Session #20: Homework Solutions

Problem #1

Identify 3 types of crystal defects in solids (one point, one linear, and one planar) and suggest for each of these one material property that is adversely affected by its presence and one that is improved. Also state what to look for in a crystal that possesses each of these defects.

Solution

Defect	Type	Improved Materials Properties	Adversely Affected Materials Properties	Visible Signs of Defect
Point Defect	Vacancy f(T)	- diffusivity - color centers - ionic conductivity	- electron mobility - carrier lifetime	-empty lattice position
	Substitutional	- conductivity (dopant) - strength (hardness) - characteristic T (like T_M)	- conductivity (impurities) - ductility - characteristic T	-foreign atom occupying lattice position.
	Interstitial	- strength - characteristic T - electrical properties	- ductility - characteristic T - electrical properties	-atom occupies non lattice position.
Line Defect	Dislocation	- ductility (malleability) - strength (at high dislocation density)	- strength - yield stress - optical properties - lasing action	-extra half-plane of atoms.
Planar Defect	Grain Boundaries	- strength	- creep resistance - electrical properties - magnetic properties	-disruption of ordered crystal structure at interface of misaligned crystal grains.

Problem #2

Identify the directions of slip for indium (In) on the (111) plane.

Solution

Indium has a FCC structure so slip occurs along the densest packed planes (planes with the highest planar density) which is the {111} family of planes. Along (111) slip occurs along the densest packed directions, which are:

$$[\bar{1}10],\ [1\bar{1}0],\ [0\bar{1}1],\ [01\bar{1}],\ [\bar{1}01],\ [10\bar{1}]$$

Problem #3

A cubic metal (r = 0.77 Å) exhibits plastic deformation by slip along <111> directions. Determine its planar packing density (atoms/m^2) for its densest family of planes.

Solution

Slip along <111> directions suggests a BCC system, corresponding to {110}, <111> slip. Therefore:

$$a\sqrt{3} = 4r$$

$$a = \frac{4r}{\sqrt{3}} = 1.78 \times 10^{-10} \text{ m}$$

Densest planes are {110}, so we find:

$$\frac{2 \text{ atoms}}{a^2\sqrt{2}} = 4.46 \times 10^{19} \text{ atoms / m}^2$$

Problem #4

(a) List four different defects in crystalline solids.

(b) What evidence is available supporting the actual existence of the listed defects?

Solution

Many answers are acceptable. For example:

(1) dopant elements in semiconductors → affect electrical conductivity
(2) vacancies in close packed metals → explain solid state diffusivity
(3) edge dislocations → explain slip; visible as etch pits and in X–ray topography
(4) grain boundaries → visible in reflected light; evidence by X–ray diffraction
(5) micro–precipitates → visible in X–ray transmission, IR transmission

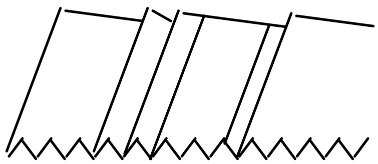
Problem #5

Attempt to account for the fact that polycrystalline aluminum (Al) has a higher tensile strength than single crystalline Al. Support your answer with an appropriate sketch.

Solution

The tensile strength is largely controlled by slip, which in FCC systems such as aluminum involves the twelve {111} <110> slip systems. The mobility of dislocations, which controls slip, is high in single crystals because of the high degree of crystal perfection, so slip proceeds from one external surface to another. In polycrystalline Al, the mobility of dislocations is slower because of mutual interference (high density of dislocations) and because precipitates are frequently encountered, so slip is retarded. Slip, moreover, is arrested at grain boundaries and deflected in different directions; thus, the strength of polycrystalline material is higher than that of single crystals.

slip systems in single crystals



slip systems in polycrystalline materials