

Absorption of Light in Silicon Nanowire Solar Cells: Designing Of Solar Cells

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ABSTRACT

In the proposed study, an investigation has been carried out in order to find a material efficient structure, capable of harnessing maximum solar spectrum. A material efficient structure designed using a thin film and Si nanowire. Silicon material is used as it leads to environmental friendly design. The principal objective of this study is to maximize the photon absorption, keeping reflection to a minimum. Such reflection are caused due to the regular surface of the thin film. As a thumb rule, the performance of the solar cell can be elevated by increasing the photon absorption phenomenon in the Si material. The proposed approach may yield an efficient hybrid structures (involving the combination of nanowire and thin film). Using such geometry, it is expected to achieve a higher efficiency (increased EHP generation), compared to nanowires or thin film alone. It is expected to achieve a higher Electron Hole Pair (EHP) generation or higher performance efficiency because of the two following reasons. First, Si nanowire exhibits low reflection due to low reflection area and the other being that such hybrid structure offers more active surface area for the EHP generation. Using this structure an internal quantum efficiency (IQE) upto 21% can be achieved which is quite good for commercially used solar cells.

KEY WORDS: Solar spectrum, Silicon nanowire, Electron Hole Pair (EHP) Generation, Internal Quantum Efficiency (IQE).

Section I

I. INTRODUCTION: NEED OF SOLAR ENERGY

Energy has been an integral part of one's life. It is a source of living for all creatures. Energy has found various applications in transportation, industries, agriculture, households and offices. In the pre-industrial area, energy was most commonly available to human in the form of fossil fuels. In 1970s, due to the limited availability and increase in cost of fossil fuels, need to find other forms of energy occurred (6,7,8). Although energy can have many forms like heat energy, electrical energy, nuclear energy and so on but sun's energy due to its abundance

and sustainability was the most favourite among the researchers. Apart from sunlight and solar heating, the energy of the sun is also available in the form of biomass and wind energy thus providing security for the future development and growth.

Section II

II. DESIGNING OF SOLAR CELL

Solar cells have been one of the best device in storing and utilizing the sun's light. In this paper, we have tried to design a solar cell using silicon material only. Only silicon was used because our aim was to make the structure cost efficient and Si on earth, after oxygen is the next material found in abundance. Various researchers have used aluminium doped zinc oxide (ZnO:Al) for fabrication purpose (3). Our designed structure may yield an efficiency upto 21% which is quite high compared to other designed cells using transparent conductive oxide, TCOs. In initial designing of a solar cell we had two options either to design a cell cuboidal in shape using Si material or to use a Si nanowire (NW) over this cuboidal structure. In both the designs only silicon material is used. The volume ($.205\mu\text{m}^3$) was kept constant in both the designs (4). Also the solar spectrum of wavelength 400nm to 1100nm (AM1.5) was chosen. At this air mass (AM) the sun is exactly above

the earth so chances of maximum absorption is increased. The thickness of the cell is not exceeded above 2500nm. The thickness has to be kept as less as possible for maximum absorption of photons.

Our main aim was to design a structure which is cost efficient as well as provide increased quantum efficiency (QE). The quantum efficiency is defined as the probability of an incident photon that results in generation and collection of an electron in the solar cell (1,2). There are two types of Quantum Efficiency are (a) External Quantum Efficiency (EQE). (b) Internal Quantum Efficiency (IQE). The photons that are absorbed results in generation and collection of electrons, which contribute to the solar cell current, thus IQE is used to study solar cell performance.

$$QE(\lambda) = \frac{P_{abs}(\lambda)}{P_{in}(\lambda)} \quad \text{Eq 1}$$

$P_{abs}(\lambda)$ is power of the absorbed light and $P_{in}(\lambda)$ is power of the incident light. Internal Quantum Efficiency (IQE) is given as

$$IQE = \frac{\text{Number of photons absorbed by the solar cell}}{\text{Number of photons falling onto the solar cell}} \quad \text{Eq 2}$$

Section III

III. SOLAR CELL USING ONLY SI THIN FILM

In designing of the solar cell using only Si thin film, a cuboid of dimensions (2500nm*2500nm*320nm) was taken. An illuminated source similar to that of solar spectrum within the range 400nm to 1100nm was applied over this thin film. As solar light consists of photons, these photons when fall upon the film get absorbed, reflected and transmitted (5). The %power photons transmitted, absorbed and reflected with respect to the wavelengths is shown in the figure 1(a), 1(b) and 1(c) respectively. For measuring the above values various DFT monitors were used on several places in the designed solar cells, especially above the film to measure the reflection, at the bottom of the film to measure the transmission and in between to determine the absorbed photons. As photons are a source of energy, the graph is determined between %power and wavelength. The overall energy is assumed to be 1. Thus once the transmission and absorption is determined, reflection can be found using $R=1-A-T$ (10,11). In designing this structure the main concern was whether the structure is correctly designed or not, and whether the photon absorption will be maximum. For this the absorption graph obtained was compared with the absorption curve obtained when Si was fabricated with ZnO (3). On comparison it was found that the curve obtained was nearly similar within the spectrum range 0.6 to 0.9 μm .

