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Use of Nanotechnology in Solar Cells: The Indian Scenario

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Abstract: The earth receives about 173000 Terawatts of solar energy. This amounts to 10,000 times more power than the total power used by the world population. Most of the solar energy goes unused. It is said that we use one by ten thousand times of the solar energy only that reaches on the earth. The whole world is now trying to convert solar energy in usable form. India is also emerging in this field. The efficiency of conventional solar cells to convert solar energy in usable form is limited. On cloudy days, conversion from solar to electrical energy becomes difficult and less efficient. To overcome these problems and to increase the efficiency of the solar cells, nanotechnology is applied. Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications" [National Nanotechnology Initiative (NNI) 2008]. Nanotechnology has become one of the most explored technologies of the 21st century. It deals with manipulating matter at nanoscale. These nanosized particles follow physical and chemical laws which are quite different from the laws applicable for materials in the macroscopic world. Due to enormous surface area to volume ratio, nanoparticles exhibit exclusive properties. Unique properties of nanomaterials include, high surface to volume ratio, small size, well-organized structure. Before introducing new solar products, which use nanotechnology, it is necessary to explain the basicprocess that a nano solar cell uses. This article attempts to discuss a number of nano solar cells, their design and working principle.

Keywords: plastic solar cells, solar energy, nano rods, quantum confinement, quantum dots

I. INTRODUCTION

Conventional solar cells: These are known as photovoltaic cells. These cells are madeout of semiconducting material, usually silicon. When light falls on the cells, they absorb energy though photons.This absorbed energy produces free electrons in the silicon, allowing them to flow. By adding different impuritiesto the silicon an electric field can be generated. This electric field acts as a diode. It only allows electrons to flow in one direction, thus producing electric current. One of the biggest disadvantages of photovoltaic cells is high cost associated with manufacturing when compared to the cost of fossil fuel. The surface of these cells reflects 2% - 10% of incident sunlight resulting decrease in efficiency. Photons must have the right energy to produce free electrons. If the photon has less energythan the band gap energy then it will pass through. If photon has more energy than the band gap extra energy will bewasted.Around 70 percent of the radiation energy incident on the cell is lost.

Drawbacks of conventional solar cells: Conventional solar cells have two main drawbacks: They can only achieve efficiencies around tenpercent and they are expensive to manufacture rather than reflected (Fig 1)

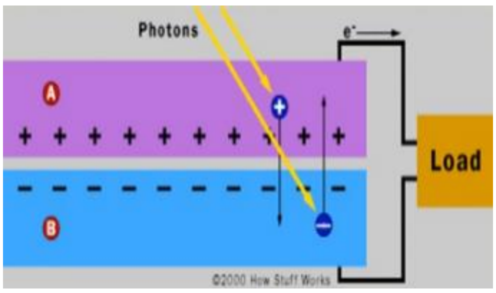

Fig. 1 A conventional solar cell

II. SOLAR NANOTECHNOLOGY

Use of Silicon nanoparticles: Some useful properties of silicon nanoparticles are they have an active surface state, unique photoluminescent and biocompatible properties. Silicon nanoparticles are used into lithium-ion batteries, solar energy cells and luminescent display devices. The size and microstructure of silicon nanoparticles are highly specific when used in solar cells.

Nano silicon films use silicon particles within the 2 to 10 nanometer range having good antireflective properties. These nano devices reduced the use of complicated integrated circuits.

Use of Plastic: This isathin,flexible,solarpanelmadeupofnanoscaleTitanium/dyecomplex.TiO_2nanoparticles absorb photons from sunlight with energies equal to or higher than its band gap (>3.0 eV). Electronsare excited from the valence band into the conduction band creatingpositiveholesinthevalenceband.Thesechargecarrierscanrecombine dissipating the input energy as heat, or get trapped and react with electron donors or acceptorsadsorbed on the surface of the photo catalyst. The competition between these processes determines the overallefficiency for variousapplicationsofTiO_2 nanoparticles. Extensive research has been carried out with titanium nanomaterials. TiO_2 can absorb lightin the visible light region to produce electricity. Hence it is effective in producing powernearly all day long. The single junction common silicon plastic solar cell can produce a maximum 0.5 to 0.6 volts (approx.) open-circuit voltage. On normal days and even on cloudy days infrared plastic solar cells are very efficient and can easily convert the sun light into the electrical power. Solar plastic cells are more efficient (up to 30%) in comparison with other solar cells. It is thin and flexible in contrast with rigid, black,silicon solar panels. The disadvantage of plastic cells is more expensive than other kind of solar cells. The life span of plastic cells is relatively short and need constant monitoring.

Nano Wires: Nano wires have a width which ranges from forty to fifty nanometers, but their length is not in the nano range. They can be made as long as required. They are especially attractive for nanotechnology applications. Nanowires reduce the size of electronic devices and increase the efficiency of those devices. The nanowires have diameters and lengths on the order of 10 nm and 10µm, respectively. The sizes of nanowires are typically large enough (>1 nm in the quantum confined direction) to have local crystal structures closely related to their parent materials. The smaller and smaller length scales now being used in the semiconductor, opto-electronics, and magnetic industries.

Nano rods: These solar cells utilize tiny nanorods dispersed (Fig 2) *w*ithin a polymer. They absorb light of a specific wavelength to generate free electrons. These free electrons flow through the nanorods due to quantum confinement and reach the aluminum electrode forming current. This type of cell is cheaper to manufacture than conventional ones. These solar cells are not made from silicon and manufacturing of these cells does not require expensive equipment. The nanorods can be "tuned" to absorb light. This significantly increase the efficiency of the solar cell because more wavelength range of the incident light can be utilized.

