UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRONIC ENGINEERING

MAIN EXAMINATION JUNE 2006

TITLE OF PAPER: ELECTRONIC MATERIALS & DEVICES II

COURSE NUMBER: E450

TIME ALLOWED : THREE HOURS

INSTRUCTIONS TO CANDIDATES:

ANSWER ANY FOUR QUESTIONS. ALL CARRY EQUAL MARKS

USEFUL DATA ND FORMULAE ARE ATTACHED.

THIS PAPER IS NOT TO BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

Question One.

(a) (i) Explain what is meant by Base-width modulation in a transistor. (3 marks)

(ii) Discuss the effects of base- width modulation in the performance of a real p-n-p transistor in normal operation.
(6 marks)

(b) The punch through voltage of a germanium p-n-p transistor is 25V. The base doping is 10^{15} cm^{-3}. The emitter and collector dopant concentrations are 10^{19} cm^{-3} each. Calculate:

(i) The built-in voltage (2 marks)

(ii) the zero bias base width (4 marks)

(iii) the common emitter current gain β and (8 marks)

(iv) the common base current gain α for a reverse bias of 10 V across the collector-base junction. (2 marks)

Assume $\tau_B = 10^{-6}$s , n_i for Ge = 2.4×10^{13} cm^{-3} T= 300 K and

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Question Two.

(a) A small signal ac voltage is superimposed on the dc bias of a p-n-p diffusion transistor in the normal operation. Neglecting the depletion region charges show that the small signal common base current gain of the transistor can be written as: $\alpha(\omega) = \dfrac{\alpha_0}{1+\dfrac{j\omega}{\omega_\alpha}}$

where symbols have their usual meanings.

(9 marks)

Hints: $I_E = \dfrac{dQ_N}{dt} + Q_N\left(\dfrac{1}{\tau_N} + \dfrac{1}{\tau_{BN}}\right)$, $I_C = -\dfrac{Q_N}{\tau_N}$

(b) Given that the beta cut - off frequency $f_\beta = f_\alpha(1-\alpha_0)$, show that the common emitter current gain can be expressed as:

$$\beta(\omega) = \frac{\beta_0}{1+\dfrac{jf}{f_\beta}}$$

(7 marks)

(c) (i) A transistor operating at 20 MHz has current gain $\beta = 20$. Neglecting junction capacitance and series resistance, calculate:

(1) the beta cut-off frequency f_β (4 marks)
(2) the alpha cut - off frequency f_α (3 marks)
(3) the gain bandwidth frequency f_T (2 marks)

[Given that $\beta_0 = 100$]

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Question Three.

(a) The current - voltage (I-V) characteristics of a JFET is given as:

$$I_D = G_0\left\{V_D - \frac{2}{3}V_P\left[\left(\frac{V_i - V_G + V_D}{V_P}\right)^{3/2} - \left(\frac{V_i - V_G}{V_P}\right)^{3/2}\right]\right\}$$

Simplify this expression to show that the drain conductance of the JFET,

$$G_D = G_0\left[1 - \left(\frac{V_i - V_G}{V_P}\right)^{1/2}\right]$$

(7 marks)

(b) The pinch - off voltage of an n – channel JFET is 3.5 V and the built - in voltage of the gate - channel junction is 0.8 V. The JFET is being used as a controlled load when it is operating in saturation. The gate is grounded.

(i) Determine the drain voltage $V_{Dsat.}$ (3 marks)

(ii) Assuming $G_0 = 1.44 \times 10^{-2}$ A/V, and using the I-V relation above, find the drain current. (5 marks)

(iii) What is the value of the load resistance? (2 marks)

(c) (i) Draw the schematic diagram of a GaAs MESFET and state briefly how the device is fabricated. (4 marks)

(ii) Explain how a MESFET operates in depletion mode and enhancement mode. (4 marks)

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Question Four.

(a) Discuss the important features of the ***Solid State Diffusion technique*** for preparation of p-n junctions. (8 marks)

(b) (i) State what is meant by epitaxial growth of materials. (2 marks)

(ii) With the help of a schematic diagram describe the molecular beam epitaxy method for growing doped AlGaAs layers on GaAs.

Mention its advantage over diffusion technique

(9 marks)

(c) (i) What are integrated circuits? (2 marks)

(ii) Distinguish between monolythic and hybrid integrated circuits. (4 marks)

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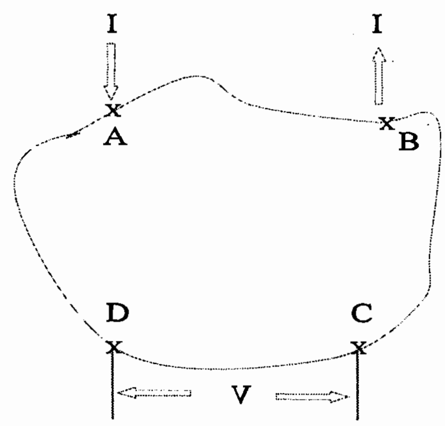
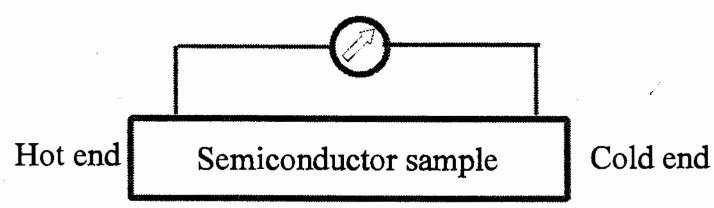
Question Five.

