# Imaging of topography and phase distributions with an EBSD detector in the SEM

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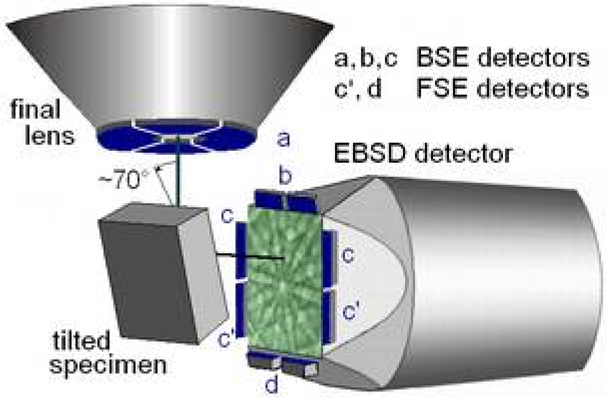
**Abstract**

In "Fast EBSD" [1] the sequence of unprocessed Backscatter Kikuchi Patterns (BKP) are streamed at a high speed of up to ~1000 pattern/sec to the hard disk. The patterns can be solved, either in a parallel task or off-line, to obtain the crystallographic orientations in the sampled points and to construct, for instance, grain orientation maps of the surface.

In addition images of the microstructure can be constructed by evaluating the intensity distributions in the BKP. These maps display the surface finish (topographic contrast, relief contrast imaging). The phase distribution may also be revealed if the differences in density are sufficiently high (Z contrast, material contrast imaging).

## Conventional BSE detectors in the SEM

In an EBSD setup the specimen is steeply tilted by typically 70° out of the horizontal to the beam. Scattering intensity is high in forward direction. Backscattered electrons (BSE) can hardly reach a conventional solid-state detector that is placed on the ceiling of the specimen chamber (a). To enable the sample to be imaged in tilted position, small solid-state detectors are mounted on the frame of the EBSD screen. Solid-state detectors at the topside of the screen (b) provide mainly material contrast, solid-state detectors placed beneath the screen (d) provide orientation contrast, and detectors on the sides (c, c’) are used for generating relief contrast images.

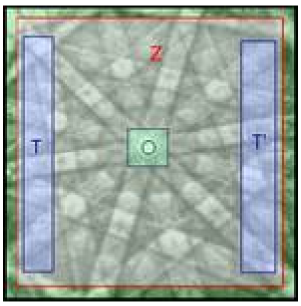



Solid-state detectors mounted on the frame of the phosphor screen have several disadvantages:

- Free space is severely restricted as a consequence of steep specimen tilt.
- Spatial interference with EDS and FIB appliances.
- The solid-state detectors must be as small as ever possible.
- They are fragile and easily damaged when touching the specimen or the stage.
- They have to be placed outside the margins of the screen, in regions of low BSE intensity.
  ==> A noisy BSE signal is obtained.
- The solid-state detectors are in fixed positions.
- Solid-state detectors are costly. The number of imaging channels is limited.

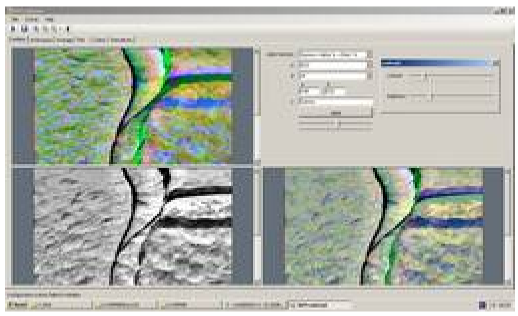
## Extracting contrast images from streams of backscatter Kikuchi patterns

