ENGINEERING TRIPOS PART IIB

Wednesday 9 May 2007 09:00 to 10:30

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

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

(i)	built in potential	0.91eV
(ii)	n-doping	$5.0 \times 10^{25} m^{-3}$
(iii)	minority carrier electron lifetime	2μs
(iv)	minority carrier hole lifetime	1ns
(v)	electron diffusion length	150μm
(vi)	hole diffusion length	0.5 μm
(vii)	Intrinsic carrier concentration	$10^{16} m^{-3}$

The junction area is 10^{-2} m^2 and is formed so that the n-type region is placed under the surface from which light enters the cell. The n-type region extends 1μm into a p-type region of 350μm, which forms the bulk of the cell. Assuming that the density of available states at the edge of conduction band (N_C) is equal to those at the edge of the valence band (N_V), calculate the following.

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

(b) The peak value of the minority carrier distribution in the p-type region when a forward voltage of 0.4V is applied across the junction. [40%]

(c) When exposed to bright sunlight the solar cell develops an open circuit voltage of 0.60V.

i) What is the ideal short circuit current, which could be expected from the cell? [10%]

ii) Estimate the optical generation rate. [10%]

iii) Sketch the current (I) vs voltage (V) output characteristic of the cell under the above conditions [10%]

Clearly state all assumptions made.

2

(a) Would an amorphous Si (a-Si:H) solar cell get hotter converting 400 nm light or 600nm light? Give reasons for your answer. [20%)]

(b) Amorphous silicon carbide (a-SiC:H) and amorphous silicon germanium (a-SiGe:H) have wider and narrower band-gaps respectively in comparison to a-Si:H. Sketch a schematic structure for a solar cell comprised of all three materials which you would expect to have a higher efficiency compared to that of a conventional a-Si:H cell and explain why this would be achieved. [40%]

(c) Using an equivalent circuit for a solar cell, comment upon the factors which will limit the efficiency of the cell proposed in (b) above [20%]

(d) Comment on the advantages and disadvantages of an a-Si:H solar cell compared to a crystalline Si solar cell. [20%]

3 A multi-crystalline Si solar cell has the following measured parameters.

Short circuit current under AM 1.5 solar light (1kW m^{-2})	3.0A
Open circuit voltage	0.6V
Ideality factor under dark conditions	1.1
Contact resistance	0.02Ω

The cell temperature was 330K during the measurements. The cell area is 10^{-2} m^2.

(a) What is the dark current which would be expected from the cell under reverse bias at 330K? [20%]

(b) Estimate the efficiency of the cell when operating under AM1.5 solar illumination. You may assume that the reverse leakage resistance (measured under dark conditions) is infinitely large. [50%]

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

4

(a) Explain what is meant by the term 'AC module solar panel'. [10%]

(b) Comment on the advantages and disadvantages of a 1kW domestic solar installation comprised of AC modules compared to one having a single centralised inverter. [20%]

c) Draw a transistor level circuit diagram for a 1kW centralised inverter for grid connection of a domestic solar installation. The control features can be shown in block diagram form. You should also indicate suitable switching frequencies for the transistor. [20%]

Write a commentary on **one** of the following topics.

i) The AC module solar panel gives consumers the option of mitigating their carbon footprint.

OR

ii) The role of legislation in driving the solar market. [50%]

END OF PAPER

D14 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

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

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**