STUDIES ON SOLAR ENERGY SYSTEM ANALYSIS AND STORAGE TECHNIQUES

THESIS

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SUMMARY

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In this thesis the solar cell energy system is studied. The solar cell electrical characteristics, the performance and design parameters are introduced. The effect of series resistance and temperature on the output parameters of a solar cell are presented.

A mathematical model of the solar cell is used and solved by computer to study the dependence of the spectral response, the photocurrent components and the output parameters on the design parameters of a silicon solar cell at one sun. Also, the effect of the operational temperature and series resistance on the output parameters of a silicon solar cell at one sun are studied.

A theoretical analysis of silicon solar cell performance and design parameters at high solar concentrations are carried out by using a computer program. The optimum values of the design parameters are obtained. The effect of temperature and series resistance on the output parameters of a silicon solar cell is calculated at high solar concentrations.

The diurnal variations in the I-V characteristics of different silicon solar cells are carried out experimentally. Also, the output parameters of a silicon solar cell are measured experimentally at high solar concentrations. The results. in this thesis could be summarized as follows :

1. The doping concentration can be optimized, for the assumed

case the optimum,base doping is found to be 10^{17} cm^{-3} and the optimum doping of the diffused layer is 10^{19} cm^{-3}.

2. The diffused layer thickness is optimum when its thickness is lower than or equal to the minority carriers diffusion length of the diffused layer.

3. The increase in the base layer thickness causes an increase in the output parameters, they saturate for thickness larger than the diffusion length of the minority carriers of the bulk material.

4. When the recombination speed (S),in general equal to or larger than 10^{6}cm sec^{-1}, the output parameters are degraded.

5. The output parameters are, in general, increasing with the concentration ratio. The optimum load is reduced by increasing the concentration ratio.

6. The temperature increasing makes a degradation for the output parameters to the level of non-useful operation at high solar concentrations.

7. The series resistance value reduces dramatically the cell efficiency. An optimum solar concentration ratio is defined for a defined series resistance.

8. The short circuit current is strongly affected by the diurnal variations in radiation intensity while the open circuit voltage is slightly affected.

CHAPTER I

INTRODUCTION

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1.1 SOLAR RADIATION :

Radiant energy from the sun is vital for life on our planet. It determines the surface temperature of the earth as well as supplying virtually all the energy for natural processes both on its surface and in the atmosphere.

Solar radiation is attenuated by at least 30% during its passage through the earth's atmosphere. The most important parameter determining the total incident power of solar radiation on the earth's surface is the length of the light path through the atmosphere. This length is minimum when the sun is directly overhead. The ratio of any actual path length to this minimum value is known as "the optical air mass" which is given by :

$$\text{Air mass} = \frac{1}{\cos\theta}$$

when the sun is an angle θ to overhead.

If the sun is directly overhead, the optical air mass is unity and the radiation is called "air mass one (AM1) radiation". Also when the sun is 60° off overhead the radiation is (AM2).

The Solar Constant or, air mass zero (AM0) radiation is defined as : The radiant power of solar radiation per unit area perpendicular to the direction of the sun outside the earth's atmosphere and at the mean earth-sun distance. The typical value of AM0 is 1.353 KW/m^2 .

