UNIVERSITI SAINS MALAYSIA

KSCP Semester Examination
Academic Session 2007/2008

June 2008

ZSC 546/4 – Semiconductor Devices
[Peranti-Peranti Semikonduktor]

Duration: 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **SEVEN** printed pages before you begin the examination.
*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **TUJUH** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

Instruction: Answer all **FOUR** questions. Students are allowed to answer all questions in Bahasa Malaysia or in English.

*[**Arahan**: Jawab semua **EMPAT** soalan. Pelajar dibenarkan menjawab semua soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

1. (a) Write short notes on:
[Tuliskan nota ringkas tentang:]

(i) Einstein Relation
[Perhubungan Einstein.]

(ii) Built-in potential in a linearly graded junction
[Keupayaan terbina dalam simpang tergred linear.]

(iii) Depletion capacitance
[Kapasitan susutan.]

(30/100)

(b)

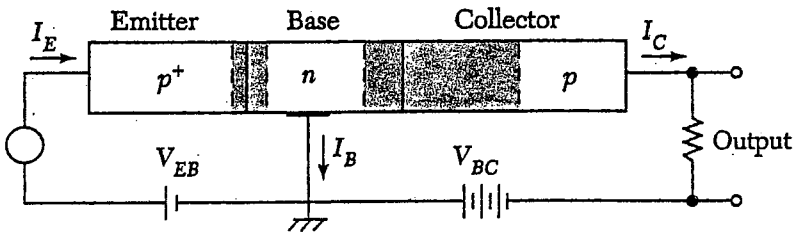

Figure 1 *[Rajah 1]*

Figure 1 shows a p^+-n-p bipolar transistor with the emitter-base junction forward biased and the collector-base junction reversed biased.
[Rajah 1 menunjukkan satu transistor dwikutub p^+-n-p dengan simpang pengeluar-tapak terpincang depan dan simpang pengumpul tapak terpincang songsang.]

Referring to this figure:
[Dengan merujuk kepada rajah 1:]

(i) Sketch the doping profile
[Lakarkan profil pendopan.]

(ii) Sketch the energy band diagram
[Lakarkan gambarajah jalur tenaga.]

(iii) Sketch the electric field profile
[Lakarkan profil medan elektrik.]

(40/100)

(c) Determine the n-type doping concentration to meet the following specifications for a Si p-n junction:
[Tentukan kepekatan pendopan bagi jenis-n untuk mematuhi spesifikasi bagi satu simpang Si p-n yang berikut:]

$N_A=10^{18}\ cm^{-3}$, $\mathcal{E}max= 4 \times 10^5$ V/cm at $V_R = 30$ V, T = 300 K.
[$N_A=10^{18}\ cm^{-3}$, $\mathcal{E}maks= 4 \times 10^5$ V/cm pada $V_R = 30$ V, T = 300 K.]

(30/100)

2. (a) Write down the equation for recombination rate for direct recombination in a direct-bandgap semiconductor and explain the meaning of each term in this equation.
[Tuliskan persamaan untuk kadar rekombinasi bagi kadar ekombinasi terus dalam satu semikonduktor dengan jurang tenaga terus dan jelaskan maksudnya setiap sebutan dalam persamaan ini.]

(30/100)

(b) Explain with the help of diagrams, the transistor action in the common-emitter configuration of a p-n-p transistor.
[Jelaskan dengan menggunakan gambarajah, tindakan transistor dalam satu transistor p-n-p dengan tatarajah pengeluar-sepunya]

(30/100)

(c) An ideal p^+-n-p transistor has impurity concentrations of 10^{19} cm^{-3},10^{17} cm^3, 5 x 10^{15} cm^{-3} in the emitter, base and collector regions, respectively. The corresponding lifetimes are 10^{-8} s, 10^{-7} s, and 10^{-6} s. Assume that an effective cross section area A is 0.05 mm^2 and the emitter-base junction is forward-biased to 0.6 V. The other device parameters are D_E = 1 cm^2/s, D_B = 10 cm^2/s, D_C = 2 cm^2/s, and W = 0.5 μm.
[Satu transistor p^+-n-p mempunyai kepekatan-kepekatan0^{19} cm^{-3}, 10^{17} cm^{-3}, 5 x 10^{15} cm^{-3} dalam kawasan-kawasan pengeluar, tapak dan pengumpul, masing-masing. Masa-hayat yang sepadan ialah 10^{-8} s, 10^{-7} s, dan 10^{-6} s. Anggapkan bahawa keratan rentas yang berkesan A ialah 0.05 mm^2 dan simpang pengeluar-tapak ialah terpincang depan 0.6 V. Parameter-parameter peranti yang lain ialah D_E = 1 cm^2/s, D_B = 10 cm^2/s, D_C = 2 cm^2/s, dan W = 0.5 μm.]

Find the common-base current gain of the transistor.
[Tentukan gandaan arus tapak-sepunya bagi transistor ini.]

(40/100)

3. (a) Write short notes on:
[Tuliskan nota ringkas tentang:]

(i) Base transport factor α_T of a p-n-p transistor.
[Faktor pengangkutan tapak α_T bagi satu transistor p-n-p.]

(ii) p-channel JFET (Junction Field Effect Transistor)
[JFET saluran-p (Junction Field Effect Transistor)]

(iii) MOSFET (Metal-Oxide-Semiconductor-Field-Effect Transistor)
[MOSFET (Metal-Oxide-Semiconductor-Field-Effect Transistor)]

(30/100)

(b)

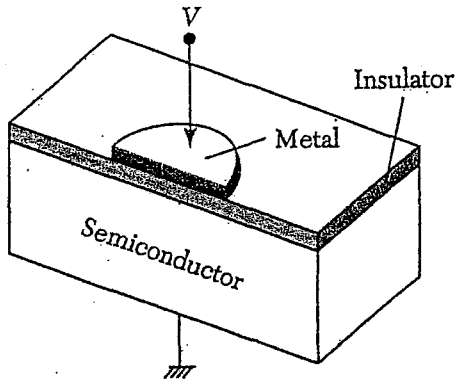

Figure 2(a) *[Rajah 2(a)]*

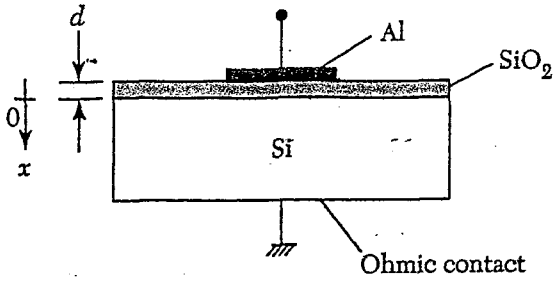

Figure 2(b) *[Rajah 2(b)]*

Figure 2(a) shows the perspective view of a MOS diode and
[Rajah 2(a) menunjukkan pandangan perspektif satu diod MOS dan]

Figure 2(b) the cross-section of a MOS diode.
[Rajah 2(b) menunjukkan keratan-rentas satu diod MOS.]

Sketch the energy band diagrams of the ideal MOS diode for the following conditions:
[Lakarkan gambarajah-gambarajah jalur tenaga untuk diod MOS unggul ini bagi syarat-syarat yang berikut:]

(i) V = 0 V
[V = 0 V]

(ii) accumulation case
[kes tumpukan]

(iii) depletion case
[kes susutan]

(iv) inversion case
[kes songsangan]

(40/100)

(c) For an ideal metal-SiO_2-Si diode having $N_A = 10^{17}$ cm^{-3}, calculate the maximum width of the surface depletion region.
[Bagi satu diod unggul logam-SiO_2-Si yang mempunyai $N_A = 10^{17}$ cm^{-3}, hitungkan kelebaran maksimum bagi kawasan susutan permukaan.]

(30/100)

4. (a) Write short notes on:
[Tuliskan nota ringkas tentang:]

(i) LED (Light Emitting Diode)
[LED (Light Emitting Diode).]

(ii) Threshold current density for laser
[Ketumpatan arus ambang bagi laser.]

(iii) Photoconductor
[Fotokonduktor.]

(30/100)

(b)

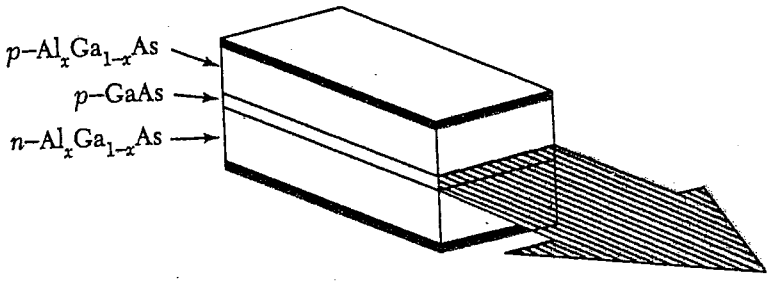

Figure 3 *[Rajah 3]*

Figure 3 shows a double-heterojunction (DH) laser. Explain, by using the principles of laser operation, how this device can produce laser light.
[Rajah 3 menunjukkan satu laser dwi-heterosimpang (DH). Jelaskan dengan menggunakan prinsip-prinsip operasi laser, bagaimana peranti ini boleh menghasilkan cahaya laser.]

(40/100)

(c) State three major differences between a photodiode and a solar cell.
[Nyatakan tiga perbezaan utama antara satu fotodiod dan satu sel suria.]
(30/100)

5. (a) Explain the principles of operation of a tunnel diode.
[Jelaskan prinsip-prinsip operasi bagi satu diod terowong.]
(30/100)

(b) Compare the performance of an IMPATT diode (IMPact ionization Avalanche Transit-Time) with the performance of a TED (Transferred-Electron Device).
[Bandingkan prestasi satu diod IMPATT (IMPact ionization Avalanche Transit-Time) dengan prestasi satu TED (Transferred-Electron Device).]
(30/100)

(c) The Czochralski technique is the most important technique to grow large silicon ingots, up to 30 cm in diameter. Sketch and label a diagram to show the Czochralski technique.
[Teknik Czochralski adalah teknik yang paling penting untuk mendapat jongkong-jongkong silikon, hingga diameter 30 cm. Lakarkan dan labelkan satu gambarajah yang menunjukkan teknik Czochralski.]
(40/100)

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