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RESEARCH ARTICLE

HYBRID SOLAR MODEL USING NOVEL DESIGN AND POLARIZATION MODULE

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ABSTRACT

The abundance and high potential of Solar Energy makes it appropriate for commercial electricity purposes. The technology to access the high potential lacks efficiency by lot. This article is a description of a novel idea, which proposes the efficiency increase by at least 120% of present efficiency. It includes framing of concepts based on fundamentals of mechanisms in Solar Cell Module and Photonic Crystals. This hybrid model of Solar Cell introduces specialized domains for future research as well as gives an open challenge for the decade to fabricate it.

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INTRODUCTION

In the past decade, the shift from use of conventional energy sources, commonly termed as fossil fuels, to Non-Conventional energy resources has been drastic. Solar Energy contributes the highest among all the green energy sources and hence is rapidly taking up major sectors of industries. The present day solar technologies fail to provide power to sectors, where the power consumption is very high. Although the solar energy is abundant in the environment, the maximum efficiency of power extraction is 44.7% (http://phys.org/news/2013-09-world-solar-cell-efficiency.html) in laboratories and nearly 25% in practical applications. Solar Power Grids don't provide the desired output, due to such low efficiency, to match with the expected increase in power demand due to population rise. The present Research in solar cell efficiency enhancement is 90% into science of materials. Design and equipment engineering is of least concern of research. This paper deals with a hybrid design based on increasing efficiency using photon polarization. Before diving into the module, it is advisable to understand the fundamentals of losses, which are responsible for reducing the overall efficiency of Solar Cells.

A.Reflection losses

These losses occur, when high velocity photons bombard at the surface of the solar cell and reflect away rather than exciting electron-hole pairs. Solar cells inherit these losses as Silicon has a high reflective property (0:3). These losses count more than 30% of the total losses. Such a significant figure arises the necessity of Anti-Reflection Coating, which reduces the losses to 13% altogether.

B.Recombination losses

Photons having insufficient energy corresponding to band gap of silicon wafer are not able to excite electrons from valence band of P-Type material. This in turn leads to the reduction of efficiency.

C.Thermal losses

Higher the rate of electron excitation and electron-hole pair recombination, more the efficiency is reduced due to energy losses by heat and friction. Other minor losses are insignificant for the study of our hybrid model. The construction aspect categorizes the model in two modules – The Design Module and the Polarizer.

The design module

Equal sized solar panels are arranged in regular polygon base analog to a Lotus Flower. They are fit on the mechanism consisting of Servo and Stepper motors, which control their motion. The base itself has mirrors placed at selected angles. The module is automated to open into a horizontal layer of

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panels and close into shell as the intensity of daylight decreases.

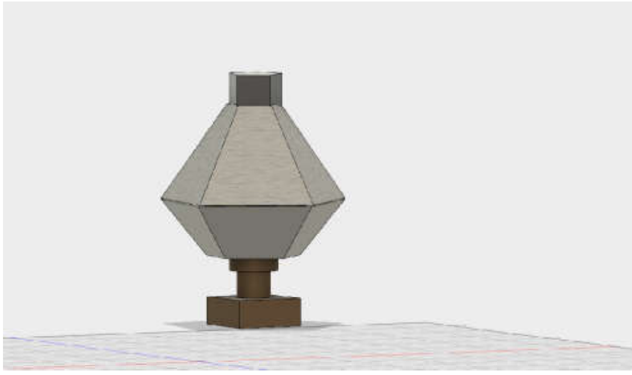

Fig.1. Overview of Module

The polarizer is placed on the top of the module. During the daylight, the motors are automated to nullify the contribution of polarizer by bringing it towards the base, thereby reducing the solid angle occupied by the polarizer. Inter-servos can be used to push the panels outwards increasing the surface area of the whole system.

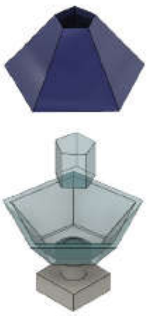

Fig.2. Insight

Polarizing unit

***A.* Need for Polarization**

A photon has to strike the silicon P-type material in selected configurations so as to excite the electrons. Most importantly, the efficiency is regulated by the photon's striking angle (Figure 3).

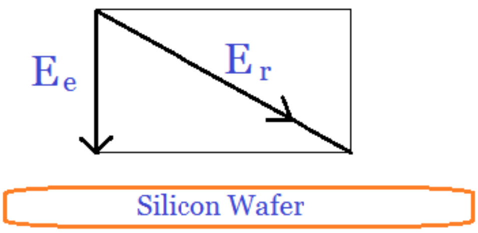

Fig.3. Striking Angle

Here in the figure, E_r represents the total energy of the photon moving in the r direction and E_e represents the effective energy contributing in exciting the electrons. In order to analyze the interference of a photon with the wafer unit cell, we must set the basis vectors. Following diagrams give a broad view of how the atoms are arranged in a unit cell.

