

# NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

## APPLIED PHYSICS DEPARTMENT

### SPH 4204 - MATERIALS SCIENCE II

BSc HONOURS PART IV: MAY 2006

DURATION: 3 HOURS

**ANSWER ALL QUESTIONS FROM SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS WHILE SECTION B CARRIES 60 MARKS.**

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#### SECTION A

1. (a) Sketch the ion arrangement on the (110) plane of ZnS and the CaF<sub>2</sub> structure [4]
  - (i) Compare the planar packing fraction on the (110) planes for these two metals,  $r_{Zn} = 0.074\text{nm}$ ,  $r_s = 0.184\text{nm}$ ,  $r_{Ca} = 0.099\text{nm}$  and  $r_F = 0.133\text{nm}$ . [4]
  - (ii) What is the co-ordination number of the ZnS structure? [3]
- (b) Show that Mg<sub>2</sub>SiO<sub>4</sub> and Fe<sub>2</sub>SiO<sub>4</sub> are expected to display complete solid solubility. [4]
- (c) Discuss in brief, the advantages and disadvantages of alumina, Al<sub>2</sub>O<sub>3</sub>, in biomedical applications. [4]
- (d) Polytetrafluoroethylene is a polymer used to coat non-stick pans. The molecular chain differs from that of polyethylene in that fluorine atoms have replaced all the hydrogen atoms. Explain the non – sticky property on the basis of this structure. [4]
- (e) A stress of 20 MNm<sup>-2</sup> is applied to a polymer serving as a fastener. At a constant applied strain, the stress drops to 15MNm<sup>-2</sup> in 100 hours. If the stress on the component is to remain above 12 MNm<sup>-2</sup> for its proper function, determine the life of the fastener. [5]
- (f) A cemented carbide cutting tool used for machining contains 75 wt % WC, 15 wt % TiC, 5wt % TaC, and 5wt %Co. Determine the density of the composite. [5]
- (g) Distinguish
  - (i) thermosetting polymers from thermoplastic polymers [3]
  - (ii) unplasticised PVC and plasticised PVC [3]

## SECTION B

2. (a) (i) Define and classify the different types of porosity. How is porosity reduced through sintering? [5]
- (ii) Give two examples of each, for lower-order and higher order functions of porous ceramic bodies. [2]
- (iii) Explain how the porous bodies function, using one example from any one of the categories. [3]
- (b) Silicon carbide has a specific gravity of  $3.1\text{gm/cm}^{-3}$ . A sintered silicon carbide component has a volume of  $500\text{ cm}^3$  and weighs 1200g in air. After soaking in water, the component weighs 1250g . Calculate
- (i) the bulk density, [4]
- (ii) true porosity, [2]
- (iii) the fraction of each type of porosity in the component. [2]
- (c) How does porosity influence opacity in materials? [2]
3. (a) Discuss, from the atomic point of view, factors that determine the mechanical properties of ceramics. [5]
- (b) Briefly describe the  $\text{CaF}_2$  ,( calcium fluoride) structure [5]
- (c) A set of ceramic parts is subjected to bend tests and the stress required for failure is measured. The results obtained were as follows:  $55.5\text{ MNm}^{-2}$ ,  $54.5\text{ MNm}^{-2}$ ,  $\text{MNm}^{-2}$ ,  $52.4\text{ MNm}^{-2}$ ,  $56.5\text{ MNm}^{-2}$ ,  $50.3\text{ MNm}^{-2}$ ,  $53.4\text{ MNm}^{-2}$ ,  $\text{MNm}^{-2}$  and  $51.7\text{ MNm}^{-2}$
- (i) Calculate the Weibull modulus for the material. [6]
- (ii) Discuss whether the material would be a good choice if one wanted to design a reasonably reliable component? [2]
- (iii) What could be the reason for such varied results? [2]

4. (a) (i) Define the specific tensile modulus and specific tensile strength of a composite material. [4]
- (ii) Explain the significance of the 'the critical length' when discontinuous fibers are used for a composite. [5]
- (iii) With the aid of graphs, explain the variation of the Young's modulus for a fiber reinforced composite under isostress and isostrain conditions. [6]
- (b) Calculate the composite modulus for a polyester reinforced with 60 vol % E-glass under isostrain conditions. The density of polyester =  $6.9 \times 10^3 \text{ Mp}$ , E-glass =  $72.4 \times 10^3 \text{ MPa}$  [5]
- 5 (a) (i) Define the degree of polymerization for a polymer chain. [2]
- (ii) Determine the mole fraction of each component in a co-polymer consisting of 15 wt % polyvinyl acetate (PVA) and 85wt% polyvinyl chloride (PVC). [4]
- (b) Explain how the elastic modulus of a polymer depends on
- (i) Degree of polymerization [2]
- (ii) Crystallinity [2]
- (iii) Amount of covalent cross – link between chairs [2]
- (c) What are organic metals? Give one example and explain the theory behind their property. [4]
- (d) Write brief notes on any one of the following:
- (i) self lubricating polymers, [4]
- (ii) heat resistant polymers? [4]
6. (a) (i) What is meant by the viscoelastic behavior of polymeric materials?[4]
- (ii) Briefly describe the models used to explain this behavior. [6]
- (b) (i) Classify refractory materials. [5]
- (ii) What are the requirements for refractory bricks that are to be used for lining iron and steel blast furnaces? Explain why silica bricks are suitable for non-highly reducing conditions being present in the kiln. [5]

**- END OF EXAMINATION -**