GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY
Faculty of Engineering
Department of Electrical, Electronic and Telecommunication Engineering

BSc Engineering Degree
Semester 4 Examination – December 2015
(Intake 31 - ET)

ET 4082 – SEMICONDUCTOR & SOLID STATE DEVICES

Time allowed: 2 hours

INSTRUCTIONS TO CANDIDATES

This paper contains 4 questions on 5 pages

Answer all questions only.

This is a closed book examination

This examination accounts for 80% of the module assessment. A total maximum mark obtainable is 100. The marks assigned for each question and parts thereof are indicated in square brackets

If you have any doubt as to the interpretation of the wordings of a question, make your own decision, but clearly state it on the script

Assume reasonable values for any data not given in or provided with the question paper, clearly make such assumptions made in the script

All examinations are conducted under the rules and regulations of the KDU

46

Q1)

A Silicon ingot is sawed into wafers after which additional structure is patterned on the substrate using various techniques before finally producing the semiconductor device. The main technique for constructing the patterns on the substrate is photolithography.

I. What is the task fulfilled by photoresist in the photolithography process? Explain the two types of photoresist used in photolithography and the two techniques of etching used to remove photoresist. [5 marks]

II. Describe the photolithographic steps involved in creating a small n-doped region in a pure Silicon substrate. Use diagrams to explain the steps. [10 marks]

III. List and compare three different diode fabrication structures. The comparison should include simple explanatory diagrams of the three structures and a discussion of advantages and disadvantages of each structure. [5 marks]

IV. Calculate the Atomic Packing Factors for FCC and BCC lattices. [5 marks]

Q2)

I. Calculate the de Broglie wavelength of a 50kg rock travelling at $100ms^{-1}$. Compare that value to the de Broglie wavelength of an electron travelling at half the speed of light. [5 marks]

II. A photo-emissive metal has a threshold wavelength of 500nm. Calculate the threshold frequency, work function of the metal and the maximum speed of electrons emitted by light of 100nm wavelength.
Could the metal be used to distinguish between red light (700nm) wavelength and blue light (400nm wavelength) incident on it? Explain. [10 marks]

III. Define the conduction and the valence bands of a solid? Through a diagram, depict the relative positioning of the valence and conduction bands for conductors, insulators and semiconductors. [5 marks]

IV. What is the difference between indirect band gap and direct band gap semiconductor materials? Gallium Nitride (GaN) has a direct band gap of 3.44eV. Calculate the wavelength of light emitted by GaN based LEDs. [5 marks]

48

Q3)

I. What is an extrinsic semiconductor material? Give the two types of extrinsic semiconductors along with possible dopant elements used to construct each of them. What are the majority current carriers in each of the two type semiconductor materials? Draw the energy band diagrams for each clearly indicating the Fermi Level in each case. [5 marks]

II. The two different types of extrinsic semiconductor materials are joined to form the p-n junction. Explain the processes involved in achieving the dynamic equilibrium within a p-n junction. Use diagrams as needed. [5 marks]

III. Draw the energy band diagrams for an npn transistor ,

a. under equilibrium
b. when the transistor is biased into operating in the active region.

Explain how the conduction of carriers occurs through the transistor in the active region of operation. What are the majority carriers in this case? [10 marks]

IV. Define the Fermi Level of a solid material. The Fermi Level of a certain solid is 10eV. Calculate the probability of finding an electron with energy greater than or equal to 10eV in this solid at 300K. [5 marks]

Use : $\frac{d}{dx}\left\{\frac{\ln(1+e^{-kx})}{(-k)}\right\} = \frac{1}{1+e^{kx}}$

Q4)

I. What are the three modes of operation of a MOSFET? Give the operating conditions for each mode. [5 marks]

A transconductance amplifier operates by amplifying an input voltage producing an output current.

II. Explain how the MOSFET can be used as a transconductance amplifier using operating conditions and equations. In which mode does the transistor operate when used as an amplifier? Is the amplification linear? Use equations to explain. [5 marks]

III. What is the process used to construct the oxide layer in a MOSFET? What is the purpose of the oxide layer? When handling MOSFETs, special care must be taken against electrostatic discharge. Explain the reason and the remedy for this vulnerability. [5 marks]

IV. MOSFETs have numerous advantages over BJTs especially when used in digital electronic circuitry. Discuss by appealing to the fabrication, operating characteristics and other properties of MOSFETs. [5 marks]

V. A certain MOSFET, named A, is used in a circuit for transconductance amplification but the current produced at the input voltage level turns out to be far too small for the given application. Hence using a different MOSFET, named B, with different internal dimensions is proposed. Using mathematical relationships you know, explain what changes in dimensionality you would expect in MOSFET B relative to MOSFET A. [5 marks]

<u>Physical Constants</u>

Mass of electron : 9.1094×10^{-31} kg

Charge of electron : 1.6022×10^{-19} C

Speed of light : 3×10^{8} ms^{-1}

Boltzmann Constant : 1.3807×10^{-23} $m^2kgs^{-2}K^{-1}$

Planck's Constant : 6.6261×10^{-34} m^2kgs^{-1}

50