Dislocation-Type Evolution In Deformed Metal

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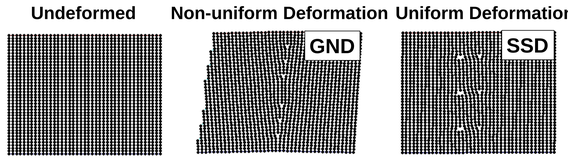
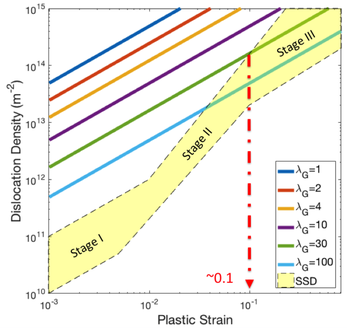
Theory





Ashby (1970):

① GND density depends on microstructure and strain.

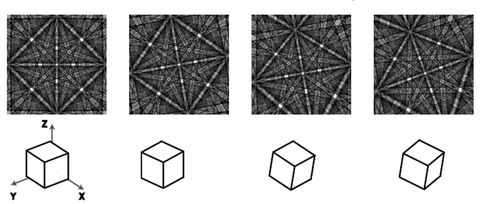
② SSD density depends on history of strain.

③ For fcc metal with 30μm grain size:

- $\varepsilon_p(<0.1)$: $\rho_{GND} > \rho_{SSD}$
- $\varepsilon_p(>0.1)$: $\rho_{GND} < \rho_{SSD}$

Measuring Crystal Orientation

Electron Backscatter Diffraction Patterns ('Kikuchi Patterns')



$(\varphi_1, \Phi, \varphi_2) = (0,0,0)$ $(\varphi_1, \Phi, \varphi_2) = (10^\circ, 0, 0)$ $(\varphi_1, \Phi, \varphi_2) = (10^\circ, 10^\circ, 0)$ $(\varphi_1, \Phi, \varphi_2) = (10^\circ, 10^\circ, 10^\circ)$

Computation (Nye Tensor)

What is the Nye Tensor?

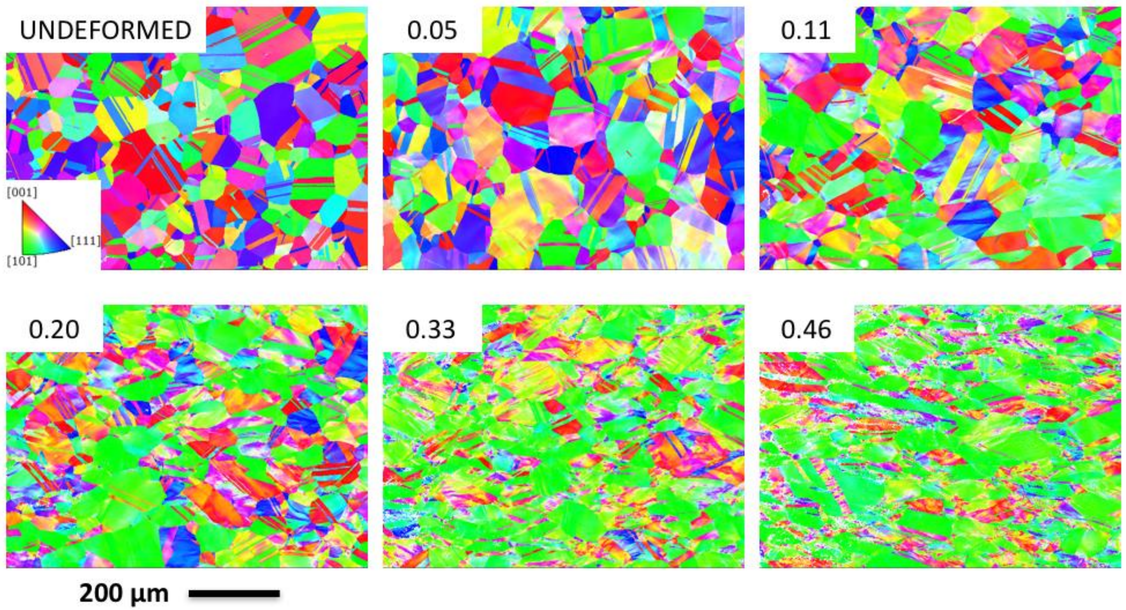
➢Dislocation tensor field (α) in a continuously dislocated state of the crystal lattice.

