Strain Heterogeneities

1. At low strains. (< 10%)

BCC metals
+ high Stacking Fault Energy FCC metals (e.g. Al, Cu, γ-Fe).

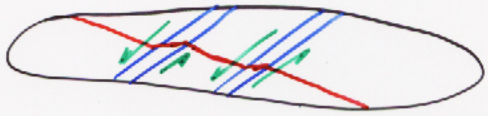
* 3D cellular arrays of dislocations
  = cell formation.
* cell diameter ≈ 1 μm
* cell boundaries have a much higher dislocation density than cell interiors
* cell boundaries have no directionality
  ↳ dislocations are incidentically trapped
  = incidental boundaries
* Implies : multiple slip state
  (→ Taylor model)
* Misorientation between cells is low:
  0.3° - 1.5°
  $(\theta_{avg} \sim e_{eq}^{1/2})$

2. At low and medium strains ($\varepsilon \approx 20-40\%$)

2.1. Subdivision by microbands

TEM observations in cold rolled copper (RD-ND section)

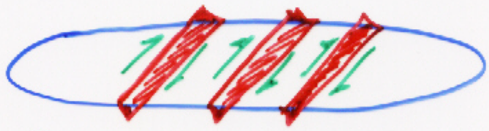
* thin (0.2 - 0.4 µm) plane regions, bounded by two parallel dislocation walls = microbands (MB^s)



* MB^s are several 10 µm long
* MB^s are // most stressed {111} plane
* Volume enclosed by a MB has a higher dislocation density.
* Only slight misorientations with the surround. matrix material.
* MB^s display localized shear !
(↳ can be visualized by surface markings)
* MB^s ≠ macroscopic shear bands, because MB^s are contained in one single grain.

Also observed in BCC iron (steel)
= in-grain shear bands.

* generate steps at grain boundaries

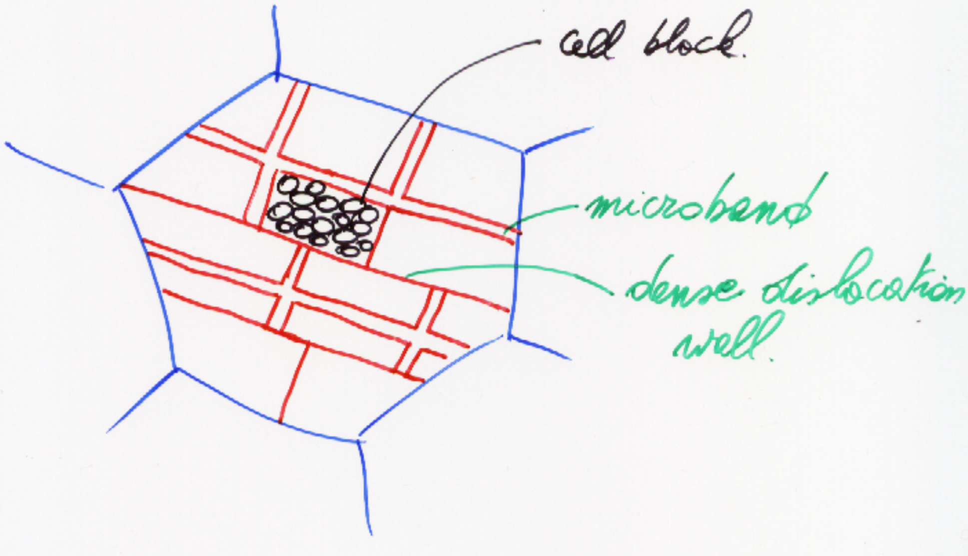


* MB^s slow down the texture evolution.

2.2. Subdivision by cell blocks (CB^s)

→ mainly observed in Al
(Risø nomenclature)

* Grains are subdivided by extended planar dislocation walls, delineating cell blocks.



* CB^s = 1-2 μm thick, parallellogram shaped

* CB^s contain cells

* planar CB boundaries:
  → Dense Dislocation walls (DDW)
  when they are single
  → Microbands (MB)
  when they are double

* CB boundaries tend to align with the most stressed {111} plane
  → later on: adapt the direction of the max. shear stress plane (±45° to ND).

* MB^s in Al
  ↳ they do not carry microscopic shear!
  The whole of the deformation takes place *inside* the cell blocks.

* Inside the cell blocks: deformation is homogeneous
  Heterogeneous slip: *between* different CB^s.

* DDW^s and MB^s separate volumes with different slip patterns
  ↳ different lattice rotation
  → misorientation exists between CB^s
  ↳ geometrically necessary boundaries (GNB^s)

* To distinguish MB^s in Al (as CB boundaries) from MB^s in Cu or Fe (as localized shear zones)
  → MB in Al: 1st generation MB
  → MB in Cu, Fe: 2nd generation MB

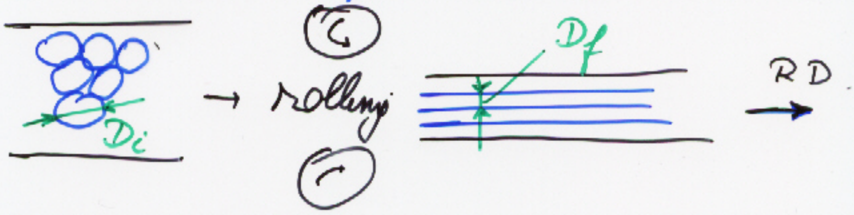
* Inside each CB: < 5 slip systems are active.

⇒ macroscopic strain can only be accommodated collectively at the grain level.

* Misorientation between CB^s: might be >15° after 40% rolling reduction.

3. At large strains (>50%)

* lamellar substructures // rolling plane.
* thickness of the lamellae < expected from rolling reduction



rolling reduction = ρ

Expected: $D_f = (1-\rho) D_i$

Observed : $D_f < (1-\rho) D_i$

→ subdivision has occurred.

* Subdivision is attributed to deformation banding (DB)
  = region of a grain which has a distinct lattice rotation as a result of a "local" plastic behaviour.

* DB^s are separated by transition bands (TB)
  → TB^s have a finite width over which the orientation gradually changes

* DB^s give rise to high misorientations inside one original grain volume

* Occurrence of DB^s is dependent on initial orientation
  → nature of this dependence is not very clear, though.

4. Shear Bands.

* Macroscopic slip localizations
* Only occurs after large rolling strains
* Extend over many grain diameters

* Orientation of SB^s is macroscopicly determined
→ no relation to a specific crystallogr. plane
→ // TD and tilted ~ 35° to RD