ENGINEERING TRIPOS PART IIB

Wednesday 5 May 2010 2.30 to 4.00

Module 4B14

SOLAR-ELECTRONIC POWER: GENERATION AND DISTRIBUTION

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*

Attachment: Sheet of Formulae and Constants (1 page)

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

ga02

1 A p-n junction Si solar cell has the following parameters at a temperature of 300K.

(i)	built in potential	0.92eV
(ii)	p-doping	10^{23} m^{-3}
(iii)	minority carrier hole life time	1 ns
(iv)	minority carrier electron lifetime	1 μs
(v)	electron diffusion length	150 μm
(vi)	hole diffusion length	0.5 μm
(vii)	intrinsic carrier concentration	10^{16} m^{-3}

The n-type region is placed adjacent to the top surface from which light enters the cell and forms a junction with the p-type substrate region 1μm beneath the top surface. The junction area is 10^{-2} m^2. Assuming that the density of band edge states in the conduction band (N_C) and valence band (N_V) are equal, calculate:

(a) The doping of the n-type region. [30%]

(b) The peak values of the minority carrier concentrations on the p-type and the n-type regions of the junction when a forward voltage of 0.5V is applied across it. [40%]

(c) An open circuit voltage of 0.6V is measured when the cell is exposed to bright sunlight.

i) What is the short circuit current which would be expected from the cell? [15%]

ii) Estimate the corresponding optical generation rate. [15%]

2 (a) Would the energy conversion efficiency for an amorphous Si (a-Si:H) solar cell be higher for 600 nm light or 300 nm light? Give reasons for your answer. [20%]

(b) Amorphous silicon germanium (a-SiGe:H) and amorphous silicon carbide (a-SiC:H) have narrower and wider band gaps respectively compared to a-Si:H. All three materials are compatible in terms of thin film growth.

i) Sketch the structure of a solar cell in which all three materials are utilized. Mark clearly the light entry and transmission path through the cell. [25%]

ii) Comment on the efficiency expected from the three material cell compared to a standard a-Si:H cell. [20%]

iii) Expand the equivalent circuit for a single material solar cell to represent the three material solar cell. [15%]

iv) Using the equivalent circuit in (iii) above comment on the design optimisation of multi-band gap solar cells. [20%]

3 A multi-crystalline Si solar cell of 10^{-2} m^2 area has the following measured parameters.

Reverse saturation current under dark conditions	10nA
Short circuit current under a solar light flux of 1kW m^{-2}	2.0A
Dark I-V characteristic ideality factor	1.1

The cell temperature was maintained at 300K during all the measurements.

a) What is the open circuit voltage V_{OC} which would be expected from this cell? [30%]

b) Estimate the power conversion efficiency of the cell. [20%]

c) If the cell has a contact resistance of 0.03 Ω, what would the efficiency of the cell be? State clearly all assumptions made. [20%]

d) In order to improve the efficiency a thin insulating layer is to be applied to the light entry surface of the cell. Estimate the optimum thickness and refractive index of such a layer stating clearly all assumptions made. [30%]

4 (a) Why is Maximum Power Point Tracking (MPPT) important for solar power plants? [20%]

(b) Describe an algorithm for MPPT making clear how stable operation can be maintained. [25%]

(c) Show in block diagram form the interface circuits required to connect a solar power plant to the single phase AC grid. Give brief descriptions of the functionality of each block. [25%]

(d) Comment on the role of *"feed in tariffs"* in stimulating the adoption of solar power generation. [30%]

END OF PAPER

4B14 SOLAR CELL ELECTRONIC POWER: GENERATION AND DISTRIBUTION

Formulae and Constants

Reflection co-efficient from the third layer of a 3 layer system comprising of a thin film sandwiched between two bulk materials extending away from their interfaces with the thin film is given as:

$$R = \frac{n_2^2 (n_1 - n_3)^2 Cos^2 \vartheta + (n_1 n_3 - n_2^2)^2 Sin^2 \vartheta}{n_2^2 (n_1 + n_3)^2 Cos^2 \vartheta + (n_1 n_3 + n_2^2)^2 Sin^2 \vartheta}$$

where $$\vartheta = \frac{2\pi n_2 d}{\lambda}$$

n_1, n_2 and n_3 are the refractive indices of 3 materials m_1, m_2 and m_3 respectively: d is the thickness of the thin film m_2 sandwiched between materials m_1 and m_2. Direction of light flow is taken to be from m_1 to m_3.

Fill Factor for a solar cell

$$FF_o = \frac{\frac{qV_{oc}}{kT} - ln\left(\frac{qV_{oc}}{kT} + 0.72\right)}{\frac{qV_{oc}}{kT} + 1}$$

where V_{oc} is the open circuit voltage for the cell.

Constants

Electronic charge unit **q: 1.602 × 10^{-19} C**

Boltzmann's Constant **k: 1.38 × 10^{-23} J K^{-1}**

Speed of light **c: 3 × 10^{8} m s^{-1}**

Planck's Constant **h: 6.626 × 10^{-34} J s**

Dielectric permittivity free space ε_0: **8.85 × 10^{-12} F m^{-1}**

Relative permittivity of **Si** ε_r: **11.9**

Refractive index (for weakly and non-absorbing wavelengths) **n** = $\varepsilon_r^{0.5}$

Band-gap energy of **Si: 1.12 qV J**