Sunday, 13 October 2024

Practice Problems - Higher order and 1-D defects

Vacancies in Metals

- In iridium, the vacancy fraction, n_V/N, is 3.091×10^{-5} at 1234°C and 5.26×10^{-3} at the melting point.
  - Calculate the enthalpy of vacancy formation, ΔHv.
- The energy of vacancy formation in palladium (Pd) is 1.5 eV per atom. At 888°C there is one vacancy for every million atom sites.
  - Is it possible to achieve a vacancy fraction of one vacancy for every thousand atom sites by simply raising the temperature?
- Given that the equilibrium number of vacancies at 500°C is 7.57×10^{23} m^{-3}. The atomic weight and density (at 500°C) for aluminum are, respectively, 26.98 g/mol and 26.2 g/cc.
  - Calculate the activation energy for vacancy formation in aluminum.
- The energy for vacancy formation in Fe is 1.08 eV/atom. The density of Fe is 7.65 g/cc (at 850ºC).
  - Calculate the number of vacancies per cubic meter in iron at 850°C.

Dislocations

- The radius of Fe and V atoms is 0.124 nm and 0.205 nm, respectively. They exhibit FCC and BCC crystal structures, respectively.
  - Calculate the magnitude of the Burgers vector for these materials.

- A dislocation with Burgers vector $\frac{1}{2}[110]$ splits into two dislocations (the so-called partial dislocations) with Burgers vector of the type <112>.
  - Determine them.
  - Is this a spontaneous process?
    - *Note: the elastic strain energy of a dislocation per unit length is* $\frac{1}{2}\mu b^2$.

      $\mu \rightarrow shear\ modulus.$

- Draw a Burgers circuit that encloses a positive and a negative edge dislocation each with one incomplete plane in a simple cubic crystal.
  - What is the Burgers vector obtained? Comment on your result.

- A copper rod (fcc metal) has a dislocation density of 10^{10} m^{-2}. The shear modulus of copper is 45 GN m^{-2} and the lattice parameter is 3.61 Å.
  - Calculate the dislocation energy per m^3.

Surfaces and Grain boundaries

- The interfaces between three phases α, β, and γ meet along an edge. The angles subtended at the edge by the three phases are respectively 120°, 105° and 135°. The surface energy of the α–β boundary is 1.00 J m^{-2}.
  - Find the surface energy of β–γ and γ –α interfaces.

- The grains in a polycrystalline solid are space-filling polyhedra which can be approximated to spheres of equivalent volume.
  - Calculate the change in the grain boundary energy per m^3 of the solid, when the average grain diameter increases from 0.01 mm to 0.1 mm.
  - Is this a spontaneous process?

- The ASTM grain size number, n, is defined through the following relation to N, which is the average number of grains per square inch at a magnification of 100x:

$$n = 2^{N-1}$$

  - Determine the ASTM grain size number of a metal specimen if 45 grains per square inch are measured at a magnification of 100x.