AK EBSD
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The EBSD camera - a multi-array image detector

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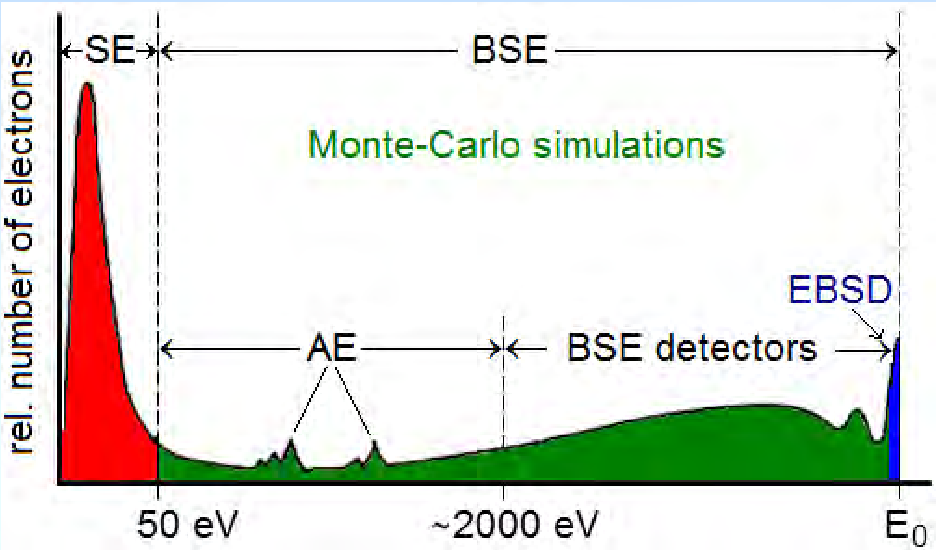
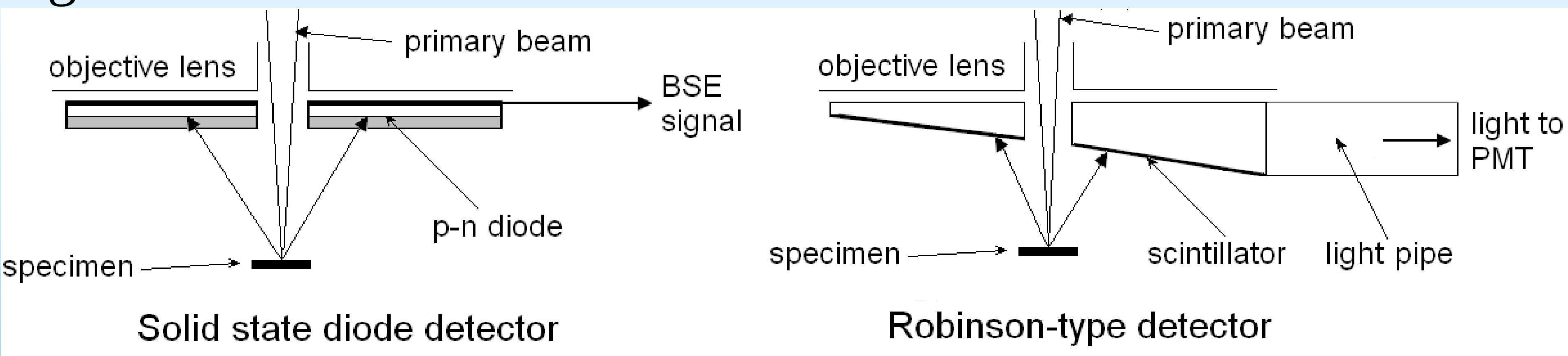
Secondary and Backscatter Electrons



A high-energy electron beam releases from the sample surface
- Secondary Electrons (SE),
- Backscattered Electrons (BSE),
- Auger Electrons (AE),
- X-rays and
- Cathodoluminescence (light).

These signals are acquired with dedicated detectors and are used to synchronously control the brightness on the monitor to produce images of the microstructure.



