UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 2003/2004

September/Oktober 2003

EBB 424E/3- Peranti Semikonduktor dan Optoelektronik

Masa: 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH muka surat beserta SATU muka surat (Lampiran) yang bercetak sebelum anda memulakan peperiksaan.

Kertas soalan ini mengandungi TUJUH soalan.

Jawab LIMA soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.

Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru.

Jawab semua soalan dalam Bahasa Malaysia kecuali soalan 1, 2, 3 dan 4 jawab dalam Bahasa Inggeris.

...2/-

1. [a] What are the requirements for the switching operations of a BJT?

(10 marks)

[b] Derive the expression for the switching time during the turn-on state and determine the conditions to minimize it.

(60 marks)

[c] A BJT in common-emitter circuit has a collector saturation current of 200 mA, a base transit time of 0.5 μs and a base minority carrier life-time of 30 μs. Find the switch on time t_s for a base current step increase from zero to (a) 4 mA and (b) 10 mA.

(30 marks)

1. [a] Apakah keperluan bagi operasi pensuisan bagi BJT?

(10 markah)

[b] Terbitkan ungkapan bagi masa pensuisan semasa keadaan merangsang dan tentukan syarat untuk meminimumkannya.

(60 markah)

[c] BJT dalam litar umum-pemancar mempunyai arus tepu pengumpul ialah 200 mA, masa tapak singgah 0.5 μs dan masa hayat pembawa majoriti tapak ialah 30 μs. Kira masa pensuisan bagi langkah arus tapak meningkat dari sifar ke (a) 4 mA dan (b) 10 mA.

(30 markah)

...3/-

2. [a] Discuss the small signal ac models for a JFET before and after pinch-off where $I_{DS} = G_o[V_{DS} + 2V_p/3 \{(V_{GS}/V_p - V_{DS}/V_p)^{3/2} - (V_{GS}/V_p)^{3/2} \}]$ and $I_{DS(sat)} = I_{DSS} (1 - V_{GS}/V_p)^2$

Where I_{DS} = drain to source current

G_o = channel conductance

V_{DS} = drain to source voltage

V_p = pinch-off voltage

V_{GS} = gate to source voltage

Provide sketches of the corresponding equivalent circuits.

(70 marks)

[b] Find the mutual conductance of a JFET in saturation with pinch-off voltage of –8V, a gate to source voltage of –4V if I_{DSS} is 20 mA. Find the small signal voltage gain if the load resistance is 1000Ω. Neglect the variation of g_m with V_{GS}.

(30 marks)

2. *[a] Bincangkan model isyarat ac kecil bagi JFET sebelum dan selepas jepitan di mana* $I_{DS} = G_o[V_{DS} + 2V_p/3 \{(V_{GS}/V_p - V_{DS}/V_p)^{3/2} - (V_{GS}/V_p)^{3/2} \}]$ *dan* $I_{DS(sat)} = I_{DSS} (1 - V_{GS}/V_p)^2$

Di mana I_{DS} = *arus salir ke sumber*

G_o = *kealiran saluran*

V_{DS} = *voltan salir ke sumber*

V_p = *voltan jerpitan*

V_{GS} = *voltan get ke sumber*

Sertakan lakaran litar yang sepadan.

(70 markah)

[b] Cari kealiran saling bagi JFET tepu dengan voltan jepitan -8V, voltan get ke sumber -4V jika beban rintangan ialah 1000 Ω. Abaikan variasi g_m *dengan* V_{GS}.

(30 markah)

...4/-

3. [a] Describe a MOS (metal oxide semiconductor) capacitor and explain the formation of accumulation and inversion layer for a n-type substrate. Draw the corresponding energy band diagrams.

(60 marks)

[b] Name the different basic MOSFET (metal oxide semiconductor field effect transistor) devices and explain the difference between the enhancement and depletion mode devices.

(40 marks)

3. *[a] Jelaskan kapasitor MOS (metal oxide semiconductor) dan terangkan pembentukan lapisan penumpukan dan lapisan songsangan bagi substrak jenis-n. Lukiskan gambarajah jalur tenaga.*

(60 markah)

[b] Namakan peranti asas MOSFET yang berbeza dan terangkan perbezaan antara peranti mod peningkatan dan mod susutan.

(40 markah)

...5/-

4. Write short notes:

(a) The explanation of an increase in collector current with increase in the base current of a BJT with the help of charge control model.

