MCG2361 – Engineering Materials II

Mid-term Exam 1

Solutions

1. List the two main characteristics of the component ions that determine the crystal structure of ceramics (*1 mark*)

   i) Charge neutrality
   ii) Coordination number (ratio of atomic radius of cation and anion)

2. Explain why ceramics are more brittle than metals. How can the toughness of ceramics be improved? (4 *marks*)

   Ceramics have strong ionic/ covalent bonding compared with metallic bonding for metals. Ionic/ covalent bonds are stronger.
   Toughness of ceramics can be improved by several methods including: Transformation toughening (example of partially stabilized zirconia), inducing mi-cracks, crack deflection and crack bridging (in ceramic composites)

3.
   a) Explain why the mechanical properties of ceramics are strongly affected by the presence of pores and cracks (*2 marks*)

      Because pores and cracks act as stress concentration, reducing the strength of ceramics

   b) How can porosity or cracks be reduced in order to produce ceramics with improved properties? (*2 marks*)

      Through close control of ceramic processing: control of powder purity, composition and microstructure formation of ceramics

4. Sintering is one of the most important steps in processing of ceramics by powder metallurgy route.

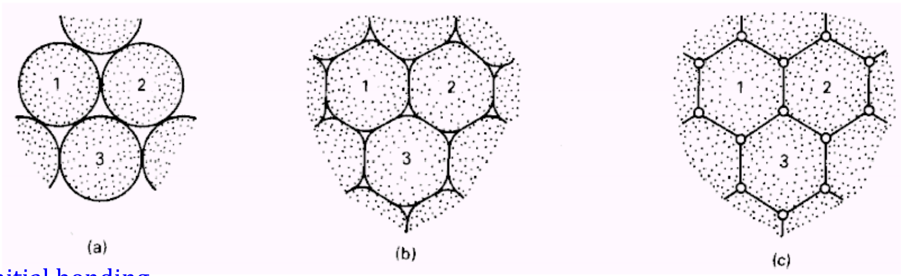
   a) List some of the factors that may affect the sintering process (*2 marks*)

      Composition of powders, Green density, powder size, shape and distribution, pore content (size, shape and distribution), extent of mixing (multi-component ceramics), sintering temperature and time.

   b) What is the purpose of sintering? (*2 mark*)

      To densify the ceramic (increase its density and reduce porosity content)

c) Using sketches, describe the main stages of sintering ceramic powders. (*4 marks*)



Initial bonding | Necking | Grain boundary formation

5. A three-point transverse bending test is conducted on a cylindrical specimen of aluminum oxide having a reported flexural strength of 390 MPa. If the specimen radius is 3 mm and the support point separation distance is 30 mm, predict whether you would expect the specimen to fracture when a load of 620 N is applied. Justify your prediction. (*3 marks*).

Given: $F_l = 4(I/Y_m)\frac{\sigma_{max}}{L}$ and $\frac{I}{Y_m} = \frac{\pi R^3}{4}$

Solution

$$\sigma_{max} = \frac{(620N)(30\times10^{-3}m)}{(\pi)(3\times10^{-3}m)^3} = 219\times10^6\,N/m^2 = 219\,MPa$$

Since this value is lower than 390 MPa, fracture does not occur

6. Distinguish between thermoplastic and thermosetting polymers on the basis of:

a) Mechanical characteristics upon heating (*2 mark*)

Thermoplastics: soften (or melt) upon heating and become solid upon cooling. They can be reheated and remelted without degradation – recyclable

Thermosets: harden upon heating (during curing) and degrade if reheated – non-recyclable

b) According to possible molecular structure (*2 mark*)

Thermoplastics: Linear and branched polymers
Thermosets: cross-linked polymers

7. There are two methods by which polymers are made.

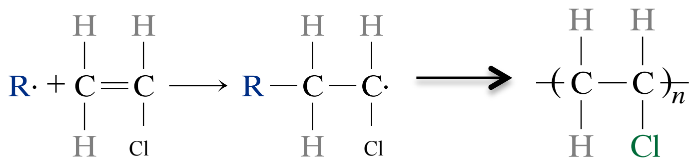
a) List the two methods (*1 mark*)
Addition (chain) polymerization, step (condensation polymerization)

b) Provide a comparison between these two methods (*4 marks*)
Addition polymerization: mostly for homopolymers, a C double bond is required in the monomer, a catalyst is required for the reaction to start, no by-product

Condensation polymerization: mostly for copolymers, no catalyst is required and a by-product is produced from the process

c) Using vinyl chloride (C_2H_3Cl) as an example, show how polyvinyl chloride (PVC) polymer is formed. (*2 marks*)

PVC is polymerized by addition polymerization.



8. How do the properties of thermosetting polymers differ from those of thermoplastics? Why? (*3 marks*)
Thermoplastics are linear/ branched polymers so they have weak bonds (secondary bonds) between the chains (in addition to covalent bonds between the atoms) making them ductile and with lower strength and low melting point.
Thermosets are cross-linked polymers with strong covalent bonds between the chains (in addition to covalent bonds between the atoms) making them strong, hard and brittle and with high melting point.

9. How would you expect the properties (strength, hardness, melting point) of a polymer material to be affected by the following: Justify your answer

a) Increasing the molecular chain length of the polymer (*2 marks*)

Increasing the length of the polymer chain would increase its molecular weight, which would increase the polymer's rigidity, strength, and T_m.

b) Increasing the degree of branching in the polymer chain (*2 marks*)

The structure would be less crystalline, more tangled. This would reduce the polymer's rigidity, strength and also decrease T_m.

c) Aligning the polymer chains with one another (*2 marks*)

Aligning polyethylene chains with one another means that the structure is more crystalline. This would increase density, rigidity, and strength. T_m would also increase.