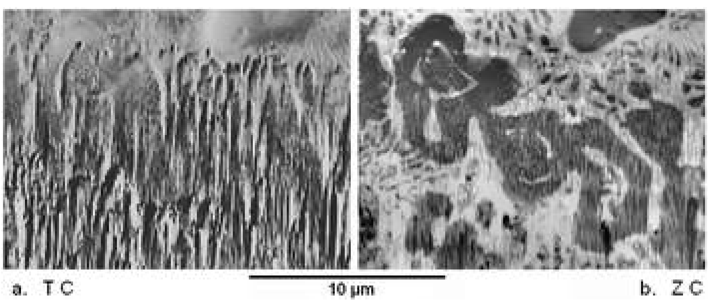
Since the x-y positions of the scan points are related to the patterns, contrast maps of the microstructure can be constructed by extracting and evaluating the intensities in pre-defined sectional boxes of the patterns. For this purpose the Kikuchi patterns need not be indexed [2]. Contrast mapping, in addition to pattern indexing and orientation imaging by EBSD analysis, is performed on-line as a second task during pattern acquisition or off-line at any time. This new approach provides crystal orientation, composition and surface topography maps. Also see [2].



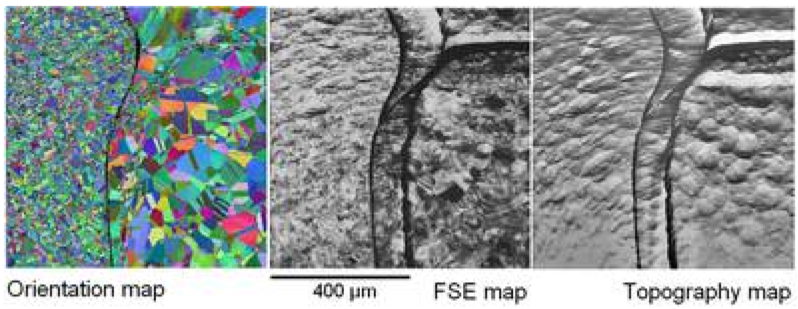

The advantages over separate solid state detectors are:

+ Optimum acquisition geometry and digital post-processing.
+ Spatial resolution is the same as in EBSD analysis (~ 30 - 50 nm).
+ The sample stays in EBSD analysis position.
+ The free space between the detector and the sample is not reduced.
+ The detector boxes are of arbitrary size, they may overlap.
+ They are placed at freely selectable positions on the patterns.
+ Signals of boxes can be added or subtracted with adjustable weights.
+ Complex arithmetic functions can be applied as well.
+ Color coding and mixing the individual detector signals.
+ No extra time is spent since pattern stream is simply re-evaluated.
+ Construction of contrast maps is a question of a few minutes only.






Example of topographic contrast (left) produced with the difference signal of two boxes placed on the sides of the screen (boxes T and T'), and material contrast (right) by integrating over a large area on the Kikuchi patterns (box Z). The sample is a silver solder joint after excessive ion etching by FIB. Curtaining has led to a strong surface relief which inhibits from indexing the backscatter Kikuchi patterns with a sufficient hit rate. Thanks to the large accepted solid angle of box Z, however, topographic and orientation contrasts are completely suppressed in the material contrast map so that the different phases are clearly seen.




Cross section through a 1 Euro coin. The silver-colored interior of the coin consists of a pure nickel core plated on both surfaces with CuNi25. The gold colored perimeter is of CuZn20Ni5. The phases have a face centered cubic lattice.

EBSD cannot discriminate phases with similar crystal lattices, i.e. when having the same Laue group and similar lattice constants. The density of the solid solutions is 8.56 g/cm³ (CuZn20Ni5) respectively 8.91 g/cm³ (CuNi25), and the density of Ni is 8.91 g/cm³. The FIBed surface is imaged in high topographic contrast, but material contrast is not sufficient to discriminate the phases in the BSE map because of similar densities.

[1] R.A. Schwarzer and J. Hjelen: High-speed orientation microscopy with offline solving sequences of EBSD patterns.
Solid State Phenomena Vol. **160** (2010) 295-300. Also visit http://www.ebsd.info and http://www.nordif.com

[2] X. Tao and A. Eades: Another way to implement diffraction contrast in SEM.
Microscopy Today **11** (2003), March/April 2003, pp. 36, 38