Secondary and Backscatter Electrons

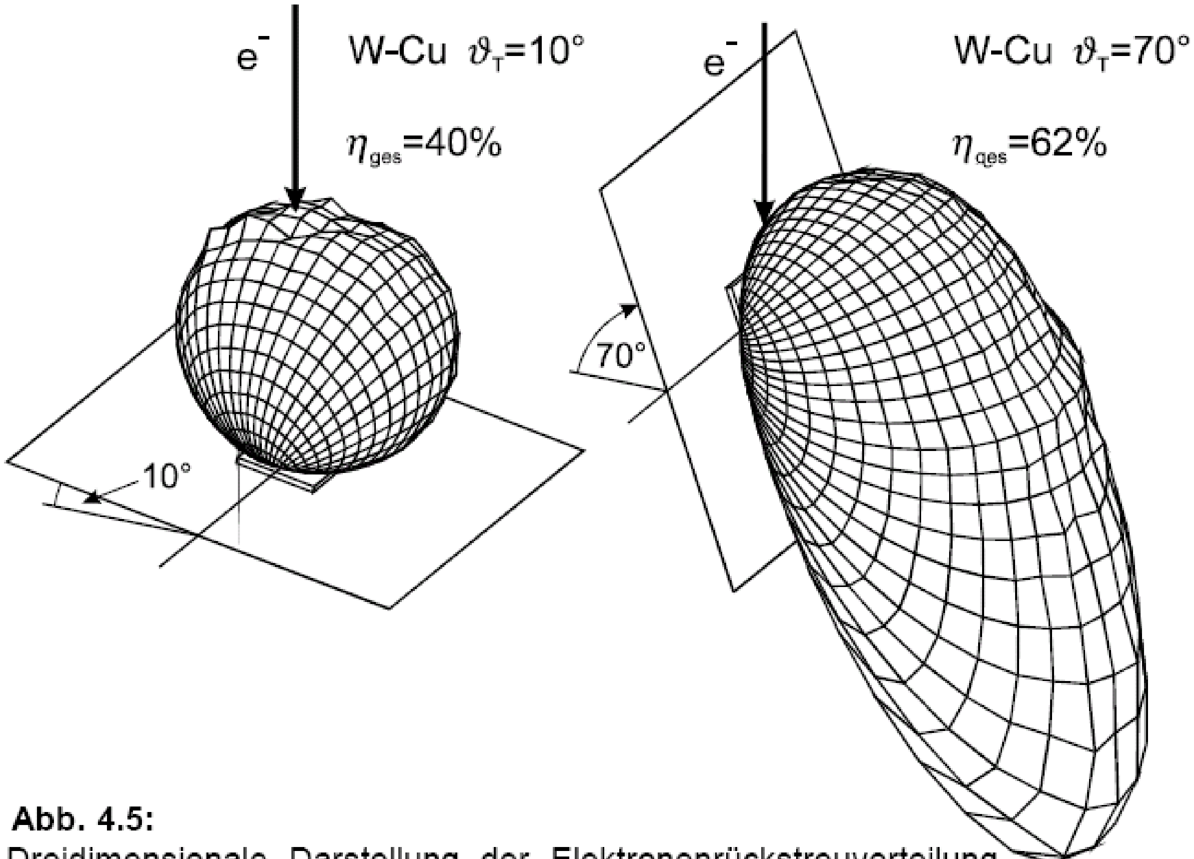


Abb. 4.5:
Dreidimensionale Darstellung der Elektronenrückstreuverteilung an einer Wolfram-Kupfer-Probe für verschiedene Einfallswinkel ϑ_T

Dirk Berger: *Hochaufgelöste Elektronenstreuexperimente für Anwendungen in der Elektronenmikroskopie und der Monte-Carlo-Simulation der Elektronenstreuung*. Diss. D83, TU Berlin 2000

If the sample is steeply tilted, BSE detectors at the ceiling of the specimen chamber are ineffective.

Solutions:

a. image with SE

b. position sample horizontal

c. use dedicated detectors at an appropriate position

d. use EBSD detector for multi-array imaging

Conventional BSE detectors in the SEM

Semiconductor diodes as BSE detectors
- take up much valuable space in the specimen chamber.
- are fragile and costly.
- The optimal adjustment of image brightness, contrast and beam current is often tricky and tedious.

- Signal height markedly depends on the take-off angle. These adjustments are often optimal for one kind of image contrast (topography and material) only (provided at all that the electronic device includes several signal channels).
- The simultaneous acquisition of microstructure images with different kinds of contrast works only in rare cases ==> loss of time.
- Signal intensity depends on the distance between spot of measurement and detector. Therefore, it is necessary to adjust the amplifier dynamically during scanning down the specimen surface.
- Analog signals are less suited for image processing.

The EBSD detector as multi-array BSE detector

The *Kikuchi pattern* represents the *angular distribution of BSE* in form of a projection on the two-dimensional phosphor screen.

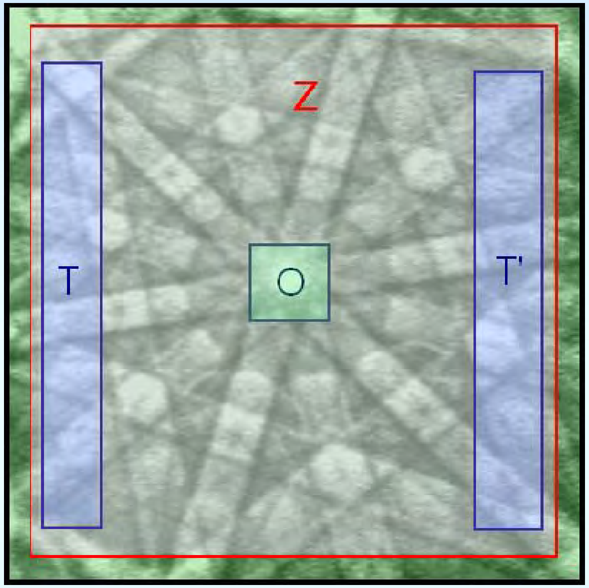
The BSE intensity emitted in a spherical element can thus be measured by integrating the intensity in the related screen segment.