(50 marks)

(b) Qualitative description of pinch-off and saturation conditions for a n-channel JFET. Provide neat sketches of the depletion region and the corresponding current-voltage curves.

(50 marks)

4. *Tuliskan nota ringkas.*

(a) Dengan bantuan model kawalan cas, terangkan peningkatan dalam arus penggumpul dengan peningkatan arus tapak BJT.

(50 markah)

(b) Berikan penjelasan kuantitatif keadaan jepitan dan tepu bagi JFET saluran-n. Sertakan lakaran rantau susutan dan lengkungan (kurva) arus-voltan yang sepadan.

(50 markah)

...6/-

5. [a] (i) Why is the recombination process of indirect semiconductor not possible?

(20 marks)

(ii) What is the required condition to achieve population inversion in a semiconductor laser?

(20 marks)

(iii) What are LED and LASER application?

(10 marks)

[b] Explain two method can be taken to produced foton emission from indirect semiconductor material.

(50 marks)

5. *[a] (i) Mengapakah penggabungan semula sinaran tidak mungkin berlaku dalam semikonduktor tak terus?*

(20 markah)

(ii) Apakah syarat yang perlu dipatuhi untuk songsangan populasi berlaku?

(20 markah)

(iii) Apakah kegunaan LED dan LASER?

(10 markah)

[b] Terangkan dua langkah yang boleh diambil bagi menghasilkan pancaran dari bahan semikonduktor tak terus.

(50 markah)

...7/-

6. [a] Illustrate a typical LED structure and give the operation principle?

(40 marks)

[b] An AlGaAs LED emitter for use in a local optical fiber network has the output spectrum shown in Figure 1. It is designed for peak emission at 820 nm at 25°C.

(i) What is the linewidth $\Delta\lambda_{1/2}$ at temperatures –40°C, 25°C and 85°C?
(Δ (hc) $\approx 3k_BT$)

(ii) What is the band gap of AlGaAs in this LED?

(iii) The bandgap, E_g, of the ternary alloys Al_xGa_{1-x} as follow the empirical expression,
E_g (eV) = 1.424 + 1.266x + 0.266x^2

What is the composition of the AlGaAs in this LED?

(60 marks)

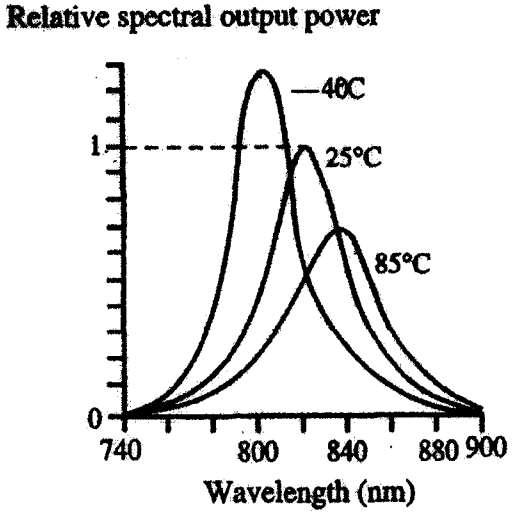


Figure 1. Output Spectrum for AlGaAs

...8/-

6. [a] *Lakarkan binaan struktur LED dan terangkan prinsip operasinya?*

(40 markah)

[b] *LED pemancar AlGaAs digunakan di dalam jaringan fiber optik menghasilkan spektrum seperti dalam Rajah 1. Ia telah direkabentuk supaya pancaran puncak adalah 820 nm pada 25°C.*

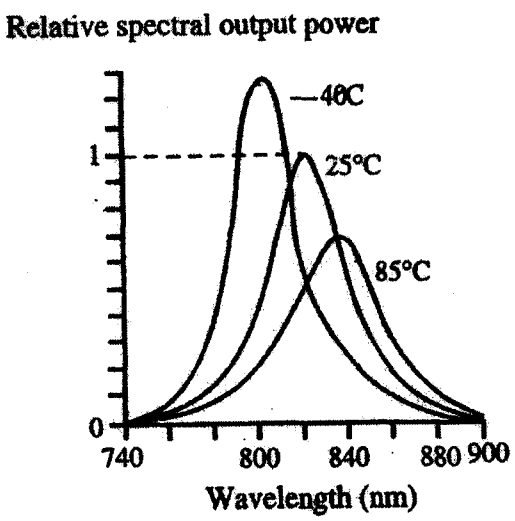
(i) *Apakah nilai lebar jalur $\Delta\lambda_{1/2}$ pada suhu –40°C, 25°C dan 85°C?*
(Δ (hc) $\approx 3k_BT$)

(ii) *Berapakah nilai jurang jalur E_g LED AlGaAs ini?*

(iii) *Jurang jalur, E_g, aloi ternari $Al_xGa_{1-x}As$, diberikan oleh persamaan empirikal berikut,*
E_g (eV) = 1.424 + 1.266x + 0.266x^2

Apakah komposisi LED AlGaAs ini?

