RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

Bachelor of Science in Applied Sciences
Third Year - Semester II Examination – Jan / Feb 2023

PHY 3210 – PROPERTIES OF MATERIALS

Time: Two (02) hours

Answer **all four (04)** questions.

Symbols have their usual meaning.

Use of a calculator is allowed.

Planck's constant $h = 6.626 \times 10^{-34}$ J s

Velocity of light c = 3.0×10^{8} m s^{-1}

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1. In solids the radiative emission process is called luminescence. Luminescence can occur by a number of mechanisms.

a) i. Discuss briefly two different mechanisms of luminescence. (12 marks)

ii. Explain why it is difficult to make light-emitting devices out of indirect gap materials. (12 marks)

b) The band gap of the III-V semiconductor alloy $Al_xGa_{1-x}As$ at $k = 0$ varies with composition according to $E_g(x) = (1.422 + 1.087x + 0.439x^2)$ eV. The material is direct for $x \leq 0.43$, and indirect for larger values of x. Light emitters for specific wavelengths can be made by appropriate choice of the composition.

i. Calculate the composition of the alloy in a device emitting at 800 nm. (12 marks)

ii. Calculate the range of wavelengths that can usefully be obtained from AlGaAs emitter. (14 marks)

2. Characteristics of motion of an electron under the influence of a uniform magnetic field play a key role in determining some important properties of electrons.

a) i. Show that an electron of mass m and charge e performs circular orbits around a magnetic field with an angular frequency (cyclotron frequency) $\omega_c = \frac{eB}{m}$, where B is the field strength. (12 marks)

ii. Explain what is meant by cyclotron resonance. (08 marks)

iii. Use the uncertainty principle to show that the basic condition for the cyclotron resonance is $\omega_c \tau >> 1$. (08 marks)

b) i. In a cyclotron resonance set-up, a klystron radiation of 3.6×10^{10} Hz is used. For a sample, the resonance absorption occurs at a magnetic field of 8.7×10^{-2} T. Calculate the effective mass of the charge carriers. (12 marks)

ii. Determine the range of relaxation time over which resonance is observable. (10 marks)

3. Crystallographic defects are the interruptions of the regular pattern of arrangement of atoms or molecules in crystalline solids. Sometimes, these crystallographic defects are intentionally introduced during the synthesis of materials to obtain materials with desired properties for various applications.

a) Briefly discuss the Kroger – Vink notation used to describe the point defects in crystalline solids. (10 marks)

b) Using Kroger – Vink notation, discuss the following point defects in crystalline solids. Use diagrams where appropriate.

i. Hf^{4+} ion sitting on a Zr^{4+} site.

ii. Cl^- ion vacancy.

iii. Cl^- ion in an interstitial site.

iv. Frenkel defect formation in MgO crystal.

v. Schottky defect formation in TiO_2 crystal. (25 marks)

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c) *"Schottky defects will decrease the density of materials whereas the Frenkel defects will not"*

Substantiate the above statement. (05 marks)

d) Briefly discuss the planar defects and bulk defects of crystals (10 marks)

4) a) What are dislocations in metals? (04 marks)

b) *"Plastic deformation of metals takes place most commonly by the slip process, involving the movement of dislocations"*

Substantiate the above statement (10 marks)

c) Define a "slip system" in crystalline materials. (04 marks)

d) What are the **TWO** important factors that determine the most likely slip systems in metals? (04 marks)

e) The metal Polonium (Po) crystallizes in Simple Cubic structure. Determine all the possible slip systems in Polonium. (20 marks)

f) Explain in detail why Polonium is a brittle metal. (08 marks)

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