlation coefficient is less sensitive to non-visibility conditions. This is because it is constructed on the difference between the intensities of all reflections including the faint ones. In particular, if the sample is in a so-called two beam condition, the main reflection g remains unchanged when the beam is crossing a dislocation line whose Burgers vector is normal to g. This reflection will be dominant in the bright field image and the dislocation will not be visible. Being constant, g will not contribute to the correlation coefficient. By contrast faint reflections that always exist in the diffraction pattern - even in two beam conditions - will be affected by the distortion around the defect line. Figure 2 compares the virtual bright-field image and the correlation coefficient map for a deformed ferritic steel sample. The thin foil is slightly bended (less than 2°, mainly from left to right) so that the contrast conditions are not homogeneous in the micrograph and part of the structural information is missing. The correlation coefficient is less sensitive to the exact illumination conditions and consequently additional dislocations appear in the map.

References:
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Figure 1. Virtual Bright-field, orientation map and the corresponding correlation coefficient map for an alumina sample with submicron grains. Note the dislocations appearing in the upper grain (arrows).

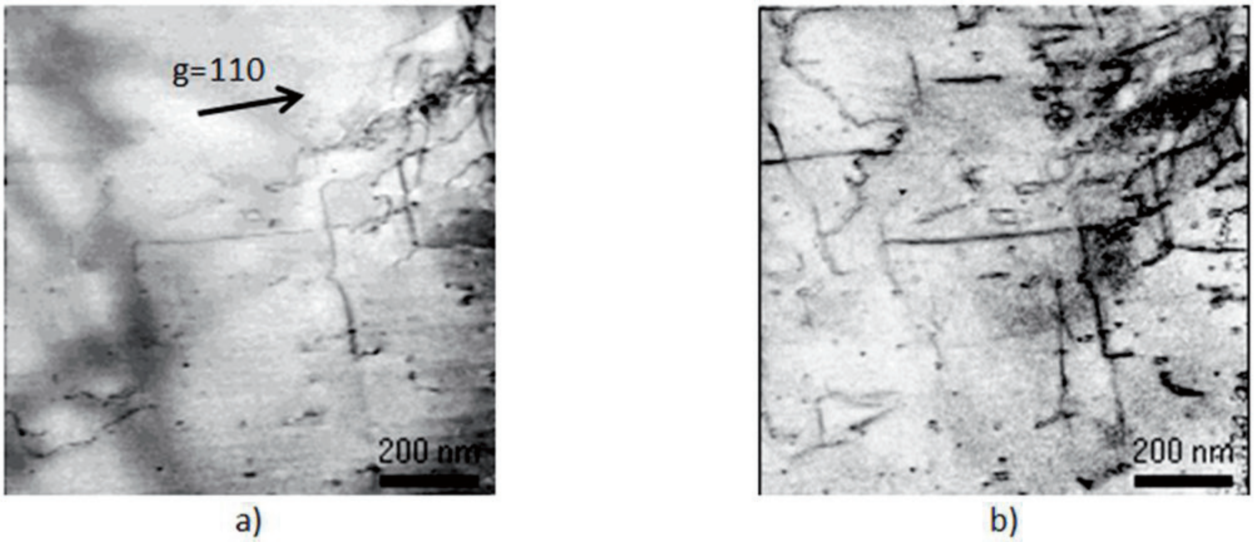

Figure 2. Virtual bright field image (a) and correlation coefficient maps (b) of the same area for a deformed low carbon steel sample observed in nearly two-beam conditions. Higher number of dislocations is made visible by correlating the diffraction patterns.