# NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

## FACULTY OF APPLIED SCIENCES

## DEPARTMENT OF APPLIED PHYSICS

## MATERIAL SCIENCE

## SPH 4214

**Second Semester Examination Paper**

**March 2025**

This examination paper consists of 4 pages

**Time Allowed:** 3 hours

**Total Marks:** 100

**Special Requirements:** None

**Examiner's Names:** Mr B Sibanda

**INSTRUCTIONS**

**ANSWER ALL PARTS OF QUESTION 1 IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.**

**MARK ALLOCATION**

| QUESTION | MARKS |
|---|---|
| 1. | 40 |
| 2. | 20 |
| 3. | 20 |
| 4. | 20 |
| 5. | 20 |
| 6. | 20 |
| Maximum possible mark | 100 |

## SECTION A

1(a) Calculate the atomic packing factor (APF) for the BCC crystal structure. [4]

(b) What is annealing and what effects does it have on the properties of metals? [4]

(c) Derive the planar packing density expression for the FCC (110) plane in terms of atomic radius R. [4]

(d) Explain why polycrystalline aluminum (Al) has a higher tensile strength than single crystalline (Al). Support your answer with an appropriate sketch. [4]

(e) Suggest the criteria for the two metals to form a perfect substitutional alloy (that is, these two will form the same crystal phase at all potential concentration of each species)? [4]

(f) Describe how one can determine or control the strength of ceramics and glasses? [2]

(g) Materials such as silicon carbide (SiC) and silicon nitride ($Si_3N_4$) are used for grinding and polishing applications. Rationalize the choice of these materials for this application. [4]

(h) A binary alloy consist of 30 wt% Sn and 70 wt% Pb. Given that the atomic masses for Sn and Pb are 118.7 g/mol and 207.2 g/mol respectively, convert this composition into atomic percent. [4]

(i) What is a diffusion couple? [2]

(j) Derive Schmid's law. [4]

(k) Explain why dislocations play an important role in the deformation of metals. [4]

## SECTION B

2(a) Why are ceramics usually much stronger in compression than in tension? (use annotated sketches in your answer) [6]

(b) What is a composite material? Give two examples of composites. [4]

(c) What measures are available to protect metals from electrochemical corrosion? [2]

(d) Briefly explain four methods of metal deformation. [8]

3(a) Differentiate between age hardening, strain hardening and precipitation hardening. [9]

(b) Explain the differences between soderberg line and Goodman line. [6]

(c) What is a Eutectic system? Explain copper/silver and lead/tin eutectics [5]

4(a) State the Hume-Rothery rules that favour extensive substitutional solid solubility. [4]

(b) Sketch binary phase diagrams for two component (i.e two metals) systems that exhibit:

(i) Complete solid solubility [2]

(ii) Partial solid solubility [2]

(iii) Zero solid solubility [2]

(c) For a system that exhibits partial solid solubility select a composition that has two different phase regions in the solid state, make sketches of the microstructure for all different phase regions. Annotate your sketches. [6]

(d) State three applications for composites and explain why they are used for that application. [4]

5(a) Explain what is meant by fracture toughness. [2]

(b) Explain why BCC and HCP metal alloys may experience a ductile-to-brittle transition with decreasing temperature, whereas FCC alloys do not experience such a transition. [4]

(c) Derive linear density expressions for the BCC[100] and [110] directions in terms of the atomic radius R. [6]

(d) For an FCC single crystal, would you expect the surface energy for a (100) plane to be greater or less than that for a (111) plane? Why? [4]

(e) What are conducting polymers and conducting ceramics? [4]

6(a) Explain the difference between the thermoplastic and thermosetting plastics. [4]

(b) Discuss the factors that determine the mechanical properties of polymers. [4]

(c) Describe one surface treatment method by which you can strengthen a borate glass. [4]

(d) In the context of amorphous inorganic compounds, name two glass network formers and two glass network modifiers. [4]

(e) Sketch the variation of molar volume with temperature for pure silica($SiO_4$). Show glass formation at two different cooling rates, labelling the melting point or the glass transition temperature on each cooling curve. [4]

**END OF EXAMINATION PAPER**