(60 markah)



Rajah 1 : Spektrum Keluaran dari AlGaAs.

...9/-

7. [a] What happen to an electron and hole that are photogenerated in photodiode?

(30 marks)

[b] Consider a silicon p-n junction solar cell of area 2 cm^2. If the doping of the solar cell are

$N_A = 1.7 \times 10^{16}\ cm^{-3}$

$N_D = 5 \times 10^{19}\ cm^{-3}$

$\tau_n = 10\ \mu s$

$\tau_p = 0.5\ \mu s$

$D_n = 9.3\ cm^2/s$

$D_p = 2.5\ cm^2/s$

$I_L = 95\ mA$

$FF = 0.75$

(i) Calculate and plot the I-V characteristics of the solar cell.

(ii) Calculate the open-circuit voltage, V_{OC}.

(iii) Determine the maximum output power of the solar cell, all at room temperature.

(iv) What is the effect of temperature to the solar cell output.

(70 marks)

7. [a] *Apakah yang berlaku kepada elektron dan lohong yang terjana secara foto di dalam fotodiod?*

(30 markah)

[b] *Pertimbangkan sel suria simpangan p-n berkeluasan 2 cm^2. Jika pendop sel suria ialah*

$N_A = 1.7 \times 10^{16}\ cm^{-3}$

$N_D = 5 \times 10^{19}\ cm^{-3}$

$\tau_n = 10\ \mu s$

$\tau_p = 0.5\ \mu s$

$D_n = 9.3\ cm^2/s$

$D_p = 2.5\ cm^2/s$

$I_L = 95\ mA$

FF = 0.75

(i) *Kira dan plot ciri I-V bagi sel suria ini.*

(ii) *Kirakan nilai voltan litar-terbuka.*

(iii) *Tentukan output kuasa maksimum sel suria, semua pada suhu bilik.*

(iv) *Apakah kesan suhu terhadap keluaran sel suria?*

(70 markah)

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Physical constants

Constant	Symbol	Value
Boltzmanns constant	k	1.38×10^{-23} J/K $=8.62 \times 10^{-5}$ eV/K
Electronic charge	q	1.6×10^{-19} C
Electron volt	eV	1.6×10^{-19} C
Plank's constant	h	6.625×10^{-34} Js
Velocity of light	c	3×10^{8} m/s

Properties of Si at 300 K
$n_i = 1.5 \times 10^{10}$ cm^{-3}
$E_g = 1.12$ eV
$N_v = 1.04 \times 10^{19}$ cm^{-3}
$N_c = 2.8 \times 10^{19}$ cm^{-3}
$\varepsilon_r = 11.8$

Equation

Einstein relation
$D_p/\mu_p = D_p/\mu_p = kT/q$
$L = D^{1/2} \tau$

Intrinsic carrier concentration
$ni = (N_cN_v)^{1/2}\exp[-E_g/2kT]$

Current density
$J_n = qD_nn_p/L_n [\exp (qV/kT)-1]$
$J_p = qD_pn_n/L_p [\exp (qV/kT)-1]$

Forward current of pn diode
$I = I_0\{\exp(qV_a/kT) -1\}$
$I_0 = qA\{D_pn_n/L_p + D_nn_p/L_n)$

PN junction without bias
$V_{bi}=\{kT/q\}\ln(N_AN_D/n_i^2\}$
$W = [2\varepsilon V_{bi} N_D/qN_A(N_A + N_D)]$

PN junction with bias
$W=[2\varepsilon V_jN_A/qN_A(N_A+N_D)]^{1/2}$
$V_B=\varepsilon E_{crit.}^2/2qN_D$

Capacitance
$C_j=\varepsilon A/X_n$
$C_j=A[q\varepsilon N_AN_D/2V_j(N_A+N_D)]^{1/2}$
$C_s=\{Aq^2L_pP_{on}/kT\}\exp(qV_a/kT)$

Photogenerated current
$I_{ph} = qg_{ph}A(W+L_n+L_p)$