ENG2000 Test on Atoms and Crystals

30 September 2003

1. [50]
    a. What characteristics define a crystal and why are crystals useful in engineering applications? [6]
    b. Define the atomic packing factor (APF). Calculate the APF for the face-centred cubic and the body-centred cubic crystal structures. [10]
    c. For a cubic system, write down the indices of the individual members of the <100> family of lattice directions and sketch them. [10]
    d. For a cubic crystal structure, sketch the (1 1 1), (2 3 4) and (3 2 1) planes. [12]
    e. Determine which planes of the face-centred cubic structure have the highest density of atoms and calculate this value for copper (a_{Cu} = 0.361nm). Hint, the answer is in units of atoms/nm^2. [12]

2. [50]
    a. Draw labelled diagrams to illustrate the four basic types of point defects in a crystal. [9]
    b. Draw labelled diagrams to illustrate edge and screw dislocations in a crystal. [9]
    c. Define the Burgers vector and show them for the situations in (a) and (b) above (you can indicate them on the diagrams you drew above). [12]
    d. The energy to form a vacancy (Q_v) in aluminium and silicon is 0.75eV and 3.6eV, respectively. Calculate the fractional concentration of vacancies (i.e. ratio of vacancies to atoms) at 660°C for Al and Si. [10]
    e. Why do you think that the energies in part (d) are so different for the two materials? [5]
    f. Speculate as to the importance of the Q_v value for Si to chip manufacture. [5]

Useful expressions:

$1\ eV = 1.6 \times 10^{-19}\ J$

$k = 1.38 \times 10^{-23}\ J/K = 8.62 \times 10^{-5}\ eV/K$

$$N_v = Ne^{-Q_v/kT}$$