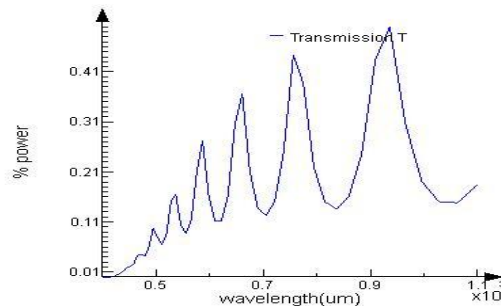


Fig.1(a). Percent power transmitted wrt wavelength range 400nm to 1100nm

The variations in other wavelengths is due to the TCO used in the reference curve. This showed us that the designed cell using Si thin film was nearly perfect to the fabricated design using ZnO. The internal quantum efficiency which depends upon the photons absorbed came out to be 17%-19%.

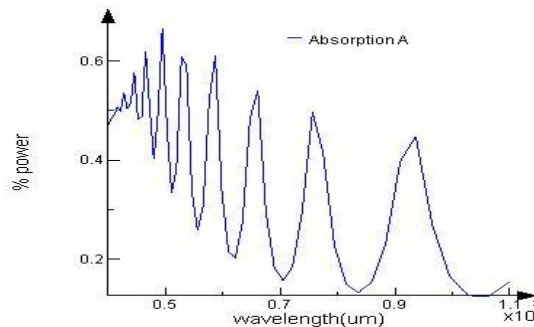


Fig1(b). Absorption curve for photons entering the solar cell

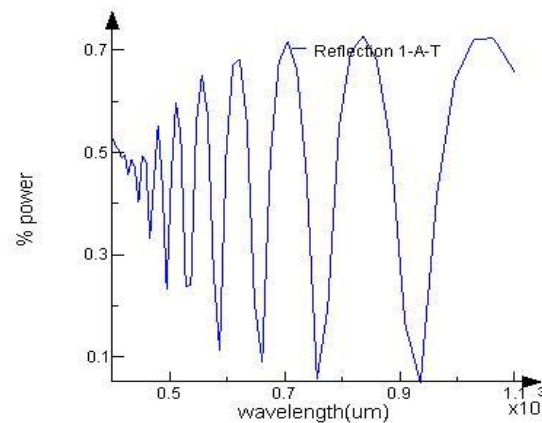


Fig1(c). Reflection of photons within the solar spectrum

3.1.Solar Cell designed using Si thin film and Si nanowire(NW)

A more efficient solar cell can be designed only by increasing the optical length of the solar cell. Optical length is the total length which the photon travels inside the solar cell. As volume and the chosen material is our most important constraint we designed a structure in which a Si nanowire of radius 35nm and height 1500 nm is taken. The dimensions of the Si thin film is reduced accordingly. The main advantage in this design is that as the thickness of the thin film is reduced, probability of photon absorption is increased, also a longer optical path is achieved. Using the above designed solar cell, an internal quantum efficiency of 21% can be achieved, which is higher than the structure designed using only Si nanowire. The absorption curve for the designed structure is shown in Fig2.

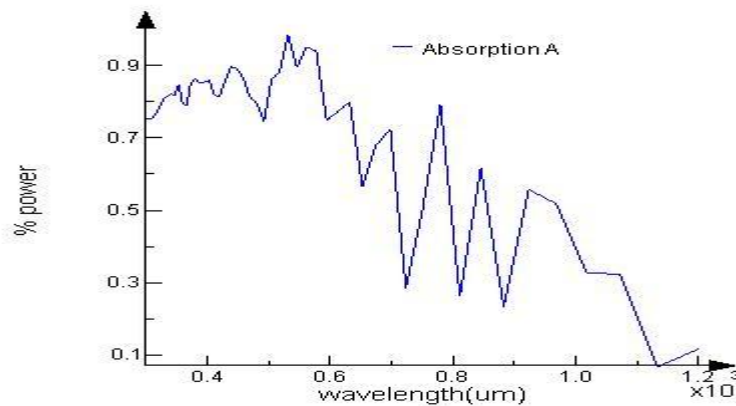


Fig2. Absorption curve for Si thin film and nanowire designed structure

Section IV

IV. CONCLUSION

Out of the two designed studied above we found that increase in the optical length of the solar cell plays an important role in increasing the photon absorption. Thus, the structure with Si film and nanowire came out to be most efficient as its optical length was increased. The designs are cost efficient as only Si has been used which only requires purification. Keeping volume constant and reducing the thickness of the substrate provided us a structure of Si thin film with Si nanowire which gave us the IQE of 21%. The comparison of the two designed structure showed us the absorption curve of photons within the solar cell. Through this absorption curve IQE was determined and hence the better structure was achieved.

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