Comparison of on-line and off-line averaging for EBSD indexing

Håkon Wiik Ånes, Lars Andreas Hastad Lervik, Ole Natlandsmyr, and Jarle Hjelen

Department of Materials Science and Engineering, Norwegian University of Science and Technology, N-7094 Trondheim, Norway
Corresponding author: hakon.w.anes@ntnu.no

In advanced polycrystalline materials, e.g. Li-ion NMC materials, the grain size is very small. Electron backscatter diffraction (EBSD) analysis of such materials demands high spatial EBSD resolution which is achieved by reducing the acceleration voltage and the beam current. At these scanning electron microscope (SEM) settings the patterns will be noisy and hard to index by conventional Hough indexing (HI) [1, 2].

To improve the indexing hit rate of noisy patterns two approaches of pattern averaging (on-line and off-line) and indexing by means of Hough and dictionary indexing (DI) [3] (without orientation refinement) were applied. Two EBSD datasets from the same area were acquired on a *JEOL JSM-IT100* SEM equipped with a *NORDIF* EBSD hardware dedicated for pattern streaming. One dataset without pattern averaging (averaging 1), the other with on-line averaging of five patterns from each position on the sample (averaging 5). The acquisition time of the latter was thus five times longer than the former. The maps were acquired with the following SEM/EBSD settings: probe current 1.7 nA, high voltage 20 kV, frame rate 150 pps, pattern resolution 96x96, step size 1 μm, and high camera gain. The specimen was a super duplex stainless steel (SDSS) containing α- and γ-iron grains. HI was done with *EDAX TSL OIM 7.3,* while off-line averaging and DI was done with the *kikuchipy* Python package [2, 4].

Figure 1 shows five inverse pole figure (IPF) maps from the two datasets acquired at 1.7 nA, coloured according to the included colour key. The IPF maps in the left and right columns in Figure 1 are indexed by HI and DI respectively. The IPF maps in the 1st and 2nd rows were based on on-line pattern averaging of 1 and 5 respectively. The IPF map in the lower right corner was based on off-line averaging according to the 3x3 window with Gaussian weights in the lower left corner. The pattern quality from one specific grain (green grain highlighted in Figure 1) is shown before and after on-line averaging at two different probe currents (1.7 nA and 3.4 nA) in Figure 2.

The frame rate is 88 pps/nA in this set up, and at this condition the signal to noise in the patterns from SDSS seems too low to be indexed successfully by conventional HI. At an averaging of 5 the hit rate is considerably improved. Indexing of non-averaged patterns using DI results in an IPF map which is quite reasonable, but the hit rate is lower compared to HI of patterns from time consuming on-line averaging of 5. DI of on-line and off-line averaged patterns results in outstanding IPF maps. Off-line averaging with *kikuchipy* seems to have a hit rate at least as high as on-line averaging according to the IPF maps in Figure 1.

Off-line averaging in combination with dictionary indexing should be preferred when analysing noisy EBSD patterns acquired at a reduced acceleration voltage and beam current, and when it is desirable to save acquisition time and reduce surface contamination. [5]

[1] S Wright *et al.*, Ultramicroscopy **159**, Elsevier (2015).
[2] HW Ånes *et al.*, IOP Conf. Series: Materials Science and Engineering 891, (2020).
[3] S Singh, *et al.,* Scientific reports **8**, Nature Publishing Group (2018).
[4] HW Ånes, O Natlandsmyr, T Bergh, LAH Lervik, pyxem/kikuchipy v0.3.4 (2021).
[5] HWÅ acknowledges NTNU for financial support through NAPIC.

