Planar Defects in Materials

- ❑ Classification of Defects in Solids: **Planar defects:**

- ❑ Planar defects:
  - ✓ Stacking faults
    - o {311} defects in Si
    - o Inversion domain boundaries
    - o Antiphase boundaries (e.g., super dislocations): analogous to partials but in an ordered material (GaN)
  - ✓ Interfaces
  - ✓ Grain boundaries
    - o Phase boundaries
    - o Tilt boundaries
    - o Twist boundaries
    - o Twin boundaries

Planar Defects in Materials

- ❑ Comparison of Packing of Atoms in the FCC & HCP Structures:

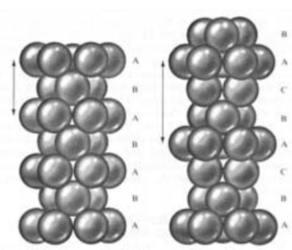

Figure 1–28 The manner in which close-packed layers of spheres can be stacked in sequence to produce (left) the hexagonal-close-packed (H.C.P.) structure and (right) the cubic-close-packed (F.C.C.) structure. After L. Pauling, *The Nature of the Chemical Bond* (Cornell, 1960).

Blakemore, Solid State Physics 2nd Ed (Cambridge, 1985)

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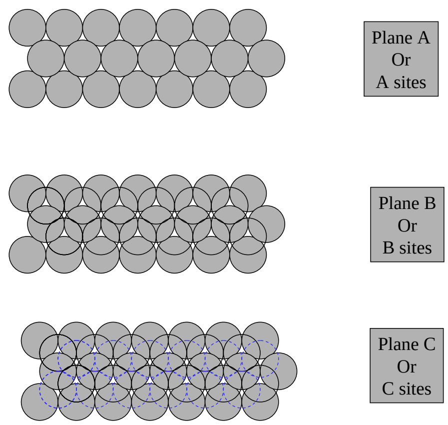
Planar Defects in Materials

- Comparison of Packing of Atoms in the FCC Structures:

Stacking sequence in FCC Crystals for (111) planes:
ABCABC



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Dislocations in Materials

- Mentioned earlier: Propagation of a dislocation that leaves the crystal unchanged in its atomic arrangement is referred to as a "*perfect*" dislocation.
- Example: ***b*** for "*perfect*" dislocation in FCC lattice:
  - ✓ ***b*** = $a_o/2$ [110]
- If the Elastic Strain Energy around a dislocation is large enough, the dislocation may dissociate into two dislocations whose ***b***'s are smaller.
- **Driving Force:** Reducing strain energy
- This will occur if:

$$b_1^2 > b_2^2 + b_3^2$$

Franks rule:

- The "smaller" dislocations are called ***Partial Dislocations.***
- The dissociation of a perfect dislocation into partial dislocations will create a planar defect between the two partial dislocations referred to as a ***Stacking Fault*** (SF).
- ***Stacking Fault:*** discontinuity in the stacking sequence.
- The distance between two partial dislocation represents a balance between the action of two forces:
  - ✓ The stress fields of the partials cause mutual repulsion.
  - ✓ The energy of the SF that stretches between them causes attraction.

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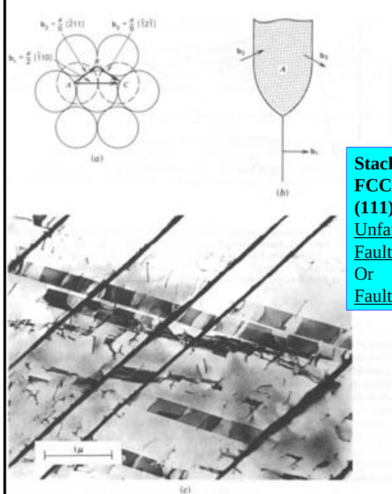
Dislocations in Materials

- ❑ Partial Dislocations:
  - ✓ Dissociation of a *perfect dislocation* into ***Partial Dislocations*** and the creation of a ***Stacking Fault*** (SF) is shown below:



Stacking sequence in FCC Crystals for (111) planes:
Unfaulted: ABCABC
Faulted: ABCA/CABC
Or
Faulted: ABCAB/ABC

FIGURE 2.17 (*a*) Path of whole and partial (Shockley) dislocations; (*b*) Shockley b_2 and b_3 surrounding stacking fault region *A*; (*c*) Long stacking fault ribbons (bands of closely spaced lines) in low SFE 18Cr–8Ni stainless steel. Faults are bounded at ends by partial dislocations. Thin black bands are mechanical twins. (After Michalak;[10] reprinted with permission from *Metals Handbook*, Vol. 8, American Society for Metals, Metals Park, OH, © 1973.)

I think Hull & Bacon?

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Dislocations in Materials

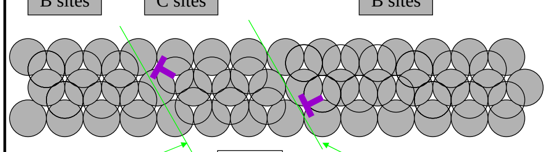
- ❑ Partial Dislocations:
  - ✓ Stacking Sites in {111} planes of a FCC crystal:

Stacking sequence in FCC Crystals for (111) planes:
Unfaulted: ABCABC
Intrinsic Stacking Fault: ABCA/CABC
Exstrinsic Stacking Faulted: ABCAB/ABC

Plane B Or B sites

Plane C Or C sites

Plane B Or B sites

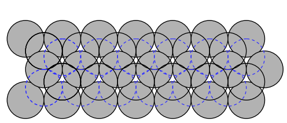


Partial dislocation

Faulted Section

Partial dislocation

⊥ = ***b***



Plane C Or C sites

Planar Defects in Materials

- Planar defects:
  - ✓ Stacking faults
    - o {311} defects in Si
      - Rod-like defect along <110> direction
      - Consists of interstitials precipitating on {311} plans
      - Deposits as a single monolayer of 5-7 member hexagonal rings of Si.
      - This atomic arrangement provides a way to insert planes of I w/o dangling bonds giving rise to a very stable defect.