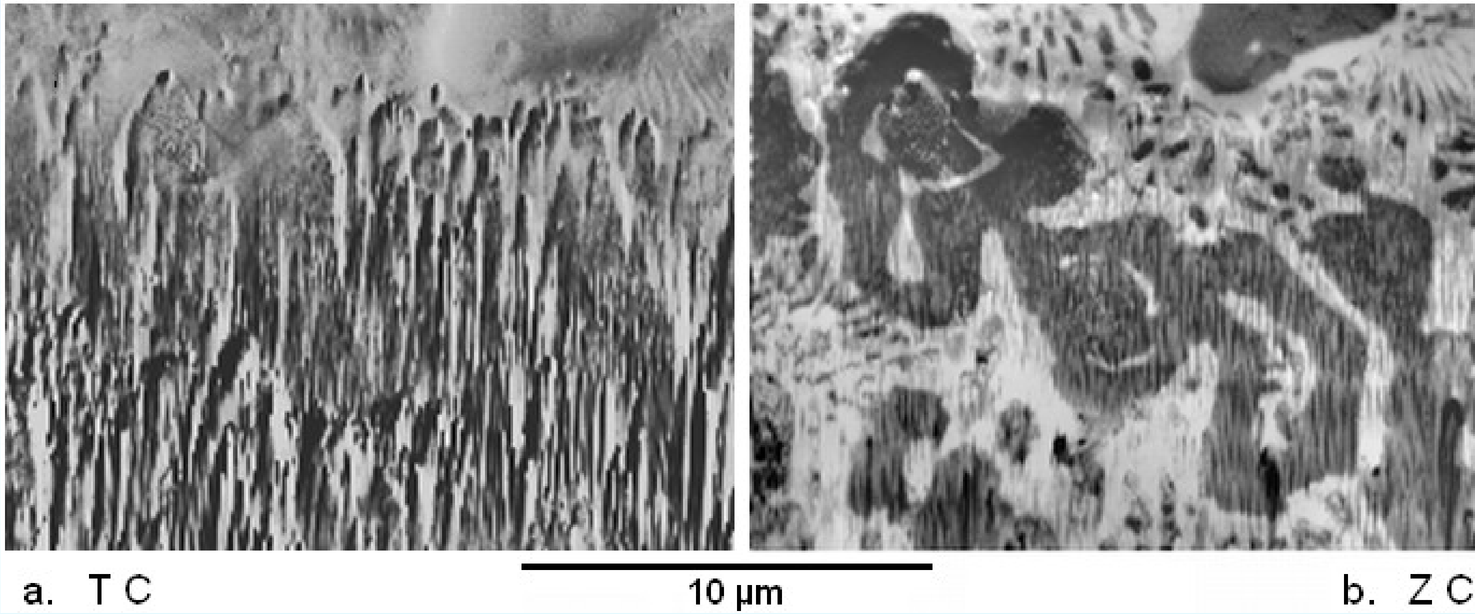
When all patterns are acquired in a sequence, the *BSE image of the microstructure* can be constructed point by point:

+ The *microstructure image* and the *orientation map* are constructed from signals of the same source, i.e. the Kikuchi pattern. Therefore, both images feature the same high spatial resolution.
+ The BSE images and the orientation maps are directly superposable.
+ Several acquisition boxes can be defined.

==> ***Multi-array detector with several signal channels***

EBSD detector replaces BSE and FSE detectors

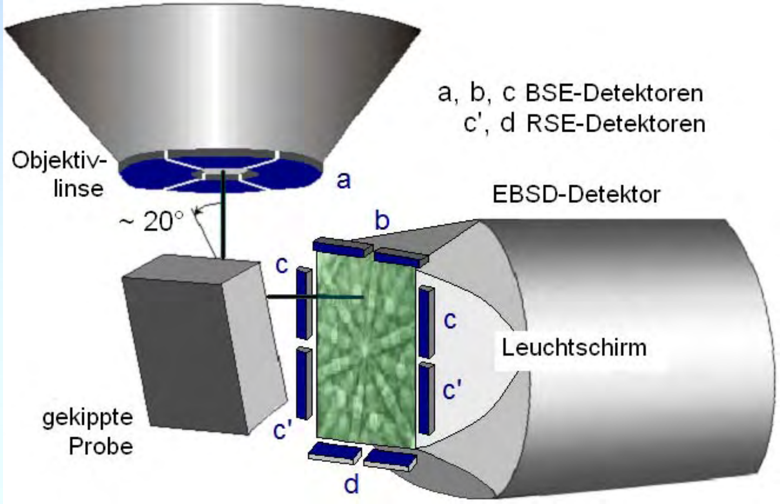




Left: Four acquisition boxes on a Cd pattern. Z marks the area for constructing material (Z) contrast, T and T' for topographical and O for orientation contrast images.

Right: (a) topographical and (b) material contrast image of a silver solder seam after excessive ion sputtering.

