

Uva Wellassa University, Sri Lanka  
Faculty of Science and Technology  
Science and Technology Degree program  
2<sup>nd</sup> Semester Examination - September 2013



SCT 343-2 Functional Properties of Materials

Instructions to candidates

Answer Four (04) questions only

Number of questions: Five (05)

Time allocation: Two (02) hours

Total marks allocated: 100

1.
  - a. What does it mean by the *electrical property of a material*?
  - b. When considering the electron energy band structures of materials, what type(s) of atomic bonding are expected to be in metals, semiconductors and insulators? Explain the answer briefly.
  - c. Make a rough sketch to show the characteristic *electron energy band structures* for a metal.
  - d. State the expression showing the relationship between the applied electric field intensity (E) and the established drift velocity ( $V_d$ ) for a material kept under an electric field.
  - e. If the room temperature electrical conductivity of intrinsic indium antimony (InSb) is  $6.77 \times 10^{-4} \text{ Scm}^{-1}$ , calculate its intrinsic carrier concentration. The room temperature electron and hole mobilities of InSb are 7900 and 3900  $\text{cm}^2 \text{ V}^{-1}\text{s}^{-1}$ , respectively. The magnitude of the charge of an electron is  $1.6 \times 10^{-19} \text{ C}$ .

(25 Marks)
2.
  - a. What is the main technique used to increase the electrical conductivity of semiconductors?
  - b. Consider the case of controlled addition of an impurity boron (B) atom to a pure intrinsic silicon (Si) structure. With the help of a schematic representation, explain the formation of an acceptor energy state in this p-type extrinsic semiconductor.

- c. If  $9.8 \times 10^{16} \text{ cm}^{-3}$  of impurity boron atoms were added to this pure silicon structure, calculate the electrical conductivity of this extrinsic semiconductor. The electron mobility and the magnitude of the electron charge is  $1880 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$  and  $1.6 \times 10^{-19} \text{ C}$ , respectively.
- d. Make a rough sketch to explain the temperature dependence of the *carrier concentration* of an extrinsic semiconductor. Label the *freeze-out temperature region*, *extrinsic temperature region* and *intrinsic temperature region* in this sketch.
- e. What are the two main carrier constituents found in an ionic conductor? Write down the expression for the *total conductivity* of an ionic conductor.

(25 Marks)

- 3.
  - a. Define the term *capacitance* of a capacitor terminology.
  - b. Briefly explain the polarization mechanism, which occurs in all materials.
  - c. A parallel plate capacitor of  $7.5 \text{ cm}^2$  area and  $0.025 \text{ cm}$  plate separation is connected to  $12 \text{ V}$  supply. If a piece of a dielectric material with a dielectric constant of  $30,000$  is inserted between the plates, calculate the capacitance and the polarization.
  - d. Make a rough sketch to show the expected variation of the dielectric constant with frequency, for a dielectric material showing all three types of dielectric polarizations.
  - e. What type of a functional material is used in transducers?

(25 Marks)

- 4.
  - a. Electromagnetic radiation is composed of two field components. Name these two components.
  - b. Calculate the energy contained in a photon of yellow light having a wavelength of  $580 \text{ nm}$ . The velocity of light in vacuum is  $3 \times 10^8 \text{ m/s}$  and Plank's constant is  $4.13 \times 10^{-15} \text{ eVs}$ .

- c. With the help of a schematic representation of electron energy band structure, briefly explain the mechanisms responsible for the color of metals.
- d. Based on that, explain the reason for metallic gold to appear in the characteristic yellow color.
- e. If a light beam from vacuum incidents perpendicularly to a solid having a refractive index of 1.75, compute the reflectivity (R) at the interface.

(25 Marks)

5.

- a. Write down the wavelength values corresponding to the violet and red colors of the visible light.
- b. If the maximum and minimum energy values carried by the visible light are given as 3.1 and 1.8 eV, respectively, also the band gap energies for diamond, sulfur and silicon materials are given as 5.4 eV, 2.6 eV and 1.1 eV, respectively. Explain briefly which of these materials appear colored, opaque and transparent under the visible light.
- c. The fraction of non-reflected radiation that is transmitted through a 68 mm thickness of a transparent material is 0.75. If the thickness is increased to 122 mm, what fraction of light will be transmitted?
- d. Make a rough sketch to show the cross section of a typical *optical fiber* and explain the main role of the *core*, *cladding* and *coating*.
- e. Name the optical mechanism responsible for confining the light to within the fiber core in optical fibers.

(25 Marks)