EBSD and BKD

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Outlook and Conclusions

1. Trends in EBSD software

- Improved accuracy
  large acceptance angle => stable indexing
  sufficient number of consistent bands => reliability
  bands from several zone axes => reliability
  less pattern coarsening or pixel binning => precision
  dynamic correction of scan field rotation with focus
  (scan field rotation does not affect grain orientation measurement but distorts crystal orientation maps only).
- High speed of measurement reduces demands on long-term stability of the SEM
  (FastEBSD at present more than 1000 patterns/sec acquisition and >2000 orientations/sec indexing of pattern sequences).

  Digital cameras enable pixel binning (combination of several pixels on the chip => increases sensitivity, reduces volume of data transfer, increases speed).

  If intragranular structure is of no concern, it is sufficient to acquire the orientation of each grain only once. Iterative mesh refinement has proven very effective by concentrating measurement along grain boundaries. Mesh refinement is inadequate if the microstructure contains twinned grains or if a broad grain size distribution is present.
  R.A. Schwarzer, Microscopy and Microanalysis 5, Suppl. 2 (1999) 242-243 .
- Low crystal symmetry is still a challenge.
- Fast phase discrimination has to be expanded to fast phase identification.
- Improved quantification of pattern quality parameter
  => correlation with stress, dislocation density.
- Radon transform and peak shape analysis
  => Evaluation of band intensities.
- 3-D reconstruction of the microstructure at subgrain resolution by consecutive sectioning.
  An excellent depth resolution is achieved with a dual-beam SEM which is a conventional SEM attached with an additional FIB (field ion beam source) column for in-situ surface sputtering.

2. Trends in EBSD hardware

The Scanning Electron Microscope (SEM)

- Clean vacuum ==> less contamination
- Variable Pressure SEM ==> no charging, no contamination
- Schottky Field Emission ==> high beam brightness
  · High current in small probes ==> improved spatial resolution
    (but be aware of damaging the specimen and increased contamination rate)
  · Small beam aperture ==> large depth of focus
- Adequate camera port (wide, perpendicular to x-y stage movement, low position)
- External computer control, computer interface

The Acquisition System

- Actual digital CCD camera
  · fast: ~ 1000 frames/sec and more with a GigE Vision or USB3
  · high sensitivity by pixel binning on the chip.
  · high dynamics (12-14 bit), no flat image for background correction required
- Actual digital CMOS camera
  · fast: ~ 7500 frames/sec and more with proprietary frame grabber

- Coming up is a lensless direct exposure of the sensor chip (high quantum efficiency, low beam voltage).
  · extremely high sensitivity
  · high sample tilt is not nessary: low tilt angles from a few to 0° avoid image distortions and shadowing. In this configuration the solid state detector is mounted on the bottom of the probe forming lens.
- Parallel processing of the Radon Transform on the GPU (dedicated graphic board replacing the computer's CPU) enables extremely high speed (analyzing 10.000 to 45.000 pps https://doi.org/10.1093/micmic/ozad067.224).

3. A survey of methods for the analysis of microscale texture

Type of pattern	Equipment	Resolution		Main applications
		spatial	angular	
Spot pattern	TEM ("SAD" = selected area diffraction)	0.5 - 1.5 µm	5° (1°)	thin foil specimens dark-field imaging dislocations (weak beam) Burgers vector analysis precipitates, nanomaterials orientation relationships (estimate of) crystal orientation
Transmission Kikuchi pattern (TKP)	TEM (SAD)	0.5 - 1.5 µm	0.2°	thick foil specimens medium size grains crystal orientations orientation differences dislocation density
	TEM, STEM ("MBD" = microbeam diffraction) SEM TKD, t-EBSD	< 10 nm	0.2°	thick foil specimens fine grain structures crystal orientations, ACOM orientation differences indexing of grain boundaries deformed materials grain growth
Backscatter Kikuchi pattern (BKP, "EBSP")	SEM with an EBSD appliance (low light level camera, computer control) several commercial EBSD systems are available	< 30 nm (FE gun) 0.05 - 1 µm (W filament)	< 0.5°	bulk specimens coarse grains, mesostructure crystal orientations, ACOM dynamic experiments (e.g. hot stage, tensile stage) fracture surfaces (residual stress) phase identification (Phase ID)
Channeling pattern (ECP)	SEM (as an option for some SEM commercially available)	10 - 50 µm (SAD)	0.5°	bulk samples semiconductors (gentle method) crystal orientation orientation differences residual stress fracture
TEM pole-figure measurement	TEM with a side-entry goniometer, high-resolution camera or computer control	1 µm (SAD) 0.1 mm (RHEED)		thin film specimens (SAD) bulk surfaces, layers (RHEED) very fine grain structures high degree of deformation shear bands texture fields
Convergent Beam Electron Diffraction (CBED) (Zone axis pattern; Kossel-Moellenstedt pattern)	TEM with cooling stage, energy filter	5 nm	0.01°	inadequate for texture analysis. determination of lattice constants residual stress phase identification space groups structure potentials
conventional X-ray diffraction X-ray scanning apparatus	Euler cradle, x-y stage " and ED detector	0.1 mm 50 µm 50 µm 0.1 mm		local pole figures texture mapping element mapping (micro XRFA) lattice strain mapping