The EBSD detector as multi-array BSE detector

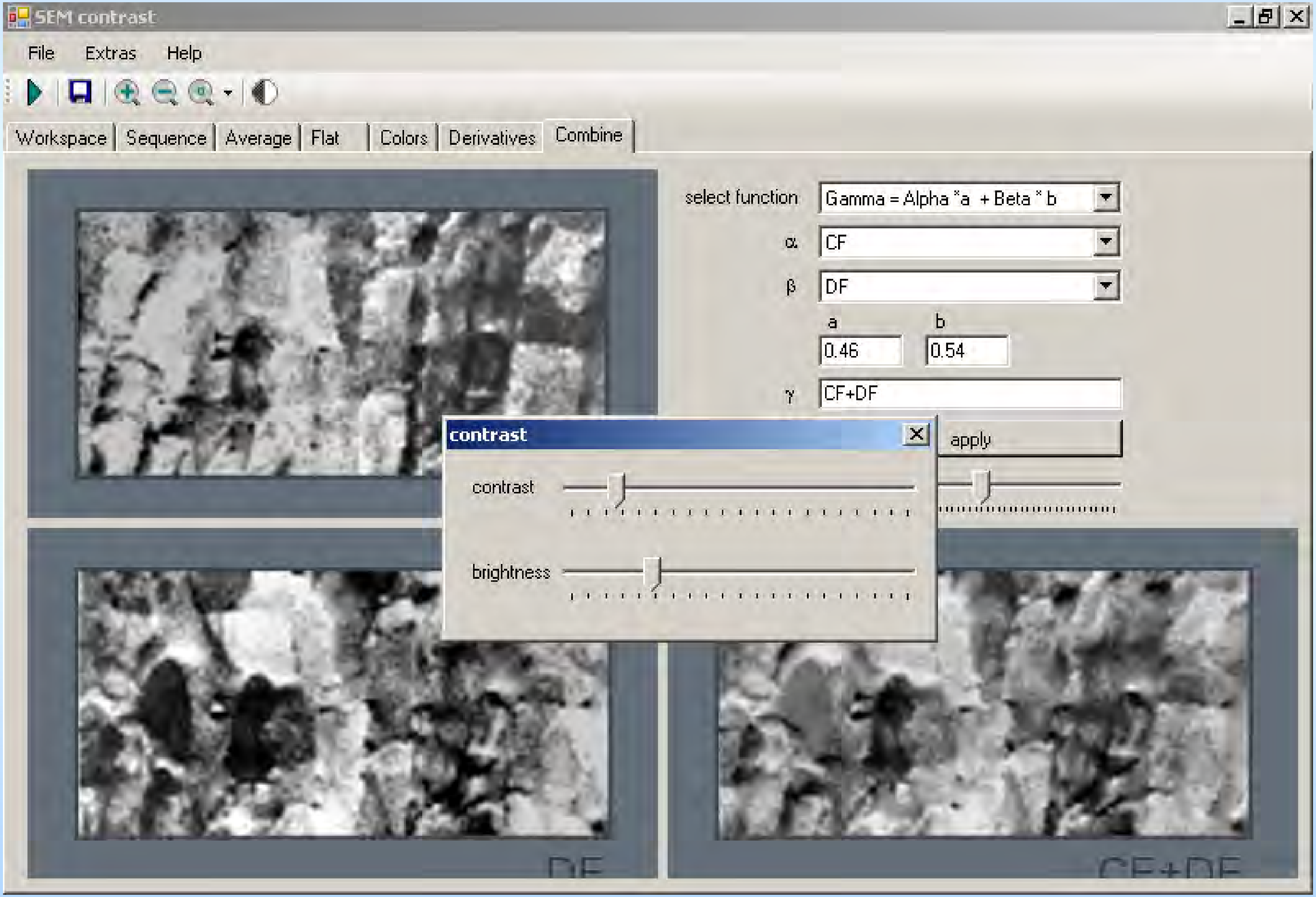


Reading BSE intensities is so fast that the microstructure images can be constructed, without delay, at the same time as the patterns are acquired and indexed.

Pattern streaming and off-line evaluation has the main advantage that the acquisition boxes can repeatedly be adjusted in size and position such that the microstructural details of interest are optimally imaged .

The image signals are already available in digital form. They can so be easily processed.

Signal mixing and contrast adjustment in the images



The EBSD detector as multi-array BSE detector

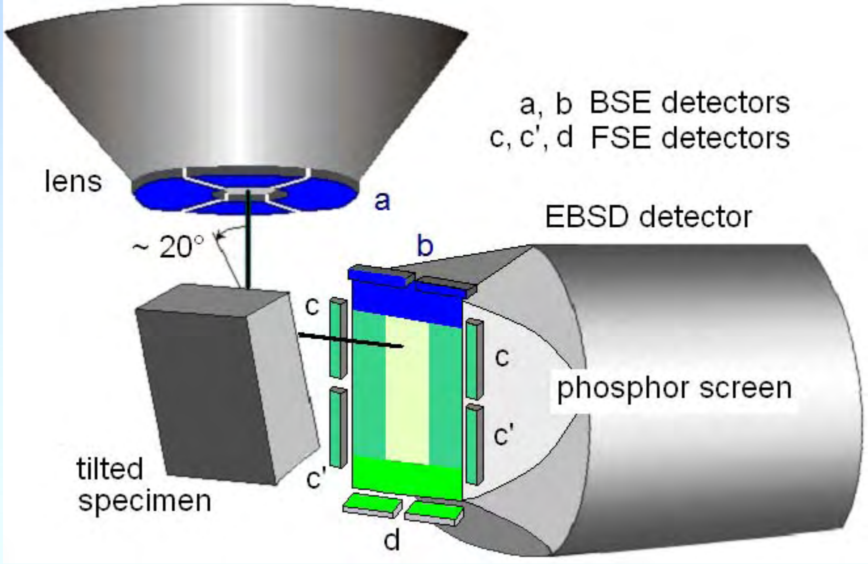
The construction of microstructure images from intensity distributions of backscatter Kikuchi patterns is almost old hat:

