Version GAJA/2

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 28 April 2015   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).

10 minutes reading time is allowed for this paper.

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

1 A crystalline Si p–n junction solar cell has the following parameters at 300 K under dark conditions:

n-doping density	1×10^{18} cm^{-3}
p-doping density	1×10^{17} cm^{-3}
minority carrier electron lifetime	1 μs
minority carrier hole lifetime	1 ns
electron diffusion length	120 μm
hole diffusion length	0.4 μm
intrinsic carrier concentration	1×10^{10} cm^{-3}
band gap	1.12 eV
the band edge density of states are equal	$N_c = N_v$

The junction area is 10 cm^2. The junction is formed so that the uniformly doped n-type region extends 1 μm from the surface, followed by the uniformly doped p-type region extending a further 250 μm to form the bulk of the cell. When operating as a solar cell the light enters from the surface adjacent to the n-type region.

(a) Calculate the built-in potential. [15%]

(b) Calculate the reverse saturation current. [15%]

(c) Calculate the width of the depletion region on the p-side of the junction under dark conditions. [20%]

(d) Assume that the transport of electrons outside the depletion region is only due to diffusion. Calculate the peak value of the minority carrier density in the p-type bulk region when a forward voltage of 0.5 V is applied across the junction. [20%]

(e) When the cell is exposed to AM 1.5 (1kWm^{-2}) sunlight, an open circuit voltage of 0.6 V is measured. Calculate the corresponding ideal short circuit current which would be expected from the cell. Hence also estimate the optical generation rate under these conditions. [30%]

2 (a) Explain why generation of heat is inevitable when converting light energy of the solar spectrum to electrical energy through the photovoltaic process using a semi-conductor. [20%]

(b) Would it be more efficient to convert energy of 800 nm or 600 nm wavelength sunlight in a crystalline Si solar cell? [20%]

(c) Explain why a tandem solar cell made from two thin film photo absorbers, for example amorphous Si (a-Si:H) and amorphous Ge (a-Ge:H) could be more efficient than using only one absorbing material. [30%]

(d) Using a cross sectional diagram of a tandem solar cell as in c) above, identify the key solar cell parameter which has to be matched between the two absorbing layers in order to achieve optimum efficiency. Give reasons for your answer. [30%]

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

open circuit voltage V_{oc} under AM 1.5 solar light	0.6 V
dark I-V characteristic ideality factor	1.1
dark reverse saturation current	2 nA

The cell temperature was 300 K during all measurements.

(a) What would the expected short circuit current from the above cell be? [20%]

(b) Estimate the efficiency of the cell under AM 1.5 ($1 kWm^{-2}$) solar light. The cell area is 10^{-2} m^2. [20%]

(c) Give a better estimate of the efficiency if the contact resistance is determined to be 0.05 Ω through enhanced measurements. The reverse leakage under dark conditions is assessed to be immeasurably large. [30%]

(d) Explain how the ideality factor of the cell can be further improved to enhance the efficiency. [30%]

4 (a) (i) Why is Maximum Power Point Tracking (MPPT) important in solar power installations? [10%]

(ii) Describe a method for implementing MPPT. [10%]

(b) Discuss the advantages and disadvantages of concentrating solar light for photovoltaic energy conversion. [30%]

(c) Write a commentary on the implications of large scale distributed solar power generation by domestic, business and industrial consumers who are also customers of the electricity utility companies, in the context of feed in tariffs/subsidies and the costs associated with maintaining the grid infrastructure. Also consider whether there may be solar power plants sited ‘off grid’ and in this case whether the analogy of mobile phones vs landline phones in not being connected to a wired network is valid. [50%]

END OF PAPER

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4B14 Numerical Answers 2015

Q1 (a) 0.90 *eV*, (b) 25.6 *pA*, (c) 104 nm, (d) $2.25 \times 10^{11} cm^{-3}$, (e) $1.4 \times 10^{25} m^{-3} s^{-1}$

Q3 (a) 2.89 A, (b) 14.2%, (c) 10.89%