How Flat is Your Detector?

Non-Uniform Annular Sensitivity in STEM Quantification

Katherine E. MacArthur, Lewys Jones, Peter D. Nellist

University of Oxford

Background: Why Map ADF Detectors?

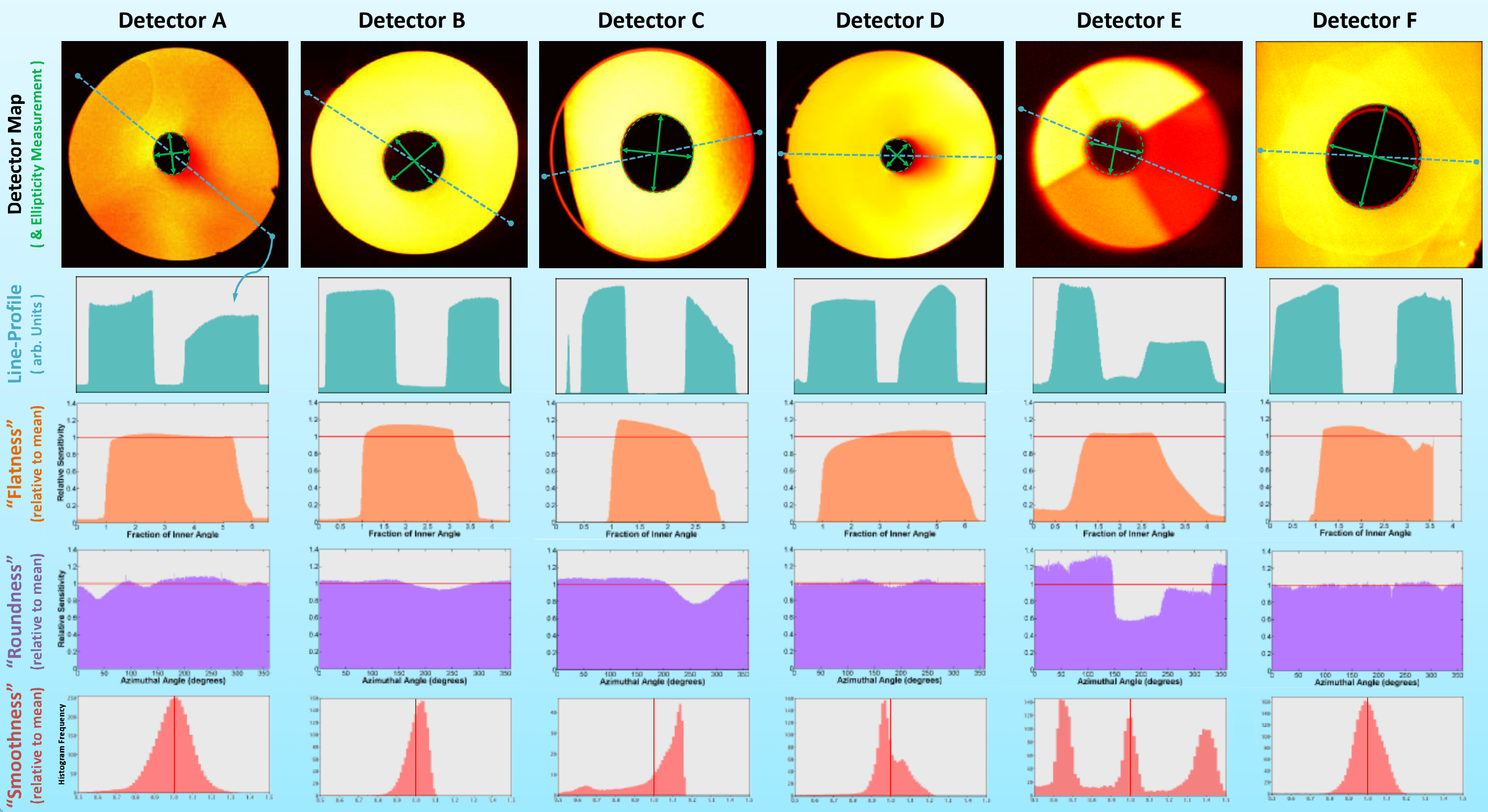
Quantification of high-angle annular dark-field scanning transmission electron microscopy (HAADF STEM) data has been growing in interest in recent years [1,2]. With this technique the images (recorded in counts) are normalised by the count-rate equivalent to the entire STEM probe being incident on the detector. The scaled images can then be expressed in units of 'fractional beam intensity' allowing for local variation in sample composition to be observed, when thickness is known [3], or variations in thickness to be measured where composition is fixed [4].

However, current detector hardware is far from perfect with detectors exhibiting significant asymmetries or non-uniformities across their active region [5]. Here we compare the current detectors of several major manufacturers rating their 'ellipticity', 'flatness', 'roundness' and 'smoothness' and discuss how these factors are likely to affect quantitative imagine results.

The Detector Sensitivity Mapping Method

To determine the dark-field 'count-rate' that corresponds to 100% of the STEM probe's current we must first map the detector's sensitivity. To produce the detector map, a focused probe is formed at the detector plane (for example using a diffractive or confocal mode) which is then rastered across the detector. If the probe-current used for imaging would saturate or damage the detector, then it is acceptable to drop the current by a known ratio by adjusting the mapping dwell-time or probe-forming aperture size (amplifier brightness and contrast must remain unchanged between mapping and imaging).

From the detector map we can measure the D.C. offset (the count-rate with the probe in vacuum) and the detector sensitivity (the additional count-rate over the detector's active region). These maps allows the entire visible surface of detectors to be inspected and analysed for their symmetry and manufacturing quality.



Detector Performance Metrics

"Flatness" - the variation in azimuthally-averaged detector sensitivity as a function of increasing collection angle (radially).

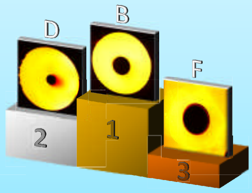
"Roundness" - a measure of the consistency of the radially-average detector sensitivity around the detector (azimuthally).

"Smoothness" - measured from the histogram of the sensitivity of the detector's active region. Histograms are normalised by the average sensitivity across the whole active region.

"Ellipticity" - is defined as the deviation from an ideal circular shape expressed as the percentage of the major over the minor diameters of the inner angle opening.

Conclusions

- The flattest detector is **Detector B**. This detector will collect scattering to different angles most fairly and will be the **most accurate for composition mapping studies**.
- The roundest detector is **Detector F**. This detector would be the **best for avoiding imaging artefacts** such as small shifts in column positions.
- The smoothest detector is **Detector B**, suggesting it may have the **best manufacturing quality**.
- The least elliptical detector is **Detector D**. This is essential for accurate inner-angle measurement for **reliable comparison with simulation**.
- The **largest collection-angle range** detector (inner-to outer-angle ratio) is **Detector D**. For a fixed inner-angle this larger ratio means a bigger outer-angle and improved total electron collection giving the **best signal to noise ratio** possible.
- Considering all these factors the 'best' detectors for all-round use are:



References

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2) Lebeau & Stemmer (2008) *Ultramicroscopy* **108**, 1653–8.
3) Rosenauer, Mehrtens et al. (2011) *Ultramicroscopy* **111**, 1316–27
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5) Findlay & LeBeau (2013) *Ultramicroscopy* **124**, 52–60.

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Further Information

Copies of this poster and the associated manuscript are available online at:

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