- X Tao und A Eades: Another way to implement diffraction contrast in SEM. *Microscopy Today* **11** (2003), March/April 2003, 36, 38
- since 2010 implemented in our (commercial) FastEBSD system
- R Schwarzer and J Sukkau: Gefügeabbildung im Relief- und Materialkontrast mit dem EBSD-Detektor. *Vortrag AK EBSD-Treffen, Halle 2011*
- R Schwarzer, J Sukkau, and J Hjelen: Imaging of topography and phase distributions with an EBSD detector in the SEM. *Microscopy Conference Kiel 2011*, Poster LBP M.P007. Download from http//:www.ebsd.de
- R Schwarzer: Orientation microscopy using an analytical SEM. *Practical Metallography* **51** (2014) 160-179

Also recently in the EDAX-TSL system: Application note: EDAX introduces new pattern region of interest analysis system (PRIAS). *EDAXinsight* **12** (2014) 4-5
++ The following presentation by René de Kloe with convincing examples ++

Therefore I won‘t address again applications on EBSD.

New applications of the EBSD detector in the SEM beyond EBSD



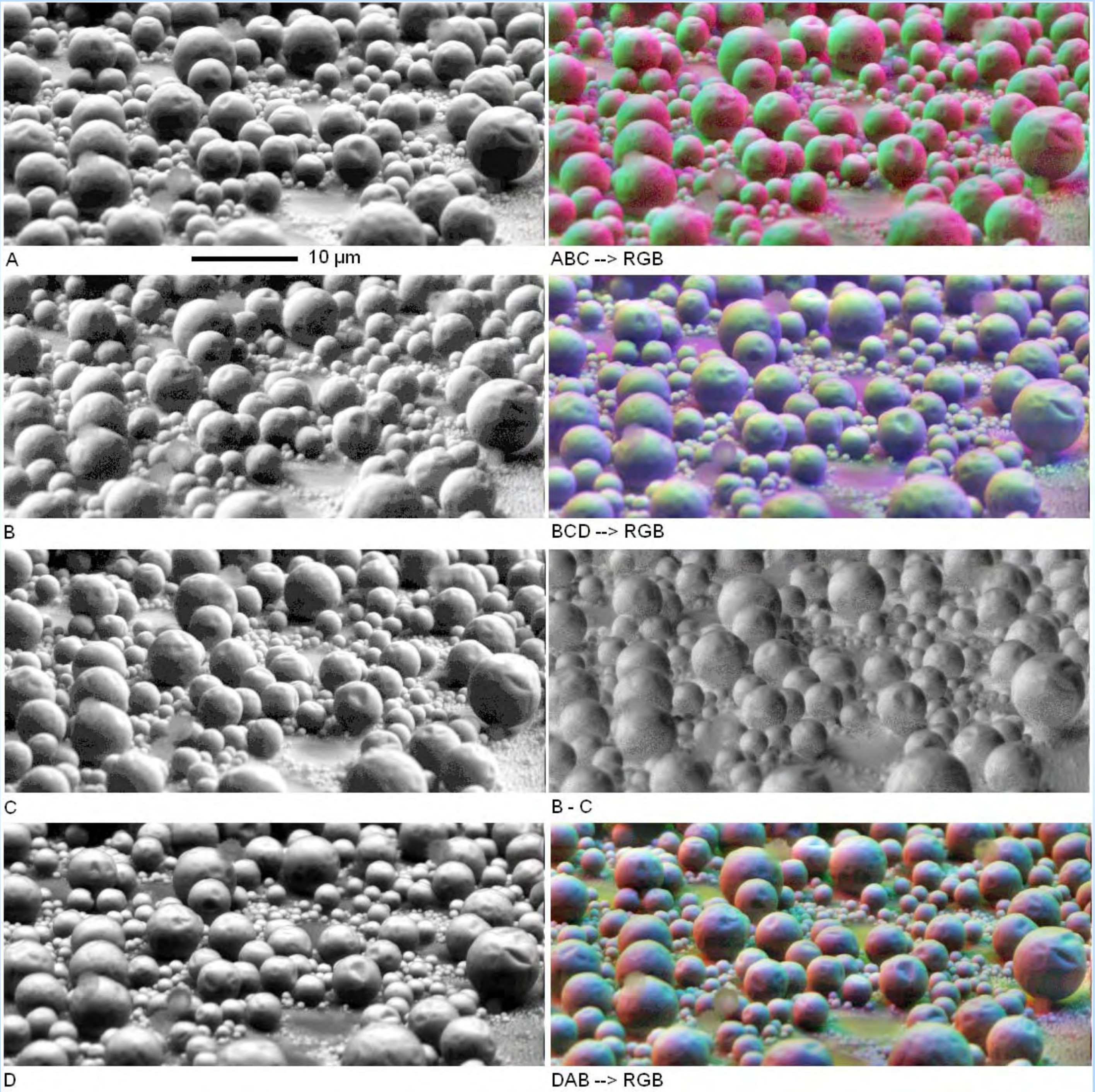
The „patterns" need not be indexed:

