Extra Questions

EXAMPLE 5.2 Calculate the efficiency and peak power of a Si solar cell operating at 27°C, with short circuit current of 2.2 A, and operating under standard illumination of 1000 W/m^2.

The area of the solar cell is about 100 cm^2.

Solution: Typical value of I_0 for solar cell is about 10^{-12} A (assumption, normally its values are given in terms of current density, i.e., A/cm^2) since the solar cell is operating at a temperature of 27°C, and also I_{sc} = 2.2 A. Based on this, the V_{oc} is calculated as:

$$V_{oc} = \frac{kT}{q} \times \ln \frac{I_{sc}/I_0}{q} = 0.616 \text{ V}$$

Considering the FF of the solar cell to be 0.75 or 75%, the efficiency is given as:

$$\eta = V_{oc} I_{sc} \frac{FF}{P_{in}}$$

$$= \frac{0.616 \times 2.2 \times 0.75}{1000 \times 100 \times 10^{-4}} = 0.10164 = 10.16\%$$

The peak power in this case is given as:

$$P_{\max} = V_{oc} \times I_{sc} \times FF = 1.01 \text{ W.}$$

EXAMPLE 5.3 In Example 5.2, if the operating temperature of the solar cell increases to about 35°C, calculate the efficiency.

Solution: In this case, the only parameter that changes with the temperature is the V_{OC}. Although current also changes, but the V_{OC} change is more dominant. The rate of change of V_{OC} is about 2 mV/°C (for crystalline Si solar cells, note that this number is process dependent and can vary from one manufacturer to another).

Therefore, the reduction in V_{OC} is:

$$V_{OC}(35°C) = V_{OC}(27°C) - 2 \times 10^{-3} \times (35 - 27) = 0.60 \text{ V}.$$

With this new value of V_{OC}, the $P_{\max}$ can be calculated as in Example 5.2:

$$P_{max} = 0.7425 \text{ W}$$

The corresponding cell efficiency would be 9.9%. Thus, there is a reduction in efficiency and P_{max} due to the increase in temperature.

EXAMPLE 5.4 Calculate the thickness required of the ARC if green wavelength is to be least reflected from the surface of the solar cell.

Solution: The green light has wavelength of about 550 nm, and the ARC is placed between the air ($n_0 = 1$) and the Si (solar cell with $n_2 = 3.8$). In order to get minimum reflectance, the refractive index of the ARC needs to be between the air and the Si which is given as:

$$n_1 = \sqrt{n_0 n_2} = 1.95$$

The ARC should have refractive index of 1.95. This could be achieved by using Si_xN_y ARC coating in which the refractive index could be controlled by varying the Si to N ratio. Further, the thickness of the ARC required for minimum reflectance of green light of wavelength 550 nm would be given by the destructive interference for that wavelength, and is shown by a quarter wavelength symmetry, that is

$$t = \frac{\lambda}{4n_1} = \frac{550}{(4 \times 1.95)} = 70.5 \text{ nm}$$

Thus, the thickness of the ARC coating required is about 70 nm in order to maximize green light absorption.

EXAMPLE 5.5 Calculate the total emitter power loss in the solar cell of area 100 cm^2, if L is 10 cm, W is 10 cm, sheet resistance R_S of the solar cell is about 45 Ω/□, peak current is 2.1 A, spacing between the fingers is 2.5 mm and width of the fingers is about 0.1 mm and that of busbar is 2.5 mm.

Solution: Number of fingers in the solar cells can be calculated as:

$$\frac{W}{S} = \frac{\text{Width}}{\text{Spacing} + \text{Finger width}}$$

$$= \frac{10}{(0.25 + 0.01)} = 38.46 \text{ approx } 38 \text{ fingers}$$

Area of the metallized region can be calculated as:

$$10 \times 0.01 \times 38 + 0.25 \times 10 = 6.3 \text{ cm}^2$$

The current density is given by

$$J_{mp} = \frac{I_{mp}}{\text{Solar cells active area}}$$

Solar cells active area is:

$$100 - 6.3 = 93.7 \text{ cm}^2$$

$$J_{mp} = \frac{2.1}{93.7} = 22.41 \text{ mA/cm}^2$$

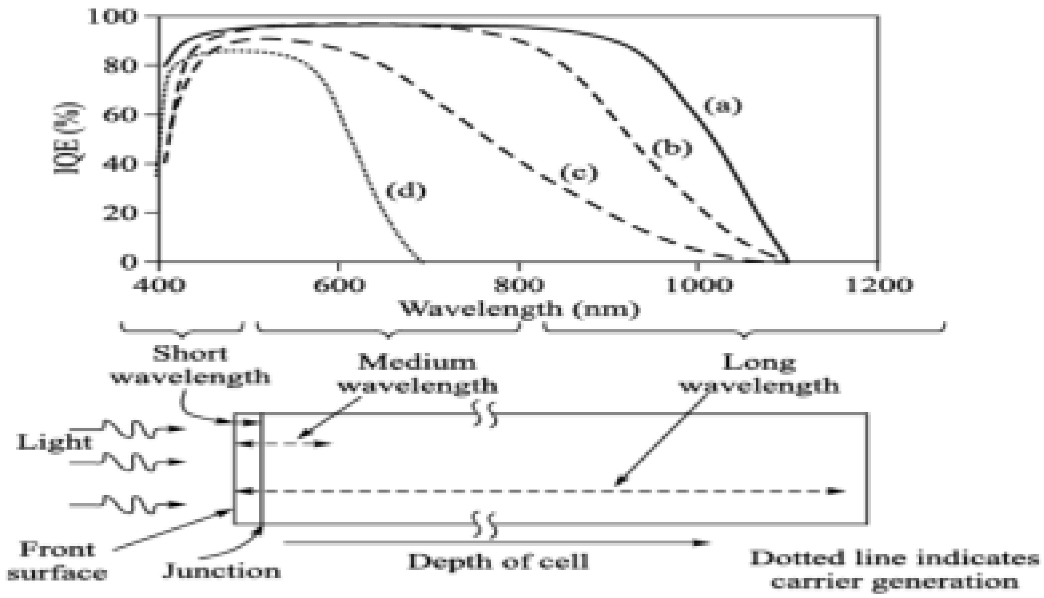
$$J_{mp} = \frac{2.1}{93.7} = 22.41 \text{ mA/cm}^2$$

From the equation derived, we have emitter power loss as:

$$P_{\text{emitter}} = \frac{J^2 b \rho_{sh} S^3}{24}$$

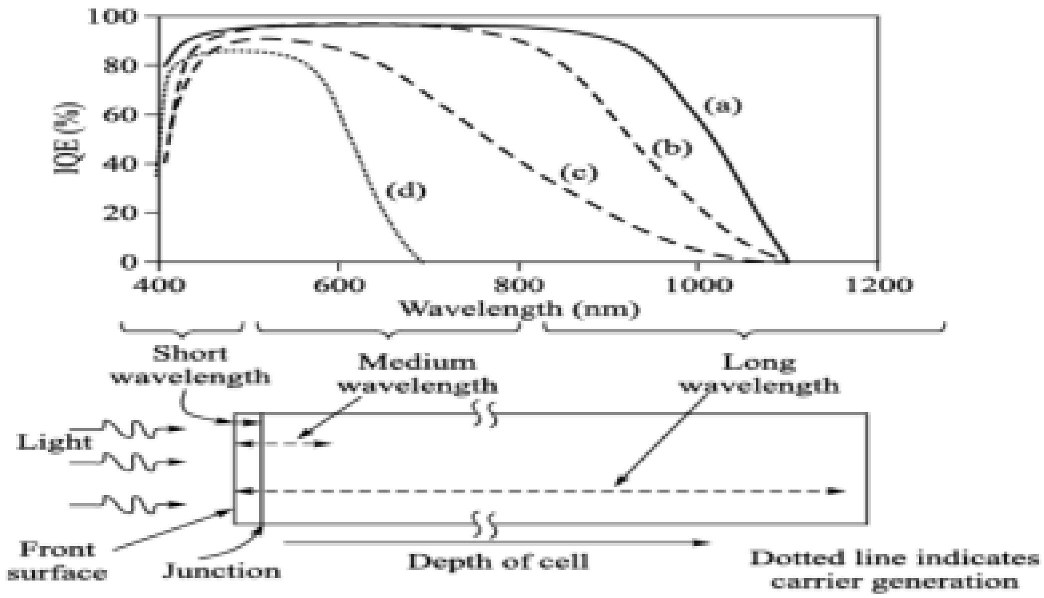
$$= (22.41 \times 10^{-3})^2 \times 10 \times 45 \times \frac{0.25^3}{24} = 1.4716 \times 10^{-4} \text{ W}$$

This power loss is in a half region between the two fingers; therefore, we need to multiply by 2 to get power loss in one finger area, and then multiply by the total number of fingers on a cell to get the total emitter power loss. The total emitter power loss would come out to be 0.01088 W.



Typical QE of four different solar cells, (a), (b), (c) and (d). The bottom of the figur
schematically demonstrates the absorption length (or generation range of carrier
for various wavelengths of solar spectrum.

The IQE is high, about 80%, for the blue light indicating that the front surface is well passivated. The IQE is also high in the green, and the red region indicates that the junction is good and the rear side surface recombination is low. The good IQE response in the red (and infrared) region also indicates that the material quality is good because the carriers generated at the rear side are able to travel to the junction for charge separation (means high diffusion lengths). The response of the cell 'a' is zero beyond 1100 nm and is corresponding to the band gap of the material.



Typical QE of four different solar cells, (a), (b), (c) and (d). The bottom of the figur
schematically demonstrates the absorption length (or generation range of carriers
for various wavelengths of solar spectrum.

The IQE response of cell ‘b’ (Fig. 5.21) indicates that the material quality of the cell is good, but the front and back surface passivation is not good, since the IQE is low for both blue and red photons. The IQE response of cell ‘c’ (Fig. 5.21) indicates that neither the material nor the surface passivation is good. In this case, the material is not good because the IQE is low even in the wavelength range of 600 nm to 800 nm. This is typically the case of polycrystalline Si solar cells. The solar cell ‘d’ is an amorphous Si solar cell. Due to its high band gap, about 1.75 eV, the QE is zero beyond 700 nm. Its IQE [Fig. 5.21, cell (d)], in general, is not close to 100% at any part of the spectrum because of the defected material quality.

5.26 Three different solar cell designs with the side from which light is falling is shown in Fig. 5.23. Which of the three cells will have the highest cell efficiency? Comment. What will happen to the cell efficiencies if light enters from the left-hand side?

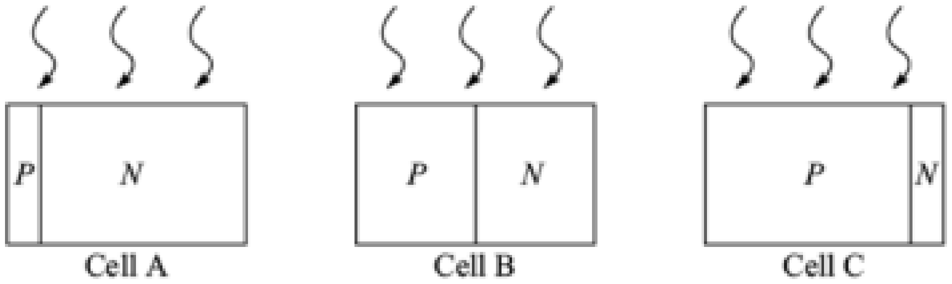


Fig. 5.23 Different designs of solar cells.