TERJEMAHAN

UNIVERSITI SAINS MALAYSIA

Third Semester Examination
2002/2003 Academic Session

April 2003

ZAT 389E/3 – Low-Dimensional Semiconductor Structures

Time : 3 hours

Please check that the examination paper consists of **EIGHT** printed pages before you commence this examination.

Answer any FOUR questions only. Students are allowed to answer all questions in English OR Bahasa Malaysia OR combinations of both.

1. (a) The lowest energy band for nearly free electrons in a crystal can be represented by

$$E(k) = \frac{1}{2} W(1 - \cos ka)$$

where k is the wave vector, W is the full width energy of the band in the first Brillouin zone and a is the lattice constant.

(i) Draw the energy band in the first Brillouin zone.

(ii) Determine an expression for the effective mass throughout the band.

(iii) Show that a broad band gives a small effective mass.

(50/100)

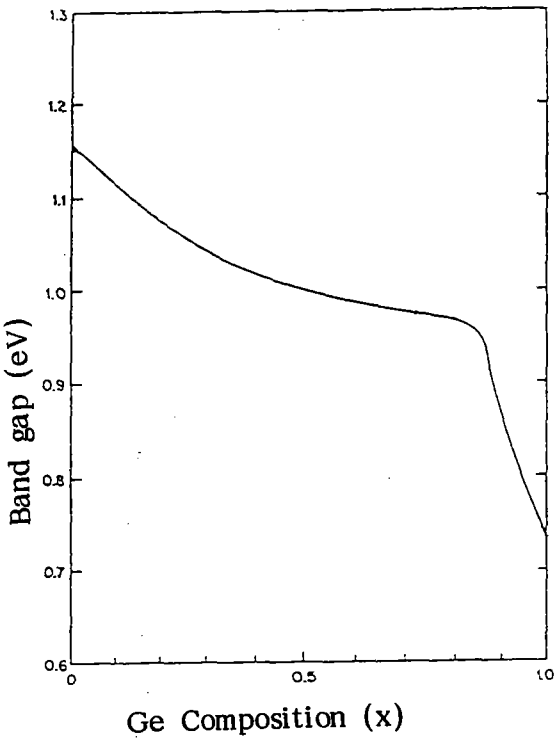
(b) Explain the physical meaning of the term monolayer in the zinc-blende structure.

(20/100)

(c) Sketch the energy band diagrams of Si and GaAs in the wave vector directions of [111] and [110]. Discuss the important features of each band and their differences.

(30/100)

2. (a) Figure below shows the dependence of the band gap of unstrained $Si_{1-x}Ge_x$ alloys as a function of the Ge fraction.



(i) Discuss the behaviour of the conduction band minima as the Ge composition increases.

(ii) Sketch a curve that represents the band gap of strained $Si_{1-x}Ge_x$ alloys as a function of x with respect to the unstrained band gap.

(50/100)

(b) Consider a metal forming an interface with a n-type semiconductor. Using suitable band diagrams describe the possible contacts that can be formed at the interface by considering the work functions of the metal and the semiconductor.

(50/100)

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3. (a) (i) Discuss the important criteria that must be fulfilled in order to grow ideal heterostrucures.

(ii) Discuss the effects on electronic properties if these criteria are not satisfied.

(20/100)

(b) The respective lattice constants of GaSb and InSb are 0.610 nm and 0.648 nm. Use Vegard's law to draw the variation in lattice constant with x for $Ga_xIn_{1-x}Sb$ alloys.

(30/100)

(c) (i) Define Anderson's rule for the alignment of energy bands at a heterojunction.

(ii) Discuss the types of band alignments between two semiconductors and give example for each case. Include in your discussions the possibility of trapping electrons and holes.

(50/100)

4. (a) Explain how a one-dimensional parabolic potential well can be created experimentally in heterostructures of GaAs-AlGaAs.

(30/100)

(b) The solutions for bound states of an electron in a square well with width a and finite depth V_o are given by

$$\begin{Bmatrix} \tan \\ -\cot \end{Bmatrix} \theta = \sqrt{\frac{mV_o a^2}{2\hbar^2}\frac{1}{\theta^2} - 1} \equiv \sqrt{\frac{\theta_o^2}{\theta^2} - 1}$$

where $\theta = ka/2$, m and k are the mass and wave vector of the electron, respectively.

(i) Explain clearly with the aid of a suitable graph the steps required to solve the above equation.

(ii) Determine the number of solutions if a = 10 nm, V_o = 0.3 eV and $m = m_o m_e$ where $m_e = 0.067$. Given that $m_o = 9.11 \times 10^{-31}$ kg and $\hbar = 1.06 \times 10^{-34}$ Js.

(70/100)

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5. (a) Define the Fermi's golden rule for an oscillating potential such as that provided by photons.

(30/100)

(b) The real part of the optical conductivity for interband absorption in a direct band gap semiconductor can be written approximately as

$$\sigma_1(\omega) \simeq \frac{\pi e^2}{m_o^2 \omega} \left| P_{cv}(\underline{O}) \right|^2 n_{opt}(\hbar\omega)$$

where $n_{opt}(\hbar\omega)$ is the optical joint density of states and the other terms have the same meaning as in the lecture notes.

(i) Discuss and draw the theoretical absorption curves for bulk GaAs, two-dimensional electron gas (2DEG) and a quantum wire of GaAs-AlGaAs heterostructure.

(ii) Experimental absorption curves however differ slightly from the theoretical curves. Explain why?

(70/100)

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