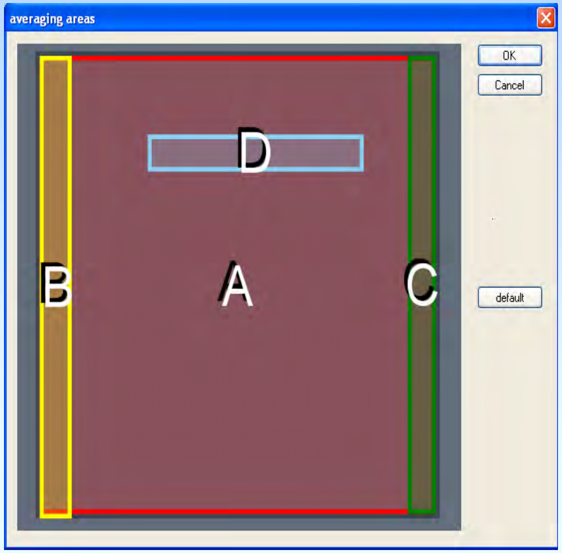
→ Imaging of partially crystalline, non-crystalline and organic samples.

+ Topographical contrast (+ sputter coating with heavy metal (Au))
+ Material contrast: if sufficient ΔZ --> distinguishable by BSE yield intensity, directional distribution, energy
+ Measurement of heights and subtle steps on steeply tilted samples
+ Imaging of Bloch walls (magnet fields, ferroelectrics)
+ dislocation analysis using channeling contrast at high resolution (FE SEM with precision goniometer stage).

(*Refer to the following presentation by Stefan Zaefferer*)

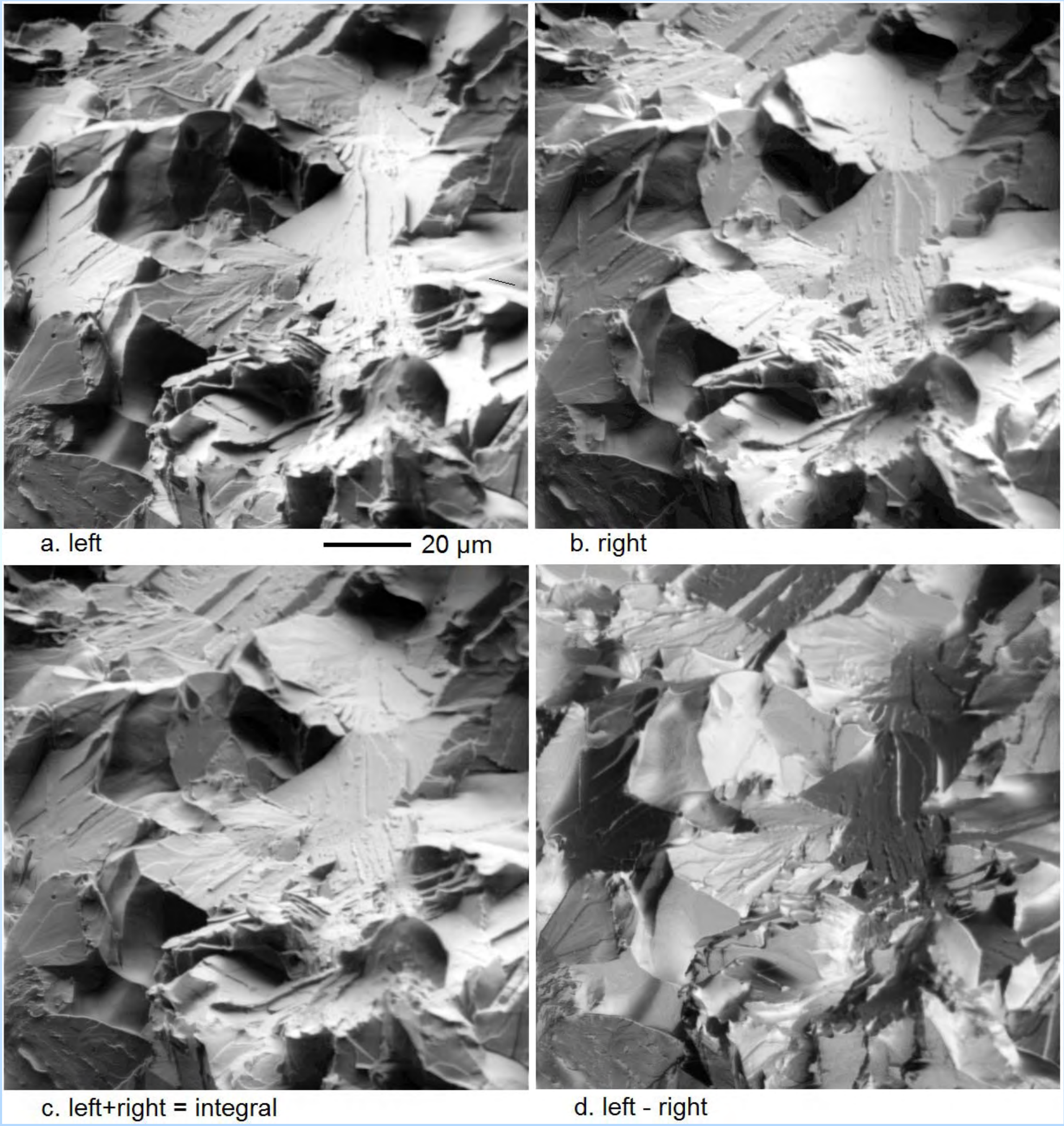
Topographical contrast with the EBSD multi-array detector





