ENGINEERING TRIPOS PART IIB

Friday 28 April 2006 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) Sketch a resonant tunnelling diode (RTD) suitable for DC I-V measurements, showing the multilayer structure and the contacts. Indicate on the diagram, for a GaAs/AlAs RTD, the typical thicknesses and doping levels of all the semiconductor layers in the completed device. [20%]

(b) Describe, in detail, the processing steps required to produce RTDs from a substrate on which the semiconductor multilayers have been grown. [20%]

(c) What is the key feature of the DC I-V characteristics that is exploited to generate 100GHz oscillations. How are figures of merit such as the output power and the efficiency of the RTD as a source related to this feature? [20%]

(d) What variations to the multilayer structure described in (a) above could be used to enhance the output power at (say) 50GHz, and why this power is enhanced as a result of your variations. [20%]

(e) Discuss the issues relevant to the low-cost manufacture of RTDs. [20%]

2 (a) What is the basic feature of the DC I-V characteristics of a semiconductor diode that enables it to be used as a detector and/or mixer of microwave radiation? Explain why. [10%]

(b) Describe the semiconductor multilayer structures and the contact metallisation of **three** different realisations of a diode detector of (say) 50GHz radiation: indicate the thickness, composition and doping level of the various layers, and describe the basis of operation as a detector. [40%]

(c) What are the desirable properties of a microwave detector over and above the basic detection function you describe in part (a)? Compare and contrast the performance of each of the three examples. [25%]

(d) Describe particular applications for which each of the three diode detectors are particularly suited. [25%]

3 (a) Describe the operation of a conventional Gunn diode as a source of 30GHz microwaves. [25%]

(b) Discuss the performance limitations of such a diode that could be circumvented by the introduction of semiconductor heterojunctions into the design. [25%]

(c) Describe, both qualitatively and quantitatively, the actual improvements when heterojunction elements are introduced into a GaAs Gunn diode. [25%]

(d) Compare and contrast the performance of a Gunn diode and an IMPATT diode as the source of radiation in the range from 30GHz to 100GHz. [25%]

4 (a) Sketch, with details of layer thicknesses, compositions and doping levels, typical homojunction and heterojunction versions of field effect transistors and bipolar transistors based on GaAs. [50%]

(b) Describe the advantages in the performance of these two transistor types with the introduction of heterojunctions. [50%]

5 (a) The following mulilayer semiconductor structure is the specification for a frequency multiplier diode.

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

Describe in detail, the ways this multilayer structure might be grown in practice, and point to the advantages and disadvantages that either molecular beam epitaxy or metal-organic-chemical vapour deposition have in the growth of this structure. [40%]

(b) Describe in detail, two techniques that might be used to verify the thicknesses of the above layers, and layer 3 in particular. Describe in detail two techniques that might be used to verify the doping of the GaAs layers. [40%]

(c) Discuss the issues of manufacturability of this device for a proposed application in low-cost, high-volume systems. [20%]

END OF PAPER