ENGINEERING TRIPOS IIB

Friday 23 April 2010 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

mjk02

1 (a) Compare and contrast molecular beam epitaxy and metal-organic chemical vapour deposition for the growth of compound semiconductor multilayers, covering such topics as the underlying processes, throughput, precision, defects, in-line analysis, safety, system cost and cost per wafer. [30%]

(b) Identify one or more techniques for characterising the following properties of semiconductor multilayers where the individual layer thickness range from nanometres to microns:

(i) the quality of interfaces;
(ii) the uniformity across a wafer;
(iii) the doping profile as a function of depth from the surface, and
(iv) the composition of a tunnel barrier layer.

For each technique describe the accuracy and resolution that can be achieved, and also give one example of a device where this particular aspect of the multilayer is critical for good performance. [40%]

(c) Compare and contrast the semiconducting properties of gallium arsenide (GaAs) and gallium nitride (GaN). Comment on the materials quality that can be achieved today using the advanced growth techniques described in (a) above. For what applications is GaAs preferred over GaN, and vice-versa? [30%]

2 The following is the growth sequence required for an asymmetric spacer layer tunnel (ASPAT) diode as might be used as a detector of microwaves and millimetre waves.

1	Substrate		Si-doped $3.10^{18}cm^{-3}$
2	GaAs	750nm	Si-doped $3.10^{18}cm^{-3}$
3	GaAs	40nm	Si-doped $10^{17}cm^{-3}$
4	GaAs	5nm	no intentional doping
5	AlAs	2.85nm	no intentional doping
6	GaAs	200nm	no intentional doping
7	GaAs	40nm	Si-doped $10^{17}cm^{-3}$
8	GaAs	750nm	Si-doped $3.10^{18}cm^{-3}$

(a) Sketch the conduction band profile through the device for no applied bias, and when the device is operating under forward bias. [15%]

(b) Describe the purpose of each layer in the device. [40%]

(c) Which layer is critical for manufacture, and how can the yield of working devices be optimised, and what is the present state-of-the-art? [15%]

(d) Describe briefly three other semiconductor multilayer structures that could be used for the same purpose and comment on one particular advantage, and one disadvantage of each of these in comparison with the ASPAT diode. [30%]

3 (a) Describe the principle of negative differential resistance in an $n^+ - n^- - n^+$ multilayer structure of Gallium Arsenide that leads to Gunn oscillations, including both the primary physical mechanism and the way that an oscillating current output is consequently generated from a dc voltage input. [40%]

(b) Describe the role of a graded composition layer of the alloy aluminium gallium arsenide in improving the performance of the cathode of a GaAs Gunn diode, citing the actual improvements in device performance that are achieved. [40%]

(c) What consideration would apply if we were to try to use the same device idea in the InP- or the GaN-based materials systems? [20%]

4 (a) What aspects of the dc current-voltage characteristics are relevant for the generation and for the detection of microwaves? Give an example of a device that generates and a device that detects microwaves. What are the appropriate device figures-of-merit that can be derived from the dc current-voltage characteristics in each case? [30%]

(b) In the example of a double barrier resonant tunnel diode, how are the various layers chosen to optimise the millimetre-wave output power? What values of efficiencies and output powers can be achieved? [30%]

(c) Describe how a low-doped transit layer immediately on the anode side of the double barrier can be used to amplify the output power of a double barrier resonant tunnelling diode, and what other properties of the device performance are thereby compromised. Cite typical performance figures achieved using the GaAs/AlAs materials system. [40%]

5 (a) Why is the heterojunction version of the bipolar transistor now ubiquitous in the III-V materials systems? Describe four theoretical advantages of using a narrow-gap base and how are these advantages achieved in practice. [40%]

(b) Compare and contrast the ease of manufacture of field effect and bipolar transistors. [20%]

(b) What is Moore's law? How does it drive silicon-based microelectronics? How and when will Moore's law fail? What will happen to microelectronics thereafter? [40%]

END OF PAPER