ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II

Friday 25 April 2003 9 to 10.30

Module 4B18

ADVANCED ELECTRONIC DEVICES

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

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1 (a) Describe both molecular beam epitaxy (MBE) and metal-organic-chemical-vapour-deposition (MOCVD) as the two techniques used for growing the multi-layer III-V semiconductors structures used in the manufacture of advanced electronic and optoelectronic devices. Compare and contrast their performance as techniques for crystal growth. [50%]

(b) Describe, with typical figures, the improvements in III-V semiconductor field-effect transistor performance that have been achieved with the use of heterojunctions and strained layers. You should consider speed, noise and power handling. [50%]

2 (a) Illustrate, with details of the multi-layer structures (including layer thicknesses, compositions and doping levels, and the relevant energy-band diagrams), how it is possible to generate each of the three phenomena:

(i) hot electron injection;
(ii) quantum confinement of electrons;
(iii) resonant tunnelling. [50%]

(b) Describe precisely how:

(i) hot electron injection improves Gunn diode performance;
(ii) quantum confinement of electrons improves laser performance;
(iii) resonant tunnelling is exploited as a microwave source. [50%]

3 (a) Describe the form of DC current-voltage characteristic that is required to detect high-frequency oscillations. [20%]

(b) Illustrate how this form of DC current-voltage characteristics is obtained for each of:

(i) Schottky barrier diode;
(ii) Planar-doped-barrier diode;
(iii) Asymmetric Spacer Layer Tunnel (ASPAT) diode. [40%]

(c) Describe, with typical figures, the performance of each of these three devices as microwave detectors. [40%]

4 (a) Describe the theoretical advantages offered to the performance of a bipolar transistor with the incorporation of a wide-gap emitter, and how these advantages are realised in practice for the GaAs/AlGaAs materials system. [50%]

(b) Describe the prospects of achieving terahertz frequency electronics, and the power handling capability at terahertz frequencies. You may refer to the performance of today's transistors with record transit time frequency f_T of order 350-400 GHz, and the Johnson criteria. [50%]

[Note: for GaAs, the product of the dielectric breakdown strength E_B and the saturated drift velocity v_s is given by $E_B v_s = 0.1\ Vs^{-1}$.]

5 (a) Describe the relevant material properties of gallium nitride (GaN) for application in modern electronic devices. [50%]

[Note: for GaN, the product of the dielectric breakdown strength E_B and the saturated drift velocity v_s, is given by $E_B v_s \sim 1 Vs^{-1}$.]

(b) Compare the performance of field-effect-transistors made from gallium arsenide (GaAs) and gallium nitride (GaN), and how close actual performance comes to that predicted in theory. [50%]

END OF PAPER