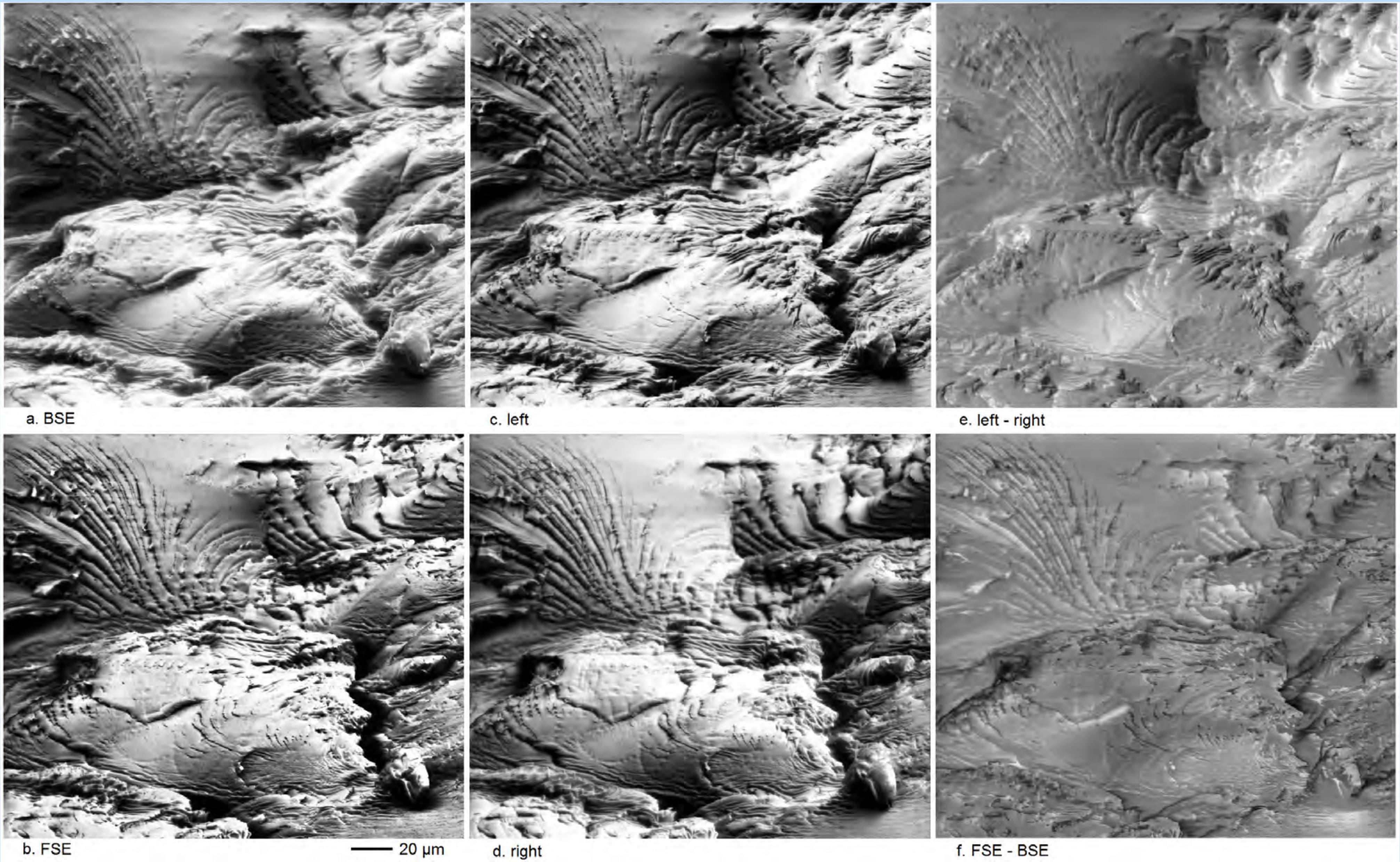
Zinc oxide spheres
U = 20 kV,
sample tilt 70°.