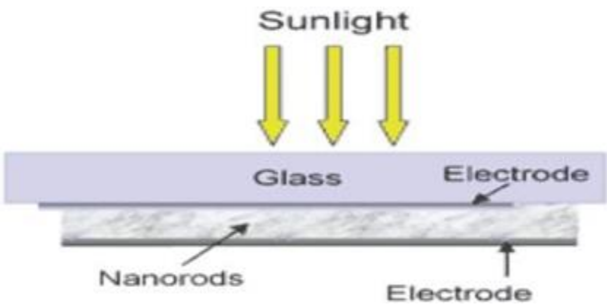

Fig. 2 Diagram of a nanosolarcell.

III. DYE-SENSITIZED SOLAR CELLS (DSSCS)

Dye-Sensitized Solar Cells (DSSCs): Third-generation solar cells (dye-sensitized solar cells, DSSCs) primarily include advanced nanomaterials and promise to reduce the cost of solar cell manufacture. DSSCs are semi-transparent and flexible thin film solar cells more efficient than rigid silicon-based photovoltaic cells. DSSCs function even in low-light and cloudy conditions. Furthermore, they are cheaper, simpler to produce and absorb more sunlight than silicon-based solar panels. DSSCs use porphyrin dye in liquid electrolyte (Fig 3).

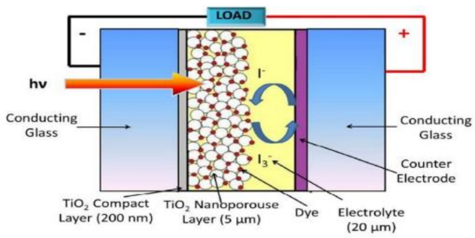

Fig. 3 Structure of Dye-Sensitized Solar Cells (DSSCs)

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Graphene in Dye-Sensitized Solar Cells: Examples of transparent electrodes are indium tin oxide (ITO). ITO films are brittle and unstable at high temperatures. Graphene, a potential nano material has high electron mobility and transparency (>90%). So, graphene is being explored as a possible replacement material of ITO. Researchers have previously achieved a PCE of 8.44% by using graphene-based materials as transparent conducting electrodes. The counter electrode in DSSCs captures electrons from the external circuit and injects them into the electrolyte. Graphene has great electrocatalytic activity and excellent conductivity, making it a possible candidate for Pt as a counter electrode.

Quantum Dots Sensitized DSSCs: Quantum dots are semiconductor nanoparticles with sizes ranging from 2 to 20 nm. They exhibit unusual behaviour due to quantum confinement. Fourth-generation solar cells use quantum dot sensitized solar cells (QDSSC). These cells, contain a photoanode, a cathode, and an electrolyte. The photosensitizer is a layer of quantum dots (Fig.4).

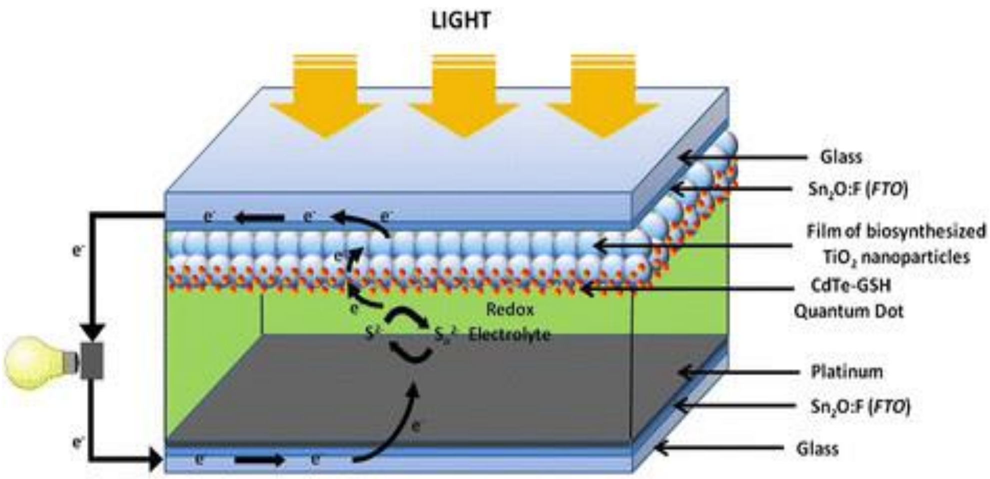

Fig 4. Structure of a Quantum Dot Sensitized Solar Cells (DSSCs)

MXenes in Dye-Sensitized Solar Cells: The most expensive component in DSSCs is the counter electrode (platinum), the catalyst layer and the transparent conducting oxide (TCO) layer. MXenes exhibit good thermal and electrical conductivity, strong catalytic activity, and flexibility. MXene electrode have 8.68% conversion efficiency and can replace Pt-based electrode.

IV. COMMERCIAL ADOPTION OF NANO SOLAR CELLS: THE INDIAN SCENARIO

Nano solar cells have lowermanufacturingcostsandmoreflexibilityinmanufacturing and is the future of non-conventional energy. Graphene Flagship, a nano technology farm has built the world's first big area (0.5 m^2) solar panels using graphene. The panel was successfully installed on the Greek island of Crete. It contains nine graphene panels with a total panel size of 4.5 m^2. The peak power production was more than 250 Watt, and an excellent PCE of 12.5%. The project aims at lowering the cost of energy production. Another commercial example is a collaboration between ZNShine and Bharat Heavy Electrical Limited. They applied graphene coating on a panel to operate as a self-cleaning coating