1 Mean, standard deviation, entropy maps of the patterns

1.1 Definitions

- $IQ_M = \frac{1}{W \cdot H} \sum_{i=1}^{W} \sum_{j=1}^{H} I_{ij}$ [4, 6]
  - W: Pattern width
  - H: Pattern height
  - I_{ij}: Intensity (0-255) of the pixel at row i and column j
- $IQ_\sigma = \sqrt{\frac{\sum_{i=1}^{W} \sum_{j=1}^{H} I_{ij} - \bar{I}}{W \cdot H - 1}}$ [4, 6]
  - W: Pattern width
  - H: Pattern height
  - I_{ij}: Intensity (0-255) of the pixel at row i and column j
  - $\bar{I}$: Average intensity (i.e. IQ_M)
- $IQ_E = -\sum_{i=0}^{255} P_i \ln P_i$ [4, 6]
  - P_i: Probability of gray level i

1.2 Advantages

- Less noise than IQ [4]
- Show micro-twins and scratches [4]
- Show small topography changes [4]
- Show strain levels [4]
- Don't rely on the detection of Kikuchi bands [4]
- Entropy maps have similar results than IQ [4]
- More related to surface topography [6]
- IQ_M very similar to FSD images (but with inverted contrast [6]
- IQ_M is mostly a measured of the overall backscatter yield (good for phase differentiation) [6]

1.3 Disadvantages

- Deteriorate with time due to contamination [4]
- Affected by gain and contrast settings of the EBSD detector unit as well as the SEM [6]
- Normalization is done using the hypothesis that the sum of all pixels in one row is constant [4]

1.4 Representation

- Black is assigned to all values less than 3σ and white to all values greater than 3σ [6]

2 Image Quality

2.1 Definitions

- $IQ_{HT} = \frac{1}{N} \sum_{i=1}^{N} H(\rho_i, \theta_i)$ [6]
  - ◇ N: number of peaks detected by the Hough transform (user defined value)
  - ◇ $H(\rho_i, \theta_i)$: Height of the ith peak
  - ◇ IQ_{HT} will be dependent on the user's selection. Because the peaks are found in decreasing order of intensity, if fewer peaks are allowed, IQ_{HT} will be large.
- Normalization [6]
  - ◇ $IQ_{\text{normalized}} = \frac{IQ_{\text{initial}}}{IQ_{\text{standard}}}$
    - ∗ IQ_{standard}: Average IQ value of a standard sample (no deformation)
  - ◇ $IQ_{\text{normalized}} = \frac{IQ_{\text{initial}} - IQ_{\text{min}}}{IQ_{\text{max}} - IQ_{\text{min}}}$
    - ∗ IQ_{min}: Minimum IQ value of a set
    - ∗ IQ_{max}: Maximum IQ value of a set
- A quality measure based on the Hough Transform should thus in some way measure the "amount" of butterfly peaks in the normalized Hough Transform [2]

2.2 Factors

- Elastic strain [6]
  - ◇ "Bend" strain → More diffuse bands
  - ◇ "Stretch" strain → Wider bands
- Plastic strain [6]
  - ◇ Superposition of individual patterns → More diffuse patterns
- Composition [6]
  - ◇ Heavier atoms have higher atomic scattering factors (brighter patterns)
- Surface topology [6]

2.3 Advantages

- Similar to confidence index [4]
- Metric describing the quality of a diffraction pattern [6]
- Doesn't show charge buildup (horizontal artifacts) like the mean, standard dev. and entropy does [6]
- Show boundaries (grain and phase) [6]
- Best map to differentiate between phases, grain boundaries and strain [6]
- Best contrast between strain and unstrained regions [6]
- IQ differences arising from orientation differences are generally mush smaller than those due to phase, grain boundaries or strain [6]
- Normalization minimized the effect of image processing on the IQ values [7]

2.4 Disadvantages

- Rely on the detection of Kikuchi bands (influence by false peaks) [4]
- Affected by various operator-defined parameters used in the calculation of the Hough transform [6]
- No distinction between high and low angles grain boundaries [6]
- IQ values are not corrected for the grain boundary contribution [7]
  - Pixels around grain boundary should be removed from the IQ value

3 Image Quality in INCA Crystal

3.1 Definitions

- From [3]
- For each pattern, the 7 strongest Hough peaks are identified
- $IQ = 256\frac{I_{\text{Max}} - I_{\text{Min}}}{20000}$ (for 8 bit)
- $IQ = \frac{I_{\text{Max}} - I_{\text{Min}}}{2000} - 20$ (for 16 bit)
  - I_{Max}: Strongest peak relative to the average gray level (128) in Hough space
  - I_{Min}: Smallest peak relative to the average gray level (128) in Hough space
- $IQ = 255\frac{\frac{1brigtheness}{std.dev.} - 4.0}{9.5}$ (latest software)
  - For a standard deviation ranging from 4 to 13.5

4 Multi-peaks Model

4.1 Definitions

- From [7]
- $N = \sum_{i=1}^{k} n_i$
- $IQ \approx \sum_{i=1}^{k} ND(n_i, \mu_i, \sigma_i)$
  - ◇ N: Number of the total scan points in a file
  - ◇ k: Number of normal distributions in the simulation
  - ◇ ND: Normal distribution
- Conditions
  1. $Min(k)$
  2. $\left\| IQ - \sum_{i=1}^{k} ND(n_i, \mu_i, \sigma_i) \right\| \leq \epsilon$
     - ◇ ϵ: Minimum acceptable error

