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Solar Power Using Nanotechnology – A Review

Mahesh G¹, Harish S², Yashwanth Kutti P³, Ajith Sankar S⁴, Naveen M⁵

Student, Department of Mechanical Engineering, Velammal Engineering College, Chennai, India^{1, 2, 3, 4, 5}

ABSTRACT: This paper is an elucidation of the present scenario of the conventional solar power usage and the possible ideas of enhancing the efficiency of the same, by ways of what is known as one of the most effective technology of modern sciences – Nanotechnology. The impact of nano-level researches on the need-of-the-hour requirements is also being dealt on.

KEYWORDS: solar cell, plastic solar cell, quantum dots, black silicon, plasmonic cavity, nano antenna

I. INTRODUCTION

There have been researches going on topics pertaining the solar energy consumption. The sun's energy release is estimated to be about 10000 times that of the energy that could possibly be extracted from the conventional fossil fuels. However, on an average the energy being generated for domestic as well as industrial purposes is relatively less. It is researched that only about 10 – 25 % of the incident solar energy is being captivated for the energy production.

II. SOLAR POWER

Conventional solar cells are called photovoltaic cells. These cells are made out of semiconducting materials, usually silicon. When light hits these cells, they absorb energy through photons. This absorbed energy knocks out electrons in the silicon, allowing them to flow. By adding, different impurities to the silicon such as phosphorus, boron, etc. an electric field can be established. This electric field acts as a diode, because it only allows electrons to flow in one direction. Consequently, the end result is a current of electrons, better known to us as electricity.

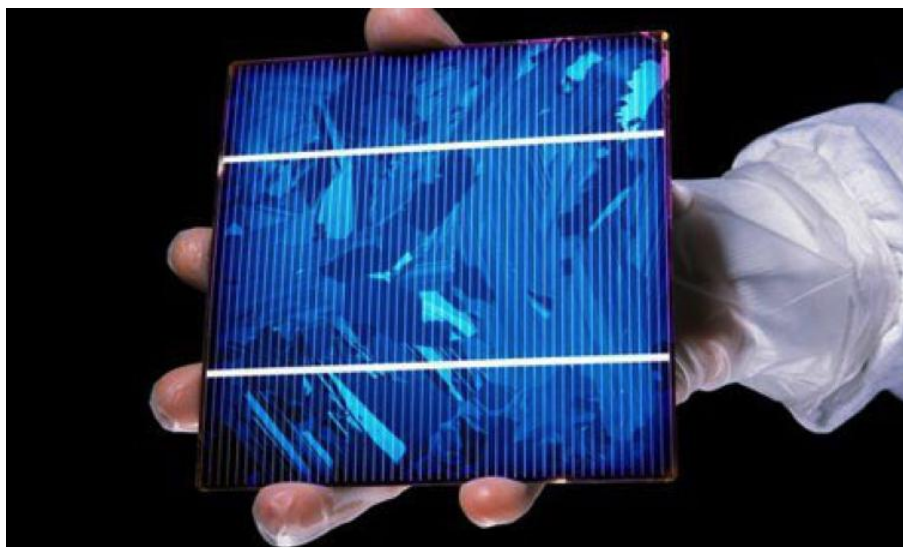


Figure 1. A typical solar cell

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Developing nations like India should rely on the renewable energy sources, for, the conventional sources are getting vanished slowly. Particularly, an equatorial nation like India, would expect to make the optimum usage of the vast source of solar power available. But the conventional methods have not been much into implementation, due to two straight reasons.

The first reason is that its efficiency is very less. Going deep into the working, we see that, in conventional silicon cells, used for solar power production, the incoming light photons are expected to have an optimum energy, so that it stimulates the photon. But, if the energy of the incident photon is less, the photon will easily penetrate and will pass through, without stimulating the electrons. On the other hand if the energy is in excess, there will be a loss of energy in the form of heat. This accounts for 70 % losses in the conventional solar cells, making them relatively less efficient.

The second reason is they are reasonably expensive. Fabrication of solar cell cost's tremendous. Its need in rural area is important. In remote places, wherein the households are spaced out, the conventional electric grid construction becomes tedious. When solar cells are used, the work gets easier and at the same time effect of pollution is reduced. But these remain unaffordable and hence less effective.