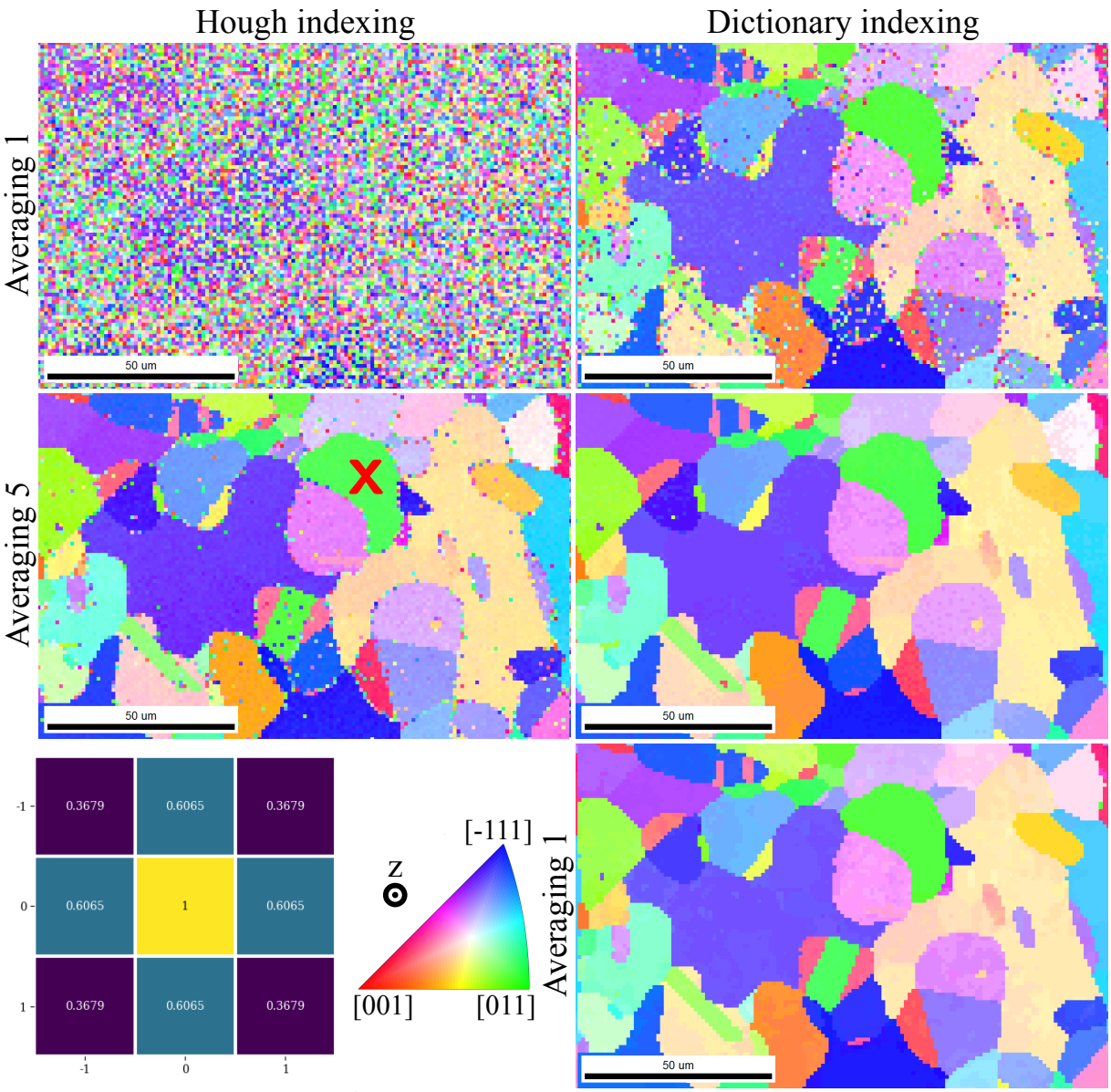

Figure 1. IPF maps. 1st and 2nd row based on averaging 1 and 5, respectively. Left and right column maps indexed by Hough and dictionary indexing in *kikuchipy,* respectively. Lower right IPF map from patterns (averaging 1) off-line averaged with the 3x3 averaging window.

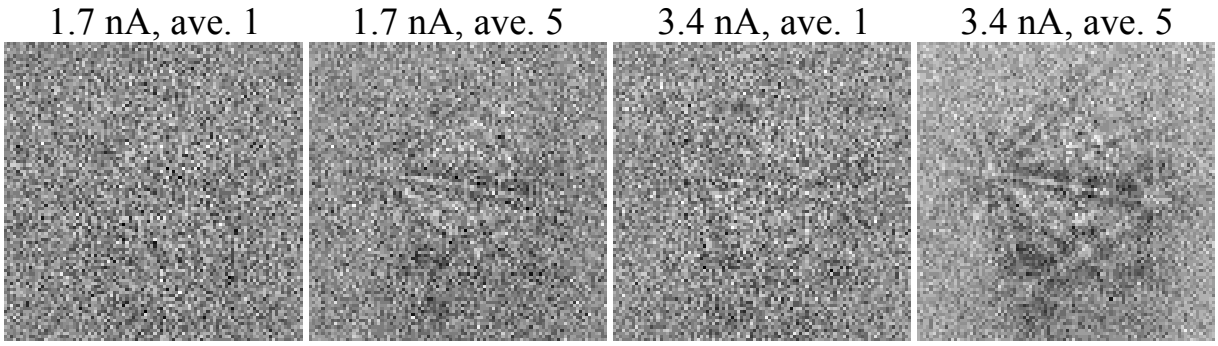

Figure 2. EBSD patterns (background subtracted and contrast-stretched) from the green grain highlighted with a red cross in Figure 1. From left to right: 1.7 nA, no on-line averaging; 1.7 nA, averaging 5; 3.4 nA, no averaging; 3.4 nA, averaging 5.