4.2 Advantages

- Study of multi-component microstructures [7]

5 Fourier Transform

5.1 Definitions

- Contrast [5]
  - ◇ Root mean square intensity of averaged band profiles
  - ◇ One dimension profiles were taken normal to the band at 1 pixel intervals along the length and superimposed, resulting in a projection of the average profile of the band
  - ◇ Bands nearly parallel to the selected band do contribute peaks in the profile, which are broadened by the misalignment with the projection direction
  - ◇ These features can be removed from the projected intensity profile by using a suitable window or weighting function
  - ◇ Hanning function was used: $H(x) = \frac{1}{2}\cos(2\pi x/X)$
    - ∗ x: Sample number
    - ∗ X: Total number of samples in the profile
  - ◇ The central peak is emphasizes, while the outer regions regions of the profile are continuously attenuated
- Sharpness/Diffuseness [5]
  - ◇ In a good quality pattern, the edges involve rapid changes in intensity (high frequency are present)
  - ◇ In a degraded pattern, the gray level changes at the edges occur more graduaylly (high frequency attenuated)
  - ◇ The attenuation of high frequency components of Fourier transform of the enhanced images and of the averaged band profiles
  - ◇ Two methods
    1. Spectral first peak area (SFPA)
       - ∗ Calculate the area under the first peak in the power spectrum obtained from the projected average intensity profile
       - ∗ Apply the Hanning function to the profile prior to transformation in order to emphasize the central Kikuchi band and to reduce leakage encountered in the use of discrete Fourier analysis.
       - ∗ Take the fraction between the area under the first peak and the total area of the spectrum (independent of pattern quality)
    2. Power spectra first moment (PSFM)
       - ∗ Use to generate a single value quantifying the quality of Kikuchi band profiles
       - ∗ As the method is highly sensitive to the position at which any one single profile is taken, the use of 2D Fourier analysis reduces this dependence on positions
       - ∗ Integration of the 2D spectrum around circular paths at each radii allows average coefficients at each frequency to be determined
       - ∗ Hanning function is used
       - ∗ Take the fraction between the first moment by the area under the spectrum (independent of pattern contrast)

- Quality index by Krieger Lassen [2]
  - ◇ $I = \frac{\sum_{u=-n/2}^{n/2-1} \sum_{v=-n/2}^{n/2-1} S(u,v)(u^2+v^2)}{\sum_{u=-n/2}^{n/2-1} \sum_{v=-n/2}^{n/2-1} S(u,v)}$
    - ∗ $S(u, v)$: Inertia of the Fourier spectrum $S(u, v) = \|F(u, v)\|$ around the center $(u, v) = (0, 0)$
    - ∗ The inertia decreases as the spectrum becomes successively more concentrated at low frequencies and should thus be large for low quality images than for images of higher quality.
  - ◇ $I_{\max} = \frac{1}{n^2} \sum_{u=-n/2}^{n/2-1} \sum_{v=-n/2}^{n/2-1} (u^2 + v^2)$
  - ◇ $Q = 1 - \frac{I}{I_{\max}}$

5.2 Factors

- Strain [5]
  - ◇ Steady decrease in the high frequency Fourier components as strain increases
  - ◇ Diffuseness of EBSP patterns is observed to increase with plastic strain
- Quality [2]
  - ◇ There are linear features in Fourier spectra from the EBSD bands. They are most notable in high quality pattern.
  - ◇ High quality patterns have a large content of low frequency components and a lower content of high frequency components than the low quality patterns
  - ◇ The frequency content of the low quality EBSP is more uniformly distributed among the different frequency components and is approaching that of white noise.
  - ◇ Essentially a measure for the noise level of the images

5.3 Advantages

- Cold work reduces both contrast and sharpness [5]
- Tilt effect contrast, but not sharpness [5]

5.4 Disadvantages

- Measurements are dependent on the contamination [5]
- Sampling of several grains is essential to build a calibration curve [5]

6 Band Contrast

6.1 Definitions

- Jump in contrast between the edge of the band and the adjacent background [1]

6.2 Disadvantages

- Not sufficient to reliably capture the deformation gradients [1]

7 Misorientation Mapping

7.1 Definitions

- Method [1]
  1. Establish grains in microstructure
  2. Determine the reference pixel for every individual grain
     - ◇ Calculate the mis-orientation for all nine-pixels clusters within a given grain, disregarding boundary pixels
     - ◇ Choose the cluster with least mis-orientation as reference (minimum distortion)
  3. Calculate and map the mis-orientation
     - ◇ For a given grain, calculate the mis-orientation between each pixel and the reference pixel
     - ◇ Map this mis-orientation for each pixel using a color table

7.2 Advantages

- Small mis-orientations represent small amount of intra-grain mis-orientation / lattice rotation and therefore large deformations [1]
- Scratches are visible [1]
- Show extent of deformation zone [1]
- Sensitive to deformation on a grain-by-grain basis [1]

7.3 Disadvantages

- Lack of connection to more quantitative measures of deformation such as strain, strain gradient or dislocation density [1]
- The choice of the reference mis-orientation can substantially affect the resulting map [1]
- Not accurate enough to measure elastic strain [1]

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