ENGINEERING TRIPOS PART IIB

Friday 29 April 2005 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*

There are no attachments.

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, with diagrams, the equipment used in the growth of semiconductor multilayers by

(i) molecular beam epitaxy and

(ii) metal-organic chemical vapour deposition. [20%]

(b) Compare and contrast the performances of these two methods of growth. [20%]

(c) Describe, with diagrams, and with estimates of accuracy and precision, two ways of determining each of the following properties of an as-grown semiconductor multi-layer:

(i) the thickness of a low band-gap layer, i.e. a quantum well layer;

(ii) the composition of a thin (3nm) high band-gap layer, i.e. a tunnel barrier;

(iii) the doping of the base layer of a heterojunction bipolar transistor; and

(iv) the across-wafer uniformity of the quantum well layer in (i) above. [60%]

2 (a) What are the Johnson criteria? What can be inferred from them in terms of the comparative performance of bipolar transistors operating at 5 GHz and at 50 GHz? [30%]

(b) What form is required of the current-voltage characteristics of a diode in order to obtain efficient mixing of signals at different microwave frequencies? [20%]

(c) Describe briefly four different realisations of a microwave mixer diode. Take any two of these and compare and contrast their performance in terms of frequency range, dynamic range, mixing efficiency, noise figure, temperature susceptibility, and any other relevant attributes. [50%]

3 (a) Why is silicon the dominant electronic material? What properties prevent it from being the only commercial electronic material? [20%]

(b) Compare and contrast the cross-sections of a silicon metal-oxide-semiconductor field-effect transistor (MOSFET) with feature sizes 1 micron and 0.1 micron. [30%]

(c) The typical carrier density of the on-state of a n-channel MOSFET is $10^{12}cm^{-2}$. The 1 micron gate-length transistor was introduced commercially in 1985, and the 0.1 micron gatelength transistor was introduced in 2000. Assuming an approximately square transistor channel, when will Moore's law cease because of statistical fluctuations when only one electron distinguishes the on and off state of an individual MOSFET? [30%]

(d) What other factors might stop the progress of Moore's law before then? [20%]

4 (a) What feature is required in the current-voltage characteristics of a diode in order that microwave power might be generated? [10%]

(b) Quoting typical layer thicknesses, compositions and doping levels, describe the semiconductor multi-layer structure required for:

(i) a homojunction Gunn diode;

(ii) a heterojunction Gunn diode. [20%]

(c) Describe the processing steps required for a typical heterojunction Gunn diode mounted for operation at 35 GHz. [20%]

(d) Quote the typical performance figures of a heterojunction Gunn diode over the 35-100 GHz range in terms of output power, efficiency, noise, temperature sensistivity, etc. [20%]

(e) Compare and contrast the performance of a Gunn diode and the double barrier resonant tunnel diode as a source of microwaves at 100 GHz. [30%]

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5 Write an essay on gallium nitride and its alloys with aluminium nitride and indium nitride as an electronic material. [100%]

END OF PAPER