UNENE UN901 – 2007 - Assignment 1

1. Show the following planes on diagrams of cubic (fcc or bcc) unit cells.
   $(121), (202), (1\bar{1}1), (002)$
2. Show the following directions and planes on diagrams of hcp unit cells.
   $(10\bar{1}1), (10\bar{1}2), (\bar{1}\bar{1}20), (\bar{1}\bar{1}21), (\bar{1}\bar{1}23)$
   $[10\bar{1}0], [11\bar{2}3], [\bar{1}\bar{1}20]$
3. Calculate equilibrium vacancy, and SIA concentrations as a function of temperature from 400 to 800°C for Zr (take the enthalpies of formation, ΔH_v and ΔH_i , as 1.3 and 4eV atom^{-1} respectively) and make a plot. Note that Boltzmann's constant, k = 8.61x10^{-5} eV.atom^{-1}.K^{-1}
4. Calculate a typical lifetime of vacancy in Zr at 400°C, if it starts at the center of a crystal 12μm in diameter, and migrates to a grain boundary by random walk. Do the same calculation for an SIA. Assume that the enthalpies of migration are 1.2 and 0.25 eV respectively and a vibration frequency of **ν** = 10^{13}s^{-1} in both cases. Take α as 3.2x10^{-10}m, and $\exp \Delta S_m / k$ as 3.0. Assess the respective values of **z**, the number of available sites for each jump from the crystal structure (hcp).
5. Calculate the typical time for an **atom** in the center of the crystal 12μm in diameter in question 4 to migrate to a grain boundary. Take $\exp \Delta S_v / k$ as 3.0.
6. Nickel has a room temperature critical resolved sheer stress of 5.7 MPa for 1/2<110>, {111}slip. How does this compare to the theoretical shear strength. Why? The shear modulus is 49GPa. The lattice parameter is $\mathbf{a_0}$ = 5x10^{-10} m.
7. Plot the shear stress required to cause a dislocation to bow between obstacles as a function of obstacle spacing for a material with a shear modulus of 30GPa and a Burgers vector of 3x10^{-10}m (remember to keep units consistent).
8. In a typical tensile test the strain rate is of the order of 1x10^{-2} s^{-1}. An annealed material may have dislocation density of 1x10^{13} m^{-2}. Cold worked materials typically have dislocation densities of 5x10^{14} m^{-2}. For a typical Burgers vector of 3x10^{-10}m, compare the dislocation velocities in annealed and cold-worked materials. If the specimen has strained 1%, how far will the average dislocation have traveled in each material?
9. Give a brief description of the phenomenon of necking in a tensile test and explain why necking starts at the elongation corresponding to maximum load.
10. Using an equation, explain how various factors affect the rate of necking once it has started. How does this effect relate to super-plasticity?
11. Using the stress concentration model calculate the fracture stress as a function of crack tip radius from 3x10^{-10}m to 3x10^{-6}m and crack length from 10^{-4}m to 10^{-2}m. Take E as 100GPa, a_0 as 3x10^{-10}m and γ_s as 0.2Jm^{-2} (remember to keep units consistent).

12. A material has a value of K_{1C} of 20 MPa.m$^{1/2}$ and a yield stress of 400 MPa. How thick must a test specimen be to get a valid result. Explain why a specimen that is too thin will give an invalid result.
13. What is crystallographic texture? Crystallographic texture is frequently represented by a "pole figure" describe and explain a pole figure.
14. Define anisotropy. Give examples of some anisotropic materials properties.
15. The Hill anisotropy parameters given in the lecture (F,G,H = 0.35, 0.19, 0.96) crudely represent a CANDU pressure tube which is strong in the tangential direction (direction 2) and week in the axial direction (direction 1). As can be seen in the notes, the yield stress in each direction is inversely related to the sum of two of the anisotropy parameters. Calculate the ratios of the strains in the three directions for this set of anisotropy parameters for uniaxial tensile tests in directions 2 and 3.
16. Give a brief description of a creep mechanisms map. How are the boundaries determined?
17. What are the characteristics of tertiary creep? What phenomena account for tertiary creep?
18. Describe the key features of a fatigue crack (typical source, surface features of the fracture) and explain why these features exist.
19. What parameters are used to characterise load history under fatigue conditions? Explain how simple fatigue data and tensile properties are used to define fatigue limits in terms of these parameters using a Goodman diagram.
20. Explain the residual stress pattern in a bent bar.
21. Can residual stresses be introduced intentially to improve structural integrity of a component? Explain how.
22. Give a brief description of "Type-2" residual stresses. How are they developed?