Imaging of rough topography



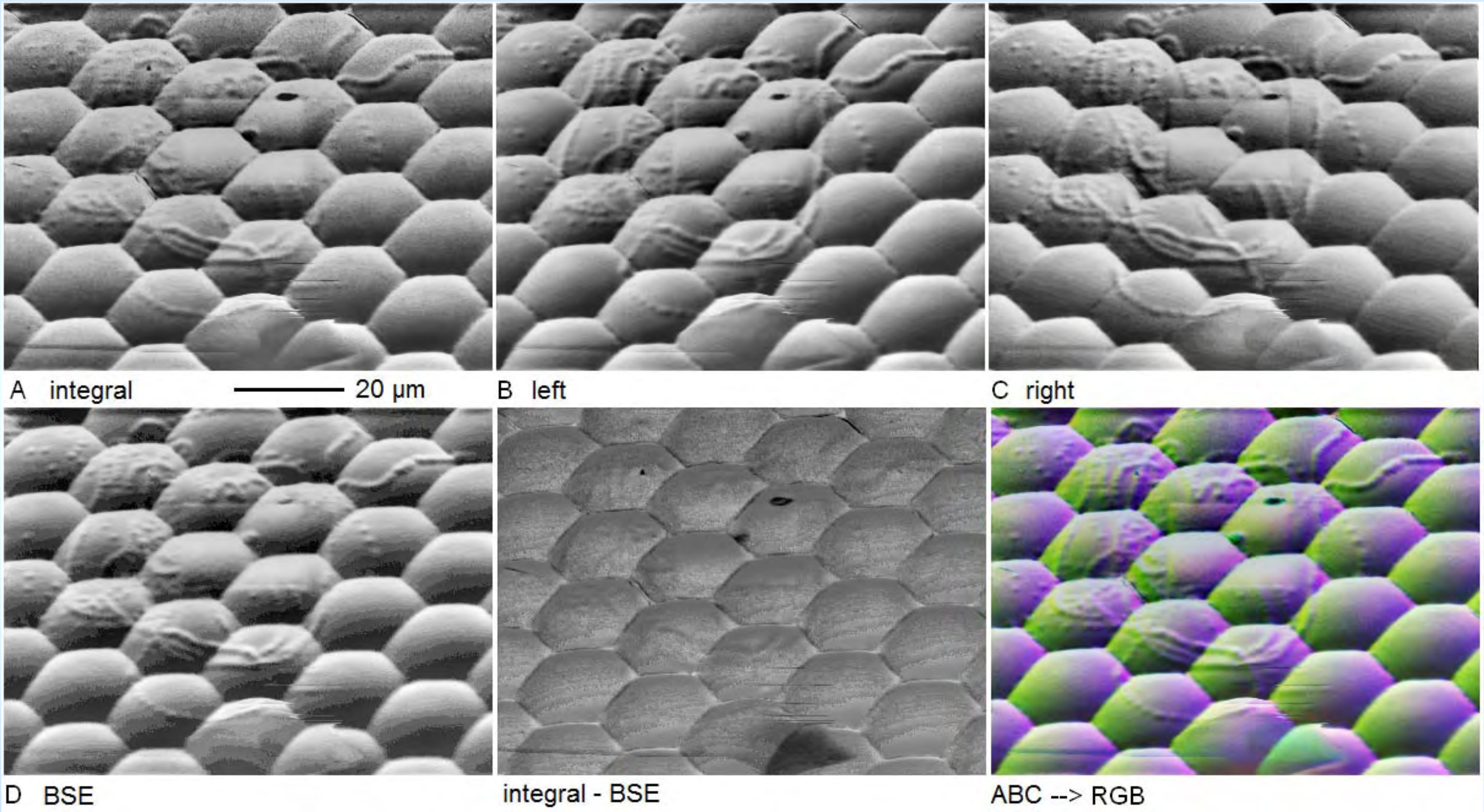
Fracture surface in steel
U = 20 kV
sample tilt 70°

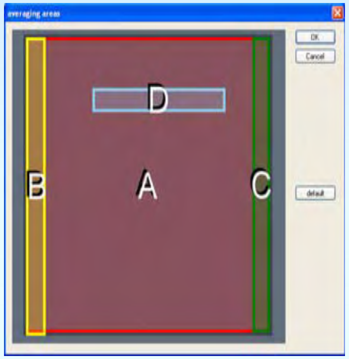
Imaging of rough topography



Fracture surface in hard plastic (thin sputter coated with gold, U = 20 kV)

Imaging of a non-crystalline biological sample with multi-array EBSD detector





Notice:
D = BSE is on the top of the image since raster scan runs from bottom to top of the sample.

Fly's eye at 10 kV
Specimen sputter coated with gold and tilted at 70°.

Conclusion

FastEBSD with separated acquisition ("pattern streaming") and interpretation of the patterns has many advantages over conventional on-line EBSD. It is supposed to soon become the measurement strategy of commercial systems.

+ Evaluation of the original data is reliably possible at any time.
+ Very high speed of acquisition and evaluation is achieved.

The EBSD detector can replace silicon diode detectors:

+ Digital image processing instead of expensive analog hardware.
+ The free space at the sample is not cut down further.
+ Now additional SEM time is required for measurement.
+ The patterns need not be indexed for the construction of material and topographical images of the microstructure.
+ The same high spatial resolution and the same sampled area as in the orientation map.

You are welcome to visit my web sites

www.ebsd.info www.ebsd.de
www.crystaltexture.com

Thank you for your kind attention.