Step 1: EBSD
- Measure the Nye Tensor $\alpha \approx curl \frac{\Delta\varphi}{l}$

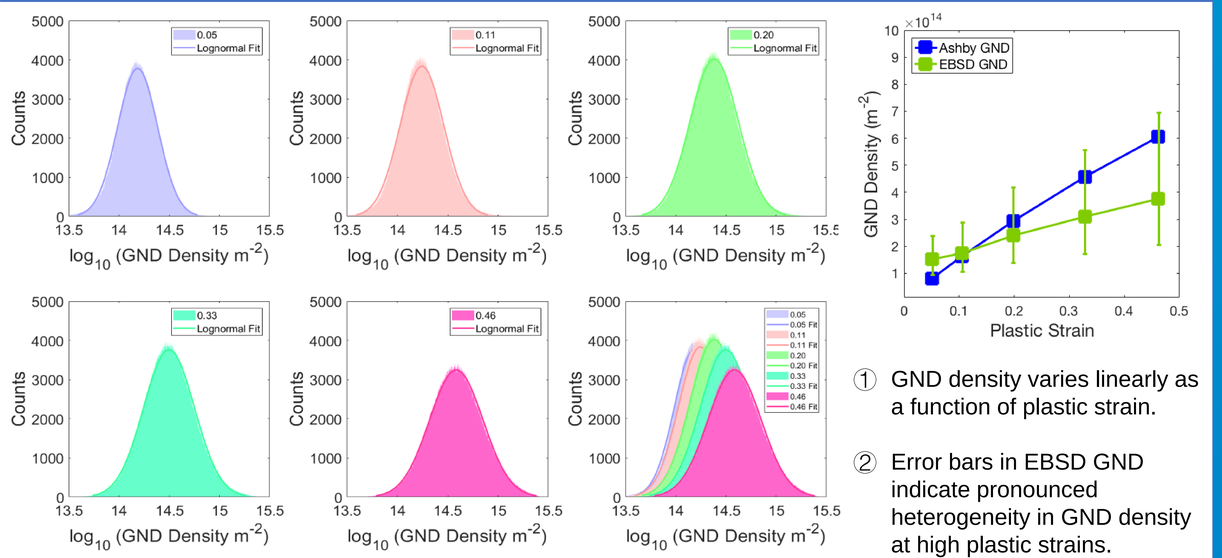
Step 2: GND Types
- Relate the Nye tensor to GND types $\alpha = \rho_{GND}(\hat{b} \otimes \hat{t})$

Step 3: Matlab
- Solve for ρ_{GND} based on L^1 dislocation energy minimization scheme

Electron Backscatter Diffraction



Geometrically Necessary Dislocation Density Evolution

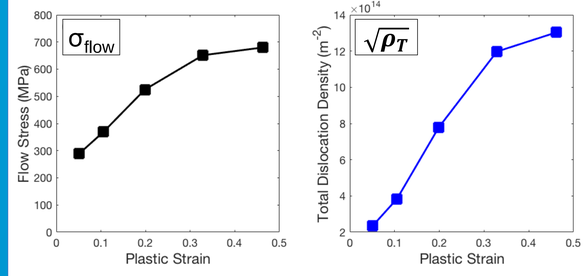


① GND density varies linearly as a function of plastic strain.

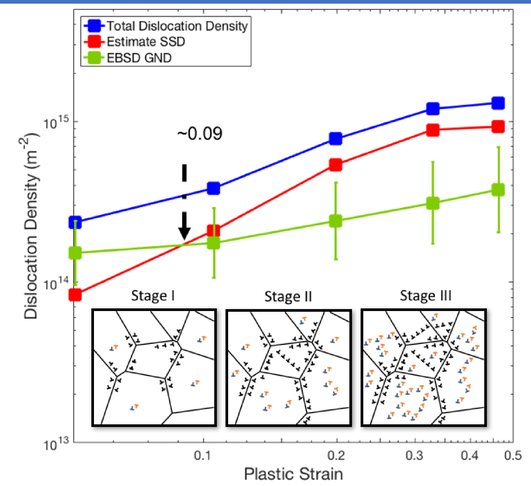
② Error bars in EBSD GND indicate pronounced heterogeneity in GND density at high plastic strains.

Taylor's Hardening Model

$$\sigma_{flow} \approx \bar{m}cG\boldsymbol{b}\sqrt{\rho_{GND} + \rho_{SSD}} \approx \bar{m}cG\boldsymbol{b}\sqrt{\boldsymbol{\rho_T}}$$



Dislocation-Type Evolution



① Stage I $\varepsilon_p(<0.09)$: GNDs dominate triple junctions and grain boundaries with limited amount of SSDs.

② Stage II $\varepsilon_p(>0.09)$: Rapid multiplication of SSDs and linear increase in GNDs.

③ Stage III $\varepsilon_p(>>0.09)$: SSDs dominate over GNDs throughout the microstructure.

Reference

1. M. Ashby, Philosophical Magazine,1970
2. G.I. Taylor, J. Inst. Metals.,1938
3. C. Zhu *et al*, Acta Materialia, 2016