VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA NEW ZEALAND

XMUT204 Electronic Design

Assignment 1: Introduction to Semiconductor

Total 90 marks.

1. It is given that Copper has 8.5 x 10^{22} conduction electrons per cm^3 and the mobility of a conduction electron is 35 $cm^2.V^{-1}.s^{-1}$ (consider that temperature is at 300°K).

   a. Calculate the conductivity of Copper. [5 marks]

   b. In an electronics project, you need to construct your own inductor. The instruction for making this inductor is to wind it from a 1.2 meters length of #20 AWG (American wire gauge) copper wire.

      i. How thick is this wire in mm (i.e. find its radius) ? [5 marks]

      ii. What will be the resistance of your inductor? [5 marks]

2. Calculate the conductivity of a piece of pure Silicon if it is given the number of intrinsic carriers at 300°K is 1 x 10^{10} cm^{-3} and that the electron and hole mobilities are μ_e = 1350 $cm^2.V^{-1}.s^{-1}$ and μ_h = 450 $cm^2.V^{-1}.s^{-1}$. [5 marks]

3. Conductivity of materials depends on the temperature.

   a. Compare the conductivities between Silicon and Copper at 300°K as calculated from Question (1) and (2) above. Give a reason for the cause of the result of your comparison. [5 marks]

   b. The temperature now increases to 350°K. Describe semi-quantitatively how and why the carrier concentration and the conductivity will change due to this temperature change for both these two materials. [5 marks]

4. A unit cell of the crystal structure of Silicon is in Figure 1 shown below. It is given that the side length of this unit cell is 0.54 nm.

   a. Calculate the number of Silicon atoms in one cm^3 (i.e. the density) of the material. [15 marks]

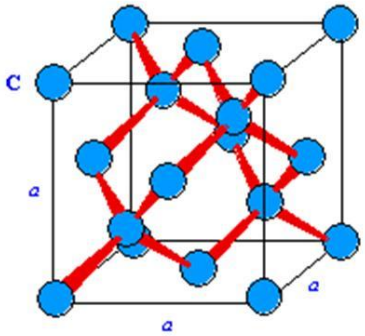

Figure 1: Silicon crystal structure

b. Another way to calculate the density is by looking at the macroscopic density. This is specified for Silicon to be 2.32 g.cm^{-3}. Calculate the number of Silicon atoms per cm^3 based on this information. [Hint: Your high school chemistry may help a bit here by making use of the Avagrado's number (6.022×10^{23} atoms/mole)] [10 marks]

c. A small Silicon wafer is 3 inches (76mm) in diameter and 300 µm thick. Calculate the number of Silicon atoms that should be contained in this wafer. [10 marks]

5. Silicon is doped by adding Arsenide atoms to a level of 5 x 10^{15} atoms/cm^3 of Arsenide (consider that temperature is at 300°K). Calculate:

   a. the concentration and type of majority and minority carriers. [5 marks]

   b. the conductivity of the Silicon. How does this conductivity compare to the conductivity values calculated in Questions (1) and (2). [5 marks]

6. Sketch the energy band diagram for a p-type semiconductor and indicate the expected position of mobile charge carriers in this diagram. [5 marks]

7. Explain the concepts of intrinsic – and extrinsic -carrier concentration in a semiconductor. [5 marks]

8. Germanium and Gallium Arsenide are two other common semiconductor materials. Obtain a value for the bandgap in each of these two semiconductors and compare that to the value of the bandgap in Silicon. What would you expect the value of the intrinsic carrier concentration to be for each of the two materials? [5 marks]

9. Describe the steps required in microfabrication of semiconductor devices. [2.5 marks]

10. Draw and describe the semiconductor layer structures of conventional diode, BJT and MOSFET transistors. [7.5 marks]

Marking Schedule

Student ID : _____

Student Name : _____

No	Description	Mark	Your Mark	Remarks
1	a. Conductivity of Copper.	5		
	b(i). Thickness of wire.	5		
	b(ii). Resistance of inductor.	5		
2	Conductivity of pure Silicon.	5		
3	a. Comparison of conductivity and reasoning of the result of comparison.	5		
	b. Description of how and why carrier concentration and conductivity change as temperature increases.	5		
4	a. Number of Silicon atoms.	15		
	b. Number of Silicon atoms by microscopic density method.	10		
	c. Number of atoms in Silicon wafer.	10		
5	a. Concentration and type of majority and minorities carriers	5		
	b. Conductivity of Silicon and its comparison with results in questions (1) and (2).	5		
6	Sketch of energy band and indicated expected position of mobile carriers in the diagram.	5		
7	Description of intrinsic and extrinsic carrier concentration in a semiconductor.	5		
8	Values of bandgaps and values of intrinsic carrier concentration.	5		

9	Steps in microfabrication of semiconductor devices.	2.5		
10	Sketch and brief description of layer structures of conventional diode, BJT and MOSFET.	7.5		
	Total			

Comment: