UNIVERSITI SAINS MALAYSIA

KSCP Semester Examination
Academic Session 2007/2008

June 2008

ZCC 543/4 – Semiconductor Physics
[Fizik Semikonduktor]

Duration: 3 hours
[Masa : 3 jam]

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

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

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

Answer all the 5 questions
Jawab kesemua 5 soalan

1. (a) Given that the group velocity of an electron wave in a periodic potential of a crystal as $v_g = \frac{\partial \omega}{\partial \mathbf{k}}$. Derive an expression for the force acting on the electron near the conduction band edge in terms of its momentum (or wave vector $\mathbf{k}$) in a given crystal direction under an applied electric field $\mathcal{E}$.
[Diberikan halaju kumpulan bagi gelombang elektron dalam keupayaan berkala hablur sebagai $v_g = \frac{\partial \omega}{\partial \mathbf{k}}$ *.Terbitkan ungkapan bagi daya yang bertindak ke atas elektron dekat tepi jalur konduksi dalam sebutan momentum nya (atau vektor gelombang* $\mathbf{k}$*) dalam suatu arah hablur tertentu di bawah pengaruh medan elektrik* $\mathcal{E}$*.]*

(50/100)

(b) It is known that in Si, the lowest minimum of the conduction band is anisotropic whereby the dispersion relation $E(k)$ can be expressed as in the following relationship:
[Diketahui bagi Si, minimum terendah jalur konduksi adalah takisotropik di mana hubungan dispersi $E(k)$ *dapat dinyatakan dengan perhubungan berikut:]*

$$E_n(k) = E_c + \frac{\hbar^2}{2}\left(\frac{k_l^2}{m_l} + \frac{k_t^2}{m_t}\right)$$

Sketch the likely shape of the constant-energy surface for electrons in the first Brillouin zone as represented by the $E(k)$ and provide a brief account of this on the electron transport properties in Si.
[Lakarkan bentuk yang mungkin bagi permukaan tenaga-tetap elektron dalam zon Brillouin pertama seperti yang diwakilkan oleh $E(k)$ dan berikan penjelasan ringkas mengenainya terhadap sifat-sifat pengangkutan elektron dalam Si.]

(50/100)

2. (a) With suitable illustrations, distinguish a Schottky defect from a Frenkel defect. Explain how the effect of temperature on the equilibrium concentration of these defects.
[Dengan penjelasan dan gambarajah, bezakan suatu kecacatan Schottky dari kecacatan Frenkel. Terangkan bagaimana kesan suhu terhadap kepekatan keseimbangan bagi kecacatan-kecacatan ini.]

(50/100)

(b) Describe with the aid of a diagram on how an edge dislocation could form a positively charged space-charge region in a semiconductor and the effects of its electronic states on the carrier mobility and conductivity of the semiconductor.
[Jelaskan dengan bantuan rajah bagaimana kehelan tepi boleh membentuk kawasan ruang-cas bercas positif dalam suatu semikonduktor dan kesan-kesan keadaan elektronik nya terhadap mobiliti pembawa dan kekonduksian semikonduktor.]

(50/100)

3. (a) The electron concentration in the conduction band of a non-degenerate semiconductor can be expressed as:
[Kepekatan elektron dalam jalur konduksi bagi semikonduktor tak-degenerat dapat dinyatakan sebagai:]

$$n = N_c \exp\left(-\frac{E_c - E_F}{kT}\right),$$

with *[dengan]*

$$N_c = 2\left(2\pi m_e^* kT/h^2\right)^{3/2} M_c$$

Derive the expression for the intrinsic carrier concentration n_i as a function of temperature T and give comment on the plot of $\ln n_i$ versus $1/T$.
[Terbitkan ungkapan bagi kepekatan pembawa intrinsik n_i sebagai fungsi suhu T *dan berikan komen terhadap plot* $\ln n_i$ *lawan* $1/T$*.]*

(60/100)

(b) Intrinsic semiconductor material A has an energy gap of 0.35 eV while material B has an energy gap of 1.12 eV. Compare the intrinsic densities of carriers in these two semiconductors at 300 K. Assume that the effective masses of all the electrons and holes are equal to the free electron mass.
[Bahan semikonduktor intrinsik A mempunyai jurang tenaga 0.35 eV dan bahan B mempunyai jurang tenaga 1.12 eV. Bandingkan ketumpatan intrinsik pembawa bagi dua semikonduktor ini pada 300 K. Anggap jisim berkesan bagi semua elektron dan lubang adalah bersamaan jisim elektron bebas.]

[$e=1.602\times10^{-19}$ C, $k=8.617\times10^{-5}$ eV K^{-1}]

(40/100)

4. (a) By taking a uniform n-type semiconductor, describe how the direct generation and recombination of minority carriers occurs under the perturbation of an incident light with the generation rate G_L. Show that the concentration of minority carrier in the process after the light is turned off at $t = 0$ is given by:
[Dengan mempertimbangkan suatu semikonduktor seragam jenis-n, jelaskan bagaimana generasi dan rekombinasi terus pembawa minoriti berlaku di bawah pengaruh sinaran cahaya dengan kadar generasi G_L. Tunjukkan bahawa kepekatan pembawa minoriti dalam proses ini selepas cahaya dimatikan pada $t = 0$ diberikan oleh:]

$$p_n(t) = p_{no} + \tau_p G_L e^{-t/\tau_p}$$

Discuss the effect of traps and high dopant concentration on the minority carrier lifetime and its implication on device operation like a p-n junction.
[Bincangkan kesan perangkap dan kepekatan pendopan tinggi ke atas masahayat pembawa minoriti dan implikasi nya terhadap operasi peranti seperti simpang p-n.]

(60/100)

(b) A Si specimen at 300 K is doped with $5\text{x}10^{14}$ P atoms/cm^3. A light source has been injecting minority carriers into the specimen in the rate of 10^{15} carriers/(cm^3.s) over a period of time long enough to reach steady state. At $t = 0$, the light is deactivated. If the minority carrier lifetime is 10 μs, at what time is the minority carrier concentration 10% above the equilibrium concentration of the sample?
[Suatu spesimen Si pada 300 K didopkan dengan $5x10^{14}$ P atom/cm^3. Suatu punca cahaya menyucuk pembawa minoriti ke dalam spesimen pada kadar 10^{15} pembawa*/(cm^3.s) dalam tempoh masa cukup lama bagi mencapai keadaan mantap. Pada $t = 0$, cahaya tersebut dimatikan. Jika masahayat pembawa minoriti adalah 10 μs, apakah masa diambil bagi kepekatan pembawa minoriti mencapai kepekatan 10% di atas kepekatan keseimbangan bagi sampel?]*

[$n_i = 1.5\text{x}10^{10}$ cm^{-3}]

(40/100)

5. Write short notes on two of the following topics:
[Tuliskan catatan ringkas bagi dua dari tajuk-tajuk berikut:]

(a) Hot electrons and its effect on the scattering process in semiconductors
[Elektron panas dan kesan nya terhadap proses serakan dalam semikonduktor]

(b) Electronic states in quantum wires
[Keadaan-keadaan elektron dalam wayar kuantum

(c) Optical properties of quantum wells
[Sifat-sifat optik bagi telaga kuantum]

(100/100)

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