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Practice HW2.4-Self Diffusion and Surface Tension (or Surface Energy)

2.4.1 Please note the following equation for the diffusion of a species "A" within a host material – it is fully described in HW-2.3

$$J_A = \frac{C_A D_A}{RT}\frac{d\mu_A}{dx} \qquad (1)$$

Now consider the diffusion of atoms within its own structure (the diffusion of isotopes of Cu, within Cu is an example). In this case we drop the subscript "A" and replace

(i) D_A by D

and,

(ii) C_A by the number of atoms (or molecules) per unit volume.

Show that the above equation now reduces to

$$J = \frac{D}{V_m RT}\frac{d\mu_A}{dx} \qquad (2)$$

where V_m is the molar volume, that is the volume of one mole of atoms (or molecules as the case may be).

2.4.2 Use a few words and sketches to show how grain boundaries that form between grains (crystallites) of different orientations can be sites were atoms can be injected or removed, that is, grain boundaries can become sites were the crystals, placed toe-to-toe, can grow or recede.

2.4.3 Write a paragraph supported by sketches that illustrate how mass transport from adjacent boundaries can lead to closure of pores accompanied by physical shrinkage of the workpiece. In particular focus on how the length scale of atom jumps (which accounts for diffusion) can be extended to much longer length scales to fill pores. Further show how this length scale of diffusion flux can be related to the physical length scale of the workpiece. In summary show how the atomic level length scale (sub-nm), can be linked to the length scale of the grain size (about one micrometer), how this length scale can be tied to the physical size of the workpiece (several cm).

2.4.4 Processes in materials are dependent on two key tenets: the driving force and the kinetics. The first can be a chemical driving force, or an electrochemical driving force, or even a gradient in applied stress. The kinetics usually refers to the diffusion of mass, and is time and temperature dependent.

2.4.5 Show that a spherical pore within a body feels an inward surface pressure (as if a mouse is pulling on the surface) which is given by

$$p_H = \frac{2\gamma_S}{R} \qquad (3)$$

where γ_S is the surface energy (units of J/m^2) or (N/m), and R is the radius of the pore. Here p_H implies hydrostatic tension with units of stress of N/m^2.

2.4.6 Extend Eq. (3) to show than the surface of a solid sphere faces inward pressure applied to the surface. Derive from first principles.

2.4.6 Show that the (tensile) pressure on the inner surface of cylinder (a tube) is given by

$$p_H = \frac{\gamma_S}{R}$$