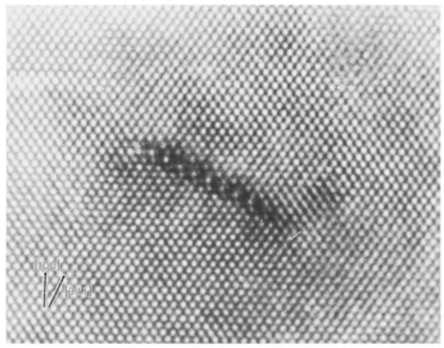


FIG. 2. Cross-section HREM showing {311} defect habit plane, and typical image contrast of {311} defects.

Eaglesham, Stolk, Gossmann & Poate, APL, **65**, (1994) 2305

2306 Appl. Phys. Lett., Vol. 65, No. 18, 31 October 1994

Planar Defects in Materials

- Planar defects:
  - ✓ Grain boundaries:
    - o High angle
    - o Low angle
    - o Phase boundary:
      - two phases rather than one in a polycrystalline material.

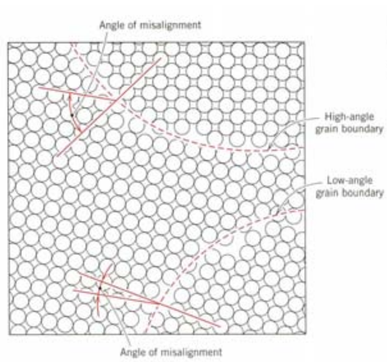


FIGURE 4.7 Schematic diagram showing low- and high-angle grain boundaries and the adjacent atom positions.

W. McCallister, 5th Ed

Planar Defects in Materials

- Planar defects:
  - **Tilt boundary** is a special type of small angle grain boundary:
    - Boundary is defined by an array of *edge dislocations* that are perpendicular to the angle of *misorientation*, θ.
  - **Twist boundary** is another special type of small angle grain boundary
    - Boundary is defined by an array of *screw dislocations* that are parallel to the *angle of misorientation*, θ.

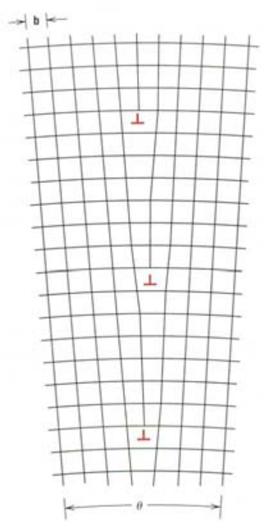


FIGURE 4.8 Demonstration of how a tilt boundary having an angle of misorientation θ results from an alignment of edge dislocations.

Planar Defects in Materials

- Planar defects:
  - Twin boundary:
    - Special type of grain boundary
    - It is defined by symmetry across the boundary
      - *Mirror plane*
    - Region between boundary is call a *twin*.
    - They are created by:
      - Applied mechanical shear forces
      - Thermal annealing following plastic deformation

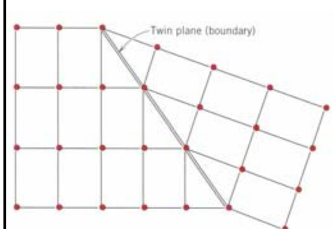
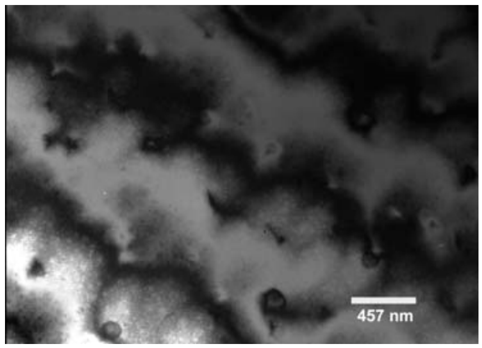


FIGURE 4.9 Schematic diagram showing a twin plane or boundary and the adjacent atom positions (dark circles).

Bulk Defects in Materials

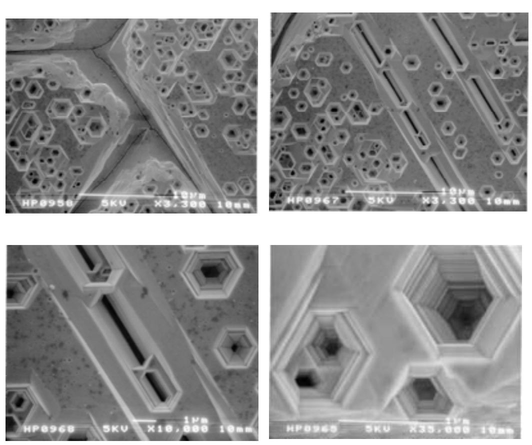
- Bulk/Volume defects:
  - ✓ Precipitates
  - ✓ Vacancy agglomeration **(see Shimura, S/C Silicon Crystal Technology, p.57, fig. 3.29b)**
    - o D-defects in Si
  - ✓ Cracks, grooves, pits



•D-defects known to cause gate oxide degradation
•D-defects created during crystal growth

Bulk Defects in Materials

- Bulk/Volume defects:
  - ✓ Cracks
  - ✓ Pits
  - ✓ Grooves



• SEM of MOCVD GaN

Work performed while at HP Labs