MSE250 Overview / Review

Updated October 26, 2011

Bonding

Do you understand how to deduce the type of bonding present in a given material?

How is a material's bonding energy diagram related to properties such as strength, thermal expansion, melting point, and density?

Crystals

- symmetry

  Can you visualize the packing of circles in various crystal directions/planes for FCC and BCC?

  Can you derive the relationship between the lattice parameter, *a,* and the radius of close-packed circles, *r*, for various crystal structures?

  What is polymorphism?

- "navigation"

  Can you determine crystal directions and Miller indices of crystal planes? [Remember to indicate the origin you are using!]

  [direction] <family of dir.'s> (plane) {family of planes}

- packing

  What does "close-packed direction" mean?

  Can you estimate of the planar density of atoms on a crystal plane just by looking at their packing?

  [Remember not to use the definitions of linear and planar density given in the book, but those given in lecture!]

- defects
  - point

    What are 3 kinds of point defects?

    What is the Arrhenius equation, and what does it represent?

    How do you determine the solubility of two materials?

  - line (a.k.a. dislocations)

    What is a Burgers vector? What does it represent, and how is it oriented in the 3 line dislocation systems (edge, screw, mixed)?

  - surface

    Given two surface crystal orientations, which would have a higher/lower surface energy (i.e. which surface would it be easier/harder to remove an atom)?

  - grain boundary

    What is polycrystallinity?

    How do the 4 defect types compare with each other energetically?

Diffusion

What are Fick's first and second laws, and when is it appropriate to use each?

Where does temperature come into the equations?

What are some processes seen in the class where diffusion occurs?

Are you solving problems efficiently, especially for second-order non steady state questions? Often, the question can be simplified greatly by gathering all constants together and equating the remaining variables (e.g. $D_1t_1 = D_2t_2$).

Mechanical Properties

- definitions

Can you define all these terms concisely and completely, and give their significance? Utilize the σ-ε graph, but also explain physical mechanisms like slip and bonding (bond energy diagram!).

- Stress
- Strain
- Elastic vs. plastic deformation
- Modulus of elasticity (Young's modulus)
- Stiffness
- Elastic recovery
- Yield strength
- Ultimate tensile strength / necking
- Fracture
- Ductility / brittleness
- Toughness
- Hardness
- Modulus of resilience (J/m^3, energy density!)
- Poisson's ratio

For common metals like aluminum or steel, what are ballpark values for the terms above which are intrinsic properties?

When asked to solve for change in length/thickness upon loading, make sure that you are checking that the applied stress is less than σ_{yield}, or else it is very *wrong* to use the equations given for the elastic region.

- factor of safety

Most real materials are designed such that their yield strength is 3 to 5 times larger than the loads they are typically subject to; this guards against unwanted plastic deformation.

- plastic deformation
  - slip

Can you write the complete logic flow of how to define the critical resolved shear stress of a material? (Remember: it is a material property, just as much as the yield stress or ductility)

Can you **quickly** (in under 5 seconds) visualize the common slip systems (i.e. the densest planes and the closed-packed directions) for FCC, BCC, HCP, and simple cubic?

If one were to calculate the strength of a perfect crystal, how would this compare to the strength of an imperfect (real-life) crystal with defects? Physically explain this discrepancy (think of how many bonds need to break to cause a shift of atoms in the two cases).

What are the stress fields above and below an edge dislocation?

What is the energy/stress required to move a dislocation line proportional to?

- twinning

What is twinning? Compare it with slip.

Strengthening

How does each of the three strengthening methods hinder dislocation motion? Draw pictures of each process.

How does hindrance of dislocation motion relate to material properties (yield strength, ductility, toughness, ultimate tensile strength)?

- Heat treatment/ annealing

What is the difference and relative effect of recovery versus recrystallization?

Why is cold work necessary for recovery or recrystallization to occur?

Draw the morphology of a polycrystalline material after it has been cold hardened, and after various times and temperatures of recovery, recrystallization, and grain growth. Explain the mechanisms that are occurring in each step of the process using terms given in class.

Failure mechanisms

- Fracture

Can you define all these terms?

- Stress intensity factor, K
- Loading modes I, II, III
- Plane stress
- Plane strain
- Fracture toughness, K_c
- Plane strain fracture toughness, K_{Ic}
- Ductile-to-brittle transition

[Remember not to use the definitions for K_c and K_{Ic} given in the book]

Can you compute the maximum stress near a through-crack inside a material, and one residing on the surface of a material?

Why is the plane strain fracture toughness the most often tabulated form of K_c? What is its relationship (qualitative and quantitative) with the plane stress fracture toughness? Which one has a higher value?

What are the typical characteristics of fracture surfaces for ductile and brittle materials?

Why does a brittle material require less energy to fracture it? (think ductile-to-brittle transition, and also the definition for toughness as the area under a stress-strain curve – the strain energy density) Alternatively, why does a ductile material usually require more energy to fracture it (where does that extra energy go)?

Make sure you understand how to solve for critical parameters using the equation for K (try Questions 8.9 thru 8.11 in the 8^{th} edition for practice).

What is the effect of temperature on fracture toughness for HCP, BCC, and FCC materials (Fig. 8.15)?

- Fatigue

What are the fatigue characteristics of HCP, BCC, and FCC materials?

Compare the fracture surfaces of a material that has undergone fatigue failure due to cyclic loading and one that has failed from a static load. What are the similarities and differences?

Make sure you know how to use/read/construct a logarithmic graph without the aid of a computer.

What does an S – logN curve represent? When using an S-N curve to design a component, what are the implications of sample non-uniformity due to flaws/defects?

- Creep

Distinguish creep deformation from elastic or plastic deformation. Think of the physical mechanisms of each one. Based on this physical mechanism, what kinds of microstructures would enhance the creep rate of a material?

What two parameters is creep dependent on?

Can you label these regions on a creep strain–time graph?
- Instantaneous deformation
- Primary creep
- Secondary (steady-state) creep
- Tertiary creep
- Rupture / rupture time

Why is a creep strain–time graph not linear? What is the physical mechanism behind each region above?

General comments

This review guide does not cover equations or example problems in homework/class, but should prepare you well for understanding all the concepts needed in this course; consult your other study sources for the “complete picture”.

The second quiz will take place in discussion this coming Thursday, October 27 and will cover Chapter 8 material only. It will be closed-book, closed-notes. You will be provided with necessary equations. A calculator and ruler are allowed.

The significance of study sources, with the most important being first, should be:

Lecture notes
Quiz / homework
Discussion handouts
Textbook

Email me at tanaaron@umich.edu regarding questions or to set up a meeting time/place. Good luck!