III. PLASTIC SOLAR CELLS

Nanotechnology promises its best application in the solar power generation. It is found that the manufacturing costs can be brought down and at the same time the efficiency of the solar panels can be enhanced to greater levels.

Chemists at the University of California – Berkeley, have discovered a way to make cheap plastic solar cells that could be painted on almost any surface! This perhaps opens the gate, for many other applications. The solar power though already being used in calculators and such mini devices, if nanotechnology is introduced the efficiency and the demerits relating to the battery usage can become negligible. Though this seems small, this can bring about a vast revolution in the field of electricity.



Figure 2. A nano cell connected by nano rods.

The plastic nano cells explained above, utilize tiny nanorods dispersed within in a polymer. The nanorods behave as wires because when they absorb light of a specific wavelength they generate electrons. These electrons flow through the nanorods until they reach the aluminum electrode, thus electricity is generated.

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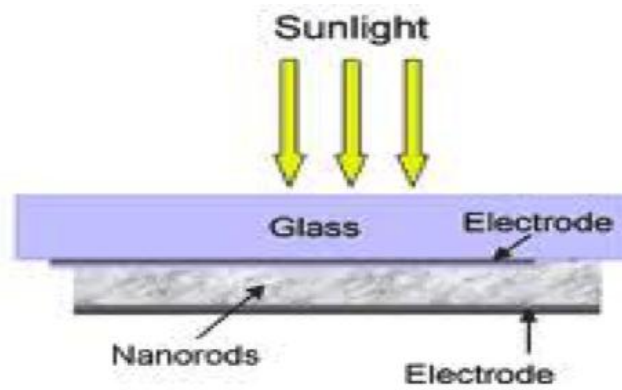


Figure 3. Working of a tiny plastic nano solar cell

IV. THE BLACK SILICON

As mentioned, one big demerit of conventional solar power cells is that they're less efficient, owing to the fact that they let the light of inappropriate wavelength to pass through it. To reduce the amount of sunlight that is reflected away from silicon solar cells, manufacturers usually add one or more layers of antireflective material. This however boosts the cost.

But recently, the National Renewable Energy Laboratory scientists proposed the following. To reduce the amount of light being scattered away from the silicon cells, a liquid process can be involved in, to put billions of nano-sized holes in each square inch of a solar cell's surface. Since the holes are smaller than the wavelength of the light hitting them, the light gets absorbed rather than getting reflected. The new material, which is called "black silicon," is nearly 20 percent more efficient than existing silicon cell designs.

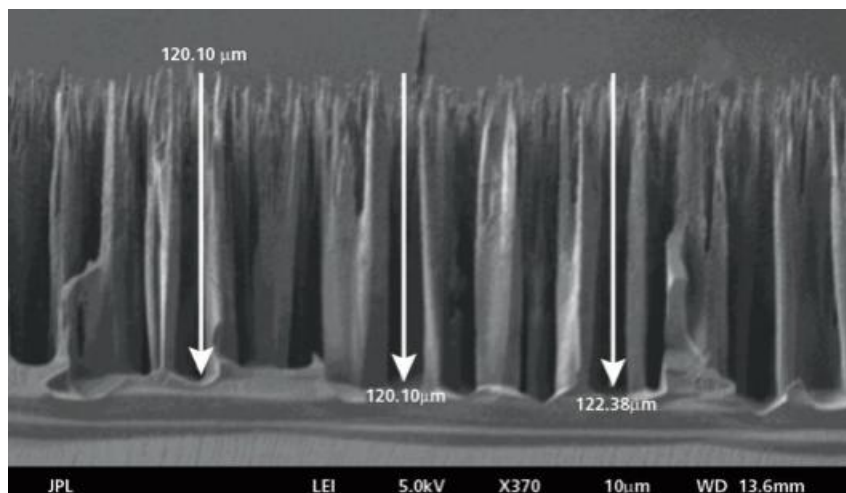


Figure 4. Black silicon at the nano scale

However this results in an unfavorable effect, called as Auger Recombination. Nano structures, as we know are basically characterized as having enormous surface area, which proves beneficial in many other applications, not here though. Due to the large surface area, the collection of photons and subsequently electricity is dramatically reduced. Later on, it was found through experiments that the auger recombination was due to the addition of too many dopant impurities. Thus, the problem was overcome by subsidizing the dopant concentration and hence 18.2 % efficient solar

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cells could be achieved, at a relatively low cost. This proves promising to have a large impact on the conventional solar cells and also the emerging nanotechnology involved ones. Many works are currently being carried out in order to increase the efficiency by optimizing the surface area and dopant concentration.

V. PLASMONIC CAVITY

Princeton University scholars have fabricated simple and excellent way of tripling the efficiency of the solar cells. This could perhaps be the future of the solar power. The researchers were able to increase the efficiency to about 175 % by using a nanostructured sandwich of a metal and plastic, in an appropriate manner, that collects and traps light. This sandwich structure called the sub wavelength plasmonic cavity has an ability of capturing eye opening 96 percent of incident sunlight light.

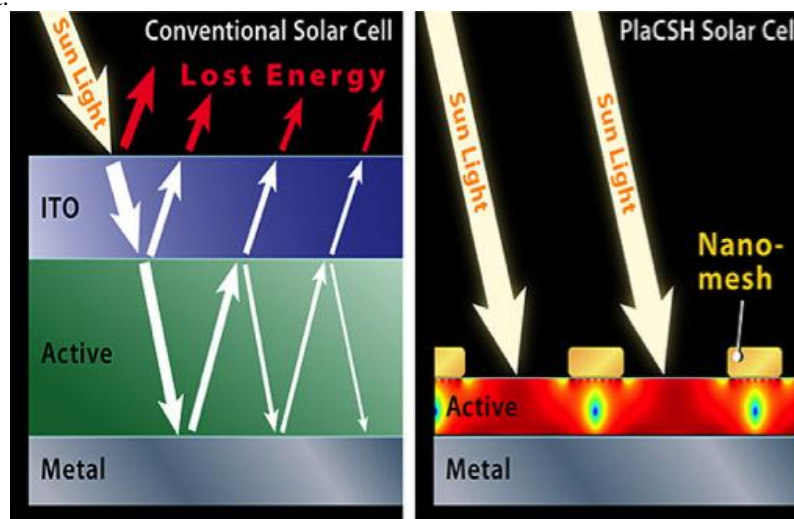


Figure 5. Difference between Conventional Solar Cell and PlaCSH Cell

When the sunlight is not direct and incident at larger angles, things only get better. With such huge benefits, the device structure goes fairly simple. The top layer, known as the window layer, of the new solar cell uses an incredibly fine metal mesh: the metal is 30 nanometers thick, and each hole is 175 nanometers in diameter and 25 nanometers apart. This makes a mesh window structure, which is placed close to the bottom layer of the sandwich.

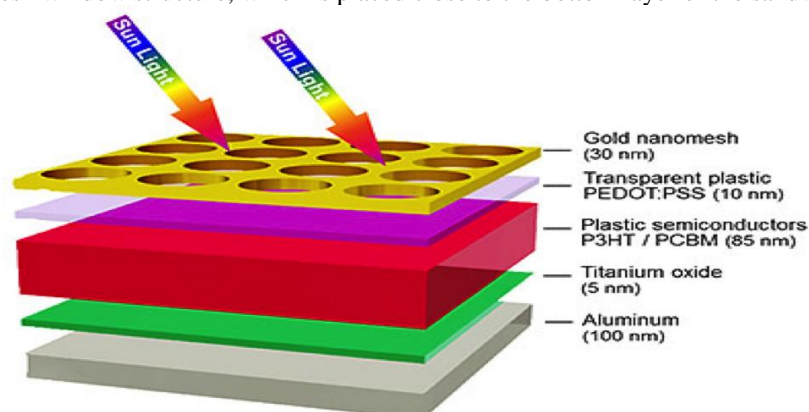


Figure 6. Composition of a PlaCSH Cell

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Between the two metals, a plastic of 85 nm thick is inserted. The spacing of the mesh, the thicknesses of the sandwich, the diameter of the holes are all smaller than the wavelength of the light being collected. This is critical because light behaves in very unusual ways in sub wavelength structures. Chou's team discovered that using these sub wavelength structures allowed them to create a trap in which light enters, with almost no reflection. These nano plasmonic cells can be manufactured cost effectively also.

VI. NANO ANTENNA ARRAYS

For years, scientists have studied the potential benefits of a new branch of solar power technology that relies on incredibly small nanosized antenna arrays that are theoretically capable of harvesting more than 70 percent of the sun's electromagnetic radiation and simultaneously converting it into usable electric power.

The nanoantenna also known as "rectenna" because of their ability to both absorb and rectify solar energy from alternating current to direct current must be capable of operating at the speed of visible light and be built in such a way that their core pair of electrodes is a mere 1 or 2 nanometers apart.



Figure 7. Nano Antenna Rays

It is through atomic layer deposition that scientists can finally fabricate a working rectenna device. In a rectenna device, one of the two interior electrodes must have a sharp tip, similar to the point of a triangle. The purpose is getting the tip of that electrode within one or two nanometers of the opposite electrode, something similar to holding the point of a needle to the plane of a wall.

The size of the gap is critical because it creates an ultra-fast tunnel junction between the rectenna's two electrodes, allowing a maximum transfer of electricity. The nanosized gap gives energized electrons on the rectenna just enough time to tunnel to the opposite electrode before their electrical current reverses. The triangular tip of the rectenna makes it hard for the electrons to reverse in direction, thus capturing the energy and rectifying it as a unidirectional current. However, the fabrication of these antenna arrays is truly challenging. Moreover, the minimum distance achieved till now is simply 10 times larger than the required one. The process is self-limiting too. It stops at 1.5 nm separations.

VII. QUANTUM DOTS

Quantum confinement can lead to increased Photovoltaic efficiency and could lead to increase in solar cell efficiency. Tiny quantum dots just a few nanometers in diameter can do great things when it comes to generating electricity. Researchers at the National Renewable Energy Laboratory (NREL) have certified the first all quantum-dot photovoltaic cell, which was based on lead sulfide and demonstrated reasonable performance, for an initial efficiency measurement along with good stability. The certified open-circuit voltage of the quantum dot cell is greater than that possible from bulk lead sulfide, because of quantum confinement. These results increase the motivation to explore

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quantum dots for their capacity to deliver multiple electrons from each photon, a phenomenon that if applied to solar cells could greatly improve, even double their efficiency.

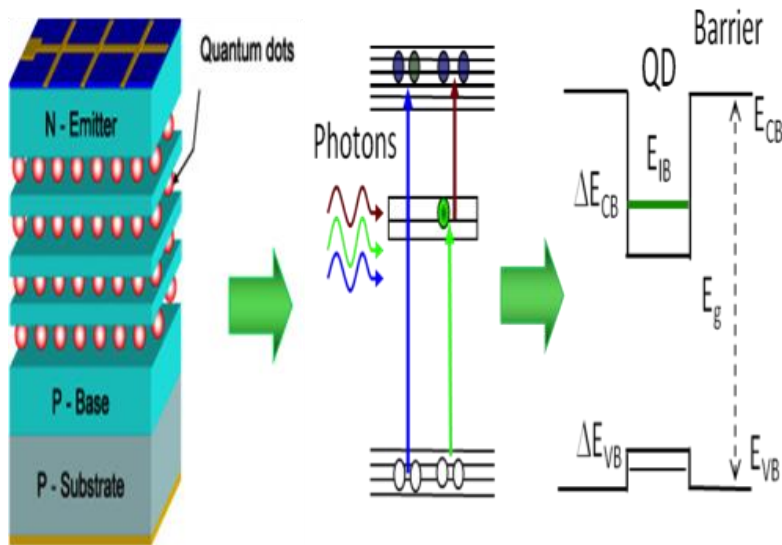


Figure 8. A Schematic Representation of operating principle and energy band diagram of proposed III – (As, SB) Solar

Quantum dots have such great photon to electricity potential because when a single photon of light, of sufficient energy is absorbed by a quantum dot, it produces more than one bound electron-hole pair, or exciton. The process is called multiple exciton generation.

VIII. CONCLUSION

One of man's enormous technical achievements is undoubtedly harnessing the omnipotent solar power. However nature proves symmetrical as always. The ill effects of the nanotechnologies are not completely negligible too. However, the present need seems to seek the best of technologies arising, provided the ill effects on environment are negligibly less. In this regard, nanotechnology surely proves worth it. Control of expenses is not optimum yet. On the whole, the reduction in size of a device to a large extent eventually makes it more efficient and reliable.

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