ENGINEERING TRIPOS PART IIB

Friday 29 April 2011 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.

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

1 (a) Describe the basic mechanisms, and the equipment involved, for the two main contemporary methods for growing single crystal semiconductor multilayers, namely molecular beam epitaxy and metal-organic chemical vapour deposition. Compare and contrast the techniques in terms of cost, throughput, safety, in-situ monitoring, and any other aspects you think are relevant. [50%]

(b) Given the following multilayer system:

Substrate: GaAs Si-doped at 10^{18} cm^{-3}

On this is grown;

Layer 1 (buffer)	GaAs	Si-doped to 10^{18} cm^{-3}, to a thickness of 0.5 μm
Layer 2	GaAs	not intentionally doped, to a thickness of 0.2 μm
Layer 3	AlAs	not intentionally doped, to a thickness of 2.8 nm
Layer 4	GaAs	not intentionally doped, to a thickness of 0.2 μm
Layer 5 (contact)	GaAs	Si-doped to 10^{18} cm^{-3}, to a thickness of 0.5 μm

What techniques would you use in order to verify that layer 3 is at the correct depth from the surface and is of the thickness and composition specified? How would you confirm the doping density and the thickness of the contact layer? In each case comment on the accuracy and precision that can be achieved in practice. [50%]

2 (a) Describe the basic operation of the $n^+ - n^- - n^+$ GaAs Gunn diode, showing how, in terms of propagating high-electric field domains, a high-frequency current in the GHz range can be derived from a strong applied dc bias. Cite typical figures of merit for the device. [30%]

(b) Discuss the harmonic content of the signal, and how the energy in the higher harmonics might be reduced. Where might these higher harmonics actually be desirable? [20%]

(c) Show how the introduction of a layer of $Al_xGa_{1-x}As$, with x increasing linearly from 0 to 0.3 over 50 nm, followed by an abrupt heterojunction (where x drops from 0.3 to 0 over one monolayer at the interface between the cathode and the n-layer) can improve the performance of the Gunn diode. Use the basic physics at the heterojunction to explain the impact of this new layer on the output power, efficiency, noise properties and temperature dependence of the heterojunction Gunn diode. [50%]

3 (a) In question 1(b) above, layers 2 and 4 are of equal thickness. What could the resulting structure be used for? [20%]

(b) If the thickness of the layer 2 of the same multilayer structure is reduced by a factor of 10, from 0.2 μm to 20 nm, what is the nature of the resulting current-voltage characteristic? What device function could the modified multilayer structure be used for? What advantages and disadvantages would this multilayer structure have in applications compared with other types of device performing the same function? [50%]

(c) Several device ideas have been put forward that use tunnel currents as their basic mode of operation, and yet none are in large volume, low cost, production. Why is this so? What are the prospects that tunnel devices might one day be manufactured? [30%]

4 (a) Compare and contrast the operation of a GaAs MESFET and a AlGaAs/InGaAs high electron mobility transistor structure where the same lithographic dimensions are used. Consider speed, noise, current handling and any other aspects you consider relevant. [40%]

(b) What are the potential advantages of a wide band-gap emitter in a heterojunction bipolar transistor? Describe the extent to which these advantages are achieved in practice. [40%]

(c) What is a T-gate in the context of a microwave field effect transistor? Why is it used? How is it made in practice? [20%]

5 (a) Derive the two Johnson criteria showing how the material's properties of the semiconductor impose limitations on the performance of transit time devices. Show what these criteria mean in the context of microwave transistors in GaAs and GaN. [50%]

(b) Heterojunctions have not had the same degree of impact on silicon technology as they have for III-V technology. Give reasons for this, and comment on the present applications of heterojunctions in silicon microelectronics. [50%]

END OF PAPER