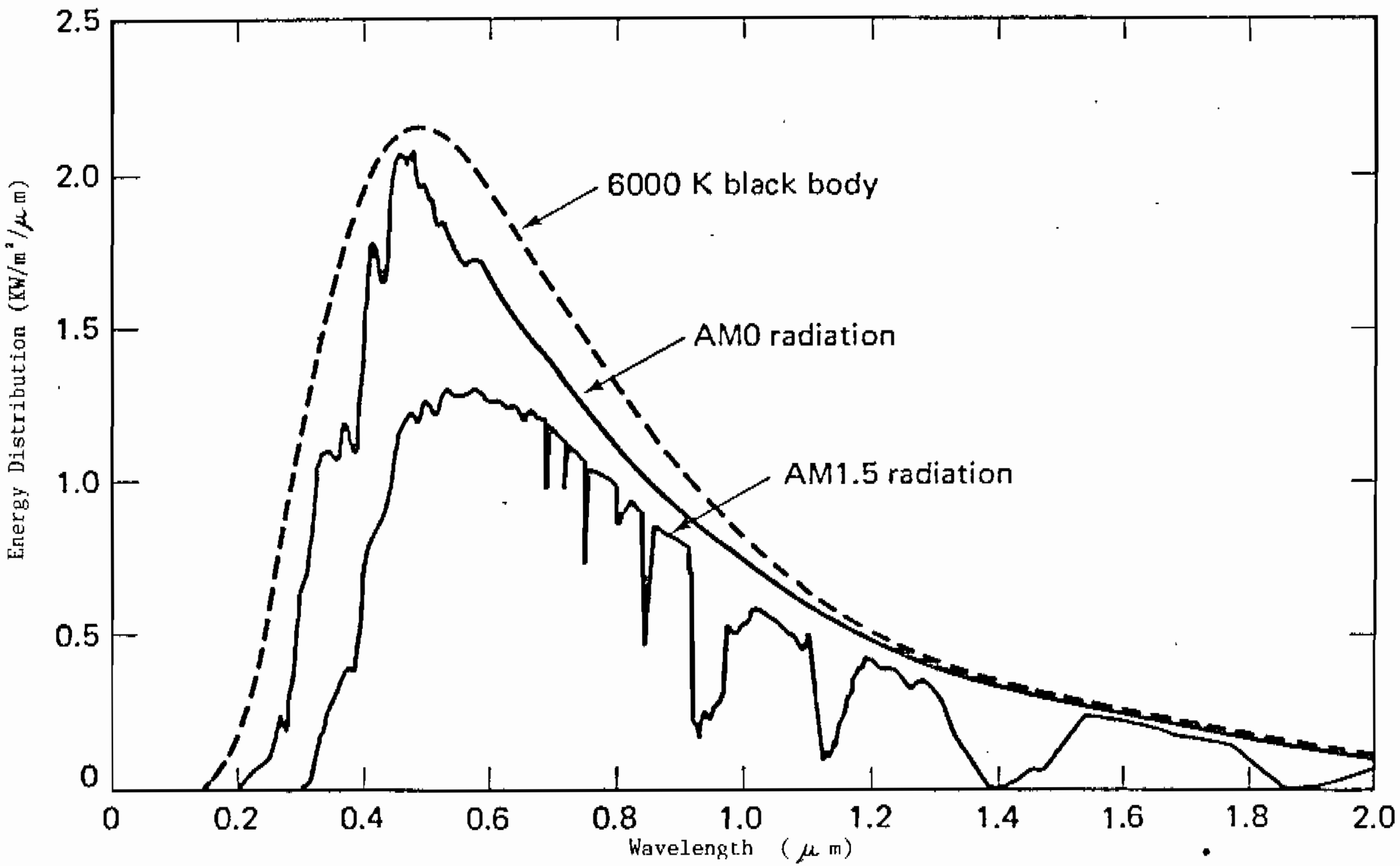

Figure 1-1 Solar Spectra at AM0 and AM1.5 Conditions and Black Body Spectrum (after[1])

A typical spectral distribution of sunlight at the earth's surface (AM 1.5) and outside the earth's atmosphere (AMO) together with the radiation distribution expected from the sun if it were a black body at 6000 K are shown in figure 1.1 .

1.2 INTERACTION OF SOLAR RADIATION WITH SEMICONDUCTOR :

When a ray of sunlight falls perpendicular on a flat section of semiconductor, a certain fraction of the incident power will be reflected and the remainder transmitted into the semiconductor. The transmitted sunlight can be absorbed within the semiconductor by using its energy to excite electrons from occupied low energy states to unoccupied higher energy states.

Reflection :

An absorbing material has an index of refraction, $\hat{n}_c$, which can be written in the form of a complex number as $\hat{n}_c = \hat{n} - L\hat{K}$, where $\hat{K}$ is the extinction coefficient.

The fraction of sunlight reflected for normal incidence is given by :

$$R = \frac{(\hat{n}-1)^2 + \hat{K}^2}{(\hat{n}+1) + \hat{K}^2} \qquad (1-1)$$

For silicon, over 30% of the incident sunlight is reflected as indicated in figure (1.2)

Absorption :

The transmitted sunlight is attenuated as it passes through the

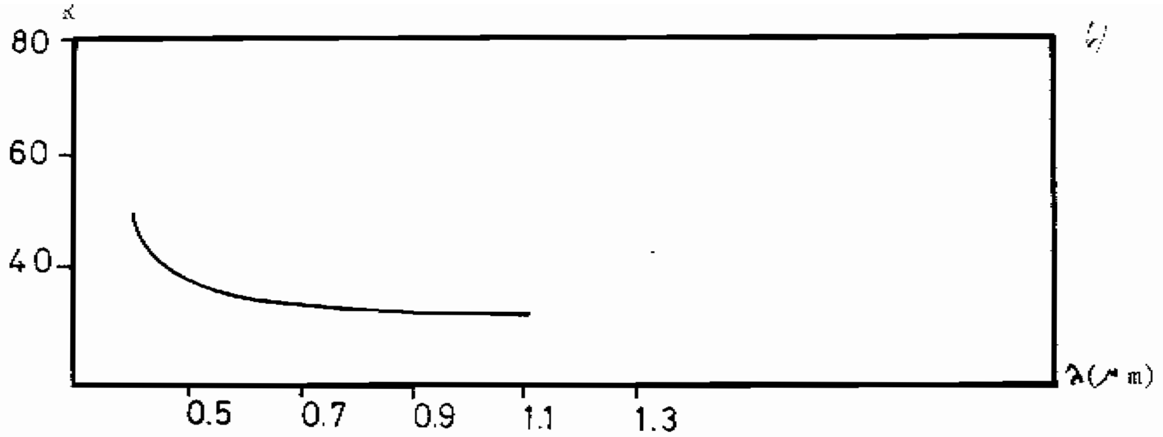

Figure 1-2 Reflectivity of Silicon as a Function of Wavelength [19]

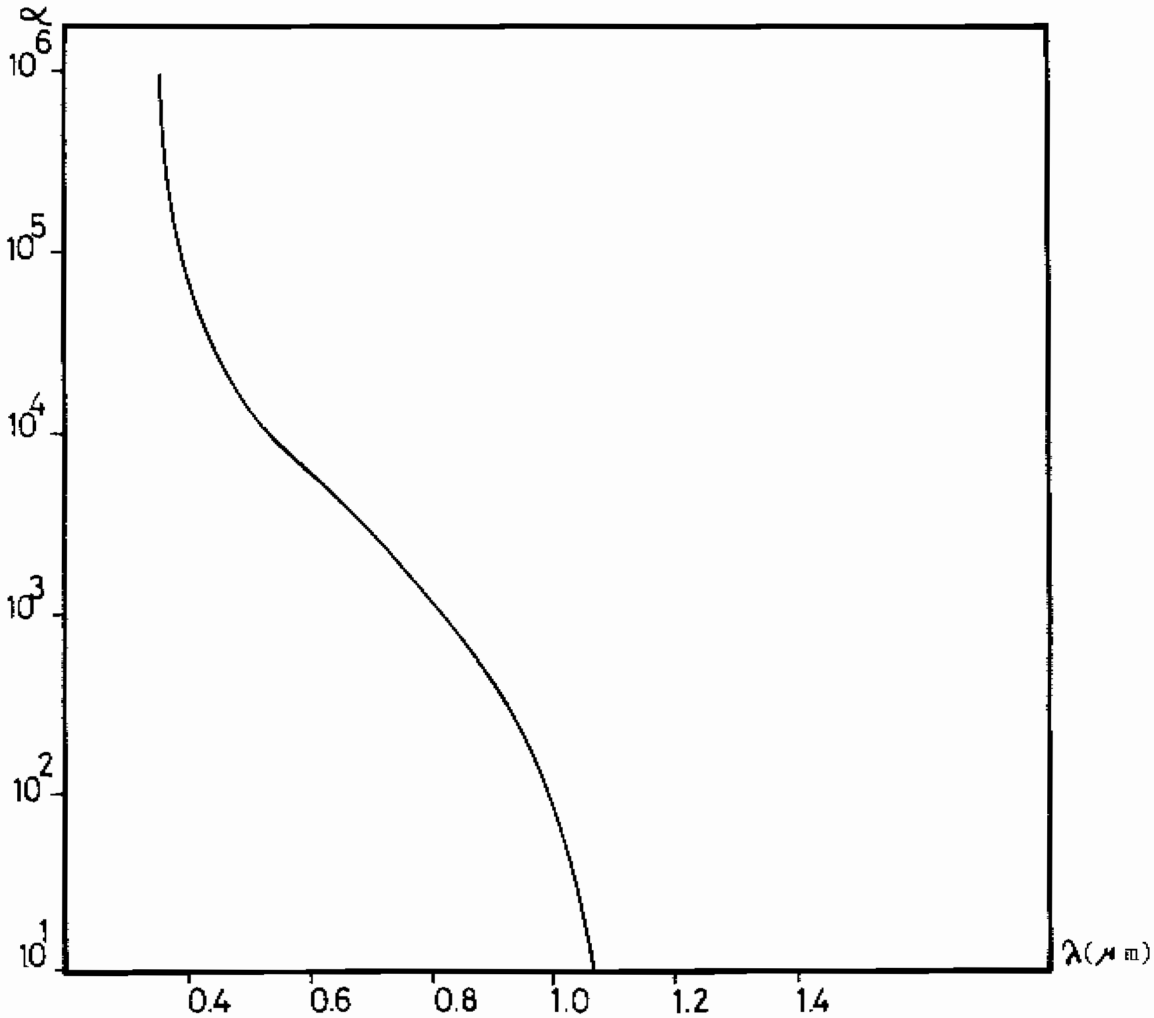

Figure 1-3 Absorption Coefficient of Silicon as a Function of Wavelength [9]

semiconductor. The rate of absorption of sunlight is exponentially proportional to its intensity for a given wavelength, this can be mathematically written as :

$$\Phi(x) = \Phi(x_o)\, e^{-\alpha(x-x_o)} \qquad 1-2$$

where : $\Phi(x)$ is the intensity of sunlight at distance x in the semiconductor ,

$\Phi(x_o)$ is the intensity of sunlight at the semiconductor surface

and α is the absorption coefficient

The absorption coefficient (α) can be expressed depending upon the extinction coefficient to be :

$$\alpha = \frac{4 \P F \hat{K}}{c} \qquad 1-3$$

where c is the velocity of light in vacuum and

F is the radiation frequency of sunlight

For silicon, the absorption coefficient variation versus the wavelength of the incident radiation is shown in figure (1.3).

1.3 SOLAR CELL ENERGY SYSTEMS :

A solar cell energy system in general consists of the cells, a storage medium, some form of back up either in the form of an auxiliary generator or the electricity supply grid, and the electrical loads, either DC or AC. Power conditioning and control are required to provide an interface between these different system elements. This is shown in figure (1.4)