(a) The following data were obtained in a Van der Pauw measurement of resistivity of an arbitrary shaped p- type silicon sample of thickness 0.15 mm as shown in figure. If $V_{DC} / I_{AB} = 100$ ohms and $V_{BC} / I_{AD} = 20$ ohms, find the resistivity and sheet resistance of the sample. (see appendix A for correction factor) (9 marks)



(b) (i) Following is a sketch of the hot probe set up to find the semiconductor type. State with reason whether the sample is n or p type. (4 marks)



(ii) The hot probe method cannot be used for all semiconductors. Comment. (2 marks)

(c) (i) Draw the schematic set up of the Photoconductivity decay method for finding the minority carrier life time of a semiconductor. (5 marks)

(ii) Calculate the carrier life time of a sample in the above experiment from the following data. (5 marks)
Constant current supplied to the sample = 1 mA.
Resistance of the sample before illumination = 120 Ω
Resistance of the sample after illumination = 100 Ω
Time constant of the voltage decay from the oscilloscope = 0.5 μs

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APPENDIX C

Some useful equations.

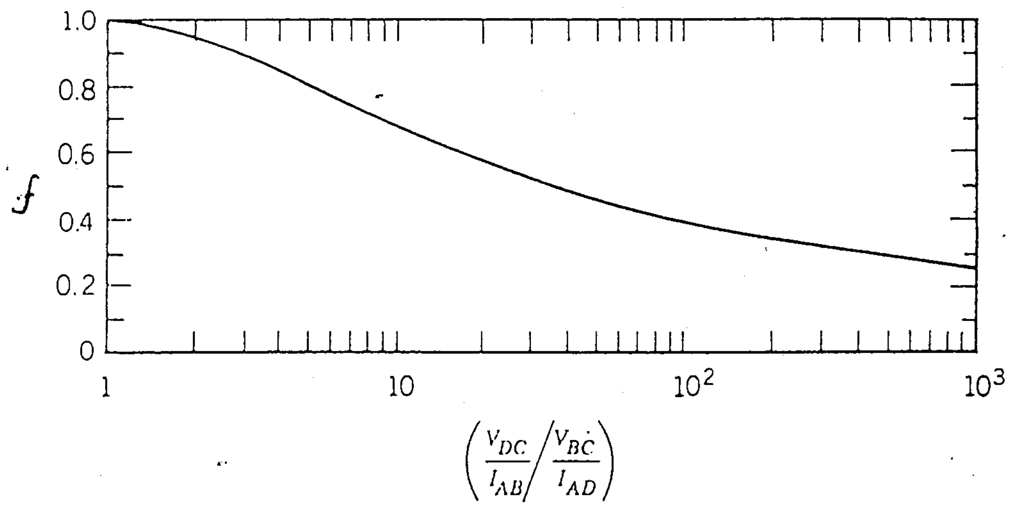
$$I_D = G_0\left\{V_D - \frac{2}{3}V_P\left[\left(\frac{V_i - V_G + V_D}{V_P}\right)^{3/2} - \left(\frac{V_i - V_G}{V_P}\right)^{3/2}\right]\right\}$$

$$f_{\max} = \left[\frac{f_T}{8\pi r_B C_c}\right]^{1/2}$$

$$\rho = \frac{\pi d}{2\ln 2}\left(\frac{V_{DC}}{I_{AB}} + \frac{V_{BC}}{I_{AD}}\right)f$$

$$W_B = W_{B0} - \left[\frac{2\varepsilon_S}{qN_d}(V_i - V_{CB})\right]^{1/2}$$

APPENDIX A



Correction factor for van der Pauw arrangement.

APPENDIX B
PHYSICAL CONSTANTS

Quantity	Symbol	Value
Angstrom unit	Å	1 Å = 10^{-8} cm = 10^{-10} m
Avogadro number	N	6.023×10^{23}/mol
Boltzmann constant	k	8.620×10^{-5} eV/K = 1.381×10^{-23} J/K
Electronic charge	q	1.602×10^{-19} C
Electron rest mass	m_o	9.109×10^{-31} kg
Electron volt	eV	1 eV = 1.602×10^{-19} J
Gas constant	R	1.987 cal/mole-K
Permeability of free space	μ_o	1.257×10^{-6} H/m
Permittivity of free space	ε_o	8.850×10^{-12} F/m
Planck constant	h	6.626×10^{-34} J-s
Proton rest mass	m_p	1.673×10^{-27} kg
$h/2\pi$	$\hbar$	1.054×10^{-34} J-s
Thermal voltage at 300 K	V_T	0.02586 V
Velocity of light in vacuum	c	2.998×10^{10} cm/s
Wavelength of 1-eV quantum	λ	1.24 μm