EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 30 April 2014   2 to 3.30

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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book
Attachment: Sheet of Formulae and Constants (1 page).

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 A Si p-n junction solar cell has the following parameters

Base wafer doping (p -type) (N_A)	10^{23} m^{-3}
Base wafer thickness	250 µm
n-region doping (N_D)	10^{25} m^{-3}
Hole minority carrier diffusion length (L_h)	100 nm
Electron minority carrier diffusion length (L_e)	100 µm
Hole minority carrier lifetime (τ_h)	1 ns
Electron minority carrier lifetime (τ_e)	1 µs

The junction area is 10^{-2} m^2 and the intrinsic concentration (n_i) is $5 \times 10^{16} m^{-3}$ at 300 K. The conduction band edge and valence band edge density of states can assumed to be equal $(i.e.\ N_c = N_v)$.

Calculate the following under dark conditions:

(a) The built in potential of the junction (V_{bi}). [15%]

(b) The reverse saturation current of the junction (I_S). [15%]

(c) The applied voltage required to get a forward current (I_F) of 5 A. [20%]

Under the forward bias conditions in (c) the p-n junction is exposed to sunlight conditions such that the average optical generation rate (g_{opt}) within the semi-conductor region is $10^{25} m^{-3} s^{-1}$.

(d) What is the forward current of the diode under this illumination? [20%]

(e) Calculate the open circuit voltage (V_{OC}) when the p-n junction works as a solar cell under the same optical conditions. [15%]

(f) Draw an equivalent circuit for the diode when it operates as a solar cell under the sunlight conditions specified. [15%]

2 (a) Assuming that the band-gap of amorphous Si ($a-$Si:H) is in the range 1.4-1.8 eV, would the conversion efficiency of an $a-$Si:H solar cell be higher for 400 nm light or 600 nm light? Give reasons for your answer. [20%]

(b) Amorphous silicon germanium ($a-$SiGe:H) has a narrower band-gap (0.6-0.8 eV) than $a-$Si:H. Sketch a schematic diagram of a solar cell comprised of both materials which would be expected to give a higher efficiency. Explain clearly the reasons for the higher efficiency. [25%]

(c) In designing a cell as in (b) above, what are the key considerations which need to be taken into account to achieve a high efficiency? [20%]

(d) A thin transparent insulating layer is applied to the front of bulk Si solar cells.

(i) What is the purpose of this layer? [10%]

(ii) If the layer has a refractive index of 2.2, calculate its optimum thickness. [10%]

(iii) Why may the layer thickness be different for a solar cell made from $a-$Si:H?

[15%]

3 (a) What does the *Fill Factor* (FF) of a solar cell signify? [15%]

(b) What are the factors which reduce the FF of a solar cell from the ideal case? [15%]

(c) Draw an equivalent circuit for a practical solar cell explaining clearly the significance of each term and how it influences the FF. [20%]

(d) If the FF for an ideal solar cell is 0.83 at 300 K, estimate its open circuit voltage. [20%]

(e) The expected efficiency for the ideal solar cell of area $10^{-2}\,\mathrm{m}^2$ under *air mass* (AM) 1.5 solar insolation ($1\mathrm{kWm}^{-2}$) is 18%. What is the corresponding short circuit current? [15%]

(f) When the cell is manufactured to achieve the specifications as in (e) above it is found to have a contact resistance of 0.06 Ω. What is the efficiency of the manufactured cell? [15%]

4 (a) Explain why *Maximum Power Point Tracking* (MPPT) is implemented in solar *photovoltaic* (PV) installations and outline a method for doing so. [20%]

(b) Show in block-diagram form the main power conversion stages required for connecting the power output from a solar PV installation to the power grid. [20%]

(c) Discuss the pricing of power generated from a PV installation based on grid demand and electricity spot pricing. [30%]

(d) By considering the total energy cycle of manufacture, operation and recycling comment on whether solar PV is a sustainable technology for electricity generation. [30%]

END OF PAPER

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