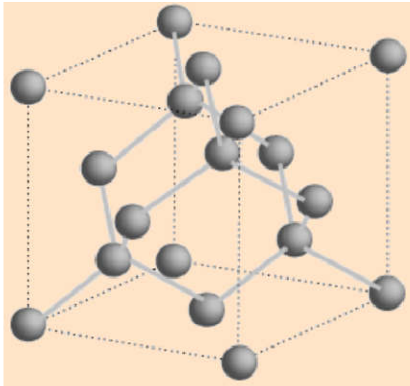

Fig.4. Unit Cell (http://hyperphysics.phy-astr. gsu.edu/ hbase/ Solids/sili2.html)

As we see from Figure 3, $\overrightarrow{E_T} = |E_T|\hat{r}$

$$\hat{r} = \alpha\hat{d}_1 + \beta\hat{d}_2 + \gamma\hat{h}$$

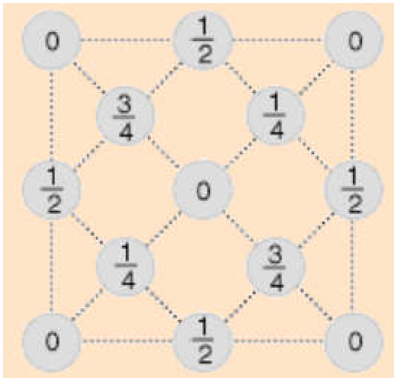

Fig.5. Atom Altitude (http://hyperphysics.phy-astr. gsu.edu/ hbase/ Solids/sili2.html)

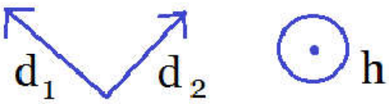

Fig. 6. Basic vectors

Figure 5 is the top view of a unit cell. The circle represents the atoms and the numerals represent the height of each atom from the base reference considering the height of unit cell to be 1 unit. The coordinate system established here consists of both the diagonal directions and the direction along depth as the basis vectors. Let us consider the alignment of photon vector in (d_1d_2) plane. We shall not deal with the motion along $\hat{h}$ as we have already realized, by figure 3, that the sine component of $\overrightarrow{E_T}$ contributes to provide the energy to excite the electrons. Any configurations of α and β will be superposition of the modes (1,0) and (0,1).

Power generated from a unit cell, considering the photon is in the either above mentioned modes is given by

$$P_c = \frac{K}{(\Delta h_u - \Delta h_l)|_d} \qquad (1)$$

Here, "K" is the proportionality constant. It is dependent of the losses discussed in the Introduction Section. $\_\_h_u$ and $\_\_h_l$ represents the height of uppermost atom and the height of lowermost atom in a single unit cell along a particular diagonal basis vector respectively. Power generated by the cell due to impact of one photon is:

$$\frac{P_c}{E_T \cdot \hat{h}} = \frac{K}{(\Delta h_u - \Delta h_l)|_d} \qquad (2)$$

Photon aligned along $\hat{d_1}$ will generate more power as compared to photon aligned along $\hat{d_2}$ as $(\Delta h_u - \Delta h_l)$ for $\hat{d_1}$ is ½ and $\hat{d_2}$ is ¾.

Hence, it is necessary for us to increase the striking angle and modulate the alignment of photon towards the mode (1,0) to increase the net efficiency of solar cell. Thereby, polarizer comes into picture.

B. Design

The apparatus used here is photonic crystal. Photonic Crystals are used to manipulate the motion of photons using differential dielectrics and number of dimensions of the material. Not all photons have the capability to pass through the crystals. Lenses mounted below the crystal gives directivity to the polarized photons such that they cover enough solid angle to cover all of the panels at night time. The number of lenses should be correspondence with the number of panels in order to maximize the efficiency by increasing the striking angle towards 90°.

System efficiency

Assuming the average polarization of photons to be along $d_{l,}$ power generated by a unit cell is 2K. Comparing it with power generated by cell on the impact of un-polarized photon, we find it to generate 120% of power. The mathematics is done as below:

$$\hat{r}(unpolarized) = \frac{1}{\sqrt{2}}\hat{d}_1 + \frac{1}{\sqrt{2}}\hat{d}_2 + 1\hat{h}$$

$$P_c = \frac{1}{2}\left(\frac{K}{\frac{1}{2}|_{\hat{d}1}} + \frac{K}{\frac{3}{4}|_{\hat{d}2}}\right)$$

$$P_c = 1.66K$$

We are taking the average contribution of the two orthogonal modes as the Δh exists only for either of the dimensions. It is also implied that this gain of 120% is corresponding to an infinite depth i.e., considering that if a photon doesn't interfere with the upper atoms of the volume, it will definitely interfere with some atom within the volume. A solar cell of definite volume is manufactured practically, further increasing the efficiency by a lot. Many unit cells in parallel and series in a solar cell will add to the net current generated, leading to the increase in power. It must be noted that the external voltage supplied to the system must be enough to stop electron – hole movement along the transverse direction of potential difference.

Theoretical assessments and comments

- The Designs presented (Fig. 1 & Fig. 2) are made on Fusion 360, a CAD environment. It demonstrates a five petal structure in which the base mirrors are inclined at 45°.
- Since the paper deals with the design aspect of the model, photonic crystals are not discussed in deep. This paper is modest approach to extract advantage from the fundamentals of photo-electronics.
- Future advances – The efficiency gain is irrespective of efficiency gain due to other domains of research – material development etc. Implying other research works on our model will result in exponential increase in efficiency.

Conclusion

The paper describes a novel hybrid design of a solar power source consisting of a polarization module. This module proves to increase the efficiency of the cell by more than 20% solely by the polarization and lancing. Even while considering the errors in our model to be as high as 10%. We gain the efficiency of more than 10%. This enormous increase in efficiency acts as a new step towards green energy.

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