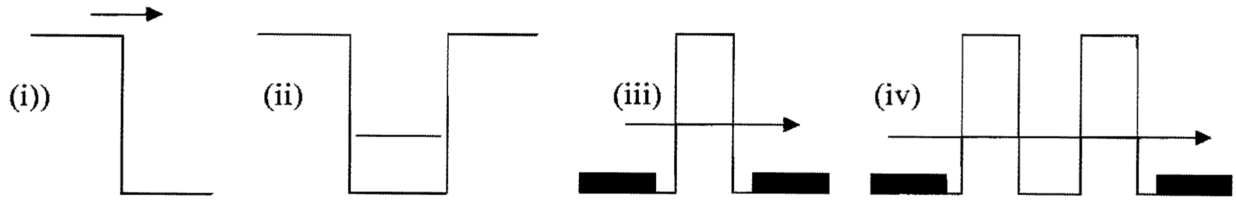
ENGINEERING TRIPOS PART IIB 2012

4B18 ADVANCED ELECTRONIC DEVICES PROF MJ KELLY

Cribs:

Q1: Multilayers



AlGaAs|GaAs AlGaAs|GaAs|AlGaAs AlGaAs|GaAs|AlGaAs etc

In (ii), (iii) and (iv) the thin layers are typically 3-5nm in thickness.

Height of energy step 0.3eV.

The dark boxes indicate layers of typically 0118cm-3 silicon doping with the other regions undoped.

(b) (i) Heterojunction bipolar transistors and heterojunction Gunn diodes use specifically hot electron effects generated by heterojunctions.

(ii) High electron mobility transistors, quantum well lasers and quantum well infrared detectors all use quantum confinement.

(iii) Single tunnel barriers in an asymmetric doping environment work as microwave detectors.

(iv) Double barrier resonant tunnel diodes act as sources of microwave and millimetre-wave radiation.

Q2: Three sources

(i) Double barrier resonant tunnelling diodes – doping and thicknesses to maximise the peak-to-valley current and valet to peak voltage ratios. Up 50% efficiency at 35GHz for 20mW (always low) output in case of QWITT version of this diode. Very low noise, significant temperature dependence, very hard to make reproducibly – when hand-picked they cost >$1.

(ii) Heterojunction Gunn Diodes: graded gap injector with thin n+ doping spike afterwards to produce exactly the correct field profile when device is under bias – low net field in injector and correct field for maximum transit velocity. Can get 100mW at 100GHz at 5% efficiency in 2nd harmonic mode. 85GHz fundamental, low noise, very low sensitivity to ambient temperature, …, in manufacture and costing 10c to make.

IMPATT diodes: very high field region that undergoes dielectric breakdown and avalanching during a part of the rf cycle. The transit region is then just as long as half the rf cycle, so that electrons exit the device just as the voltage is most negative going, so giving a form of negative resistance. Very nosiy, but very powerful – 30W CW at up to 100GHz.

Could also mention HEMT oscillator circuits, but not covered in detail in the course.

3: Detector diodes: (4)
Material here is straight from tables in the lecture notes and cribs from previous years when a question like this has been set.

4: Growth and Qualification of Multilayers
Main techniques: MBE – a form of ultra-high-quality evaporation, again with details in notes and previous cribs. 1m sphercial UHV chamber cooled to 77K on the surface – Knudsen cells evaporate and form beams of elemental species that cross 50cm to impact on substrate heated to 550C to form 1 layer per second. Shutters allow control over different species, and separate cells for dopant at high and at low levels. Still used for microwave devices and tunnelling devices, as it has superior in-situ monitoring techniques.
MOCVD – a gas phase form of cracking – to note this year an update on vertical reactors now being used pervasively for III-V, while horizontal reactors still used for silicon. Trimethyl gallium and arsine make methane and gallium arsenide. Hydrogen as a carrier gas, premixing chambers, the substrates are heated with rf or conductive heating to 550C. Growth at 10 monolayers per second. Pervasive for optical devices.

Qualification:
Layer thickness: depth profiling by SIMS, bevel etching, infer from X-ray or PL in certain conditions, TEM
Composition: SIMS, XRAY, TEM
Doping: SIMS, CV profiling, PL under certain circumstances, IR reflectivity.

5 Manufacturability:
Yield, reproducibility, tailorability, right first time design capability, simulator for reverse engineering, in-service life-time, reliability, ...
At nanoscale nearly all these aspects are challenged, and below 10nm every aspect is being pushed.
Arrays below 7nm half-pitch cannot achieve 6-sigma yield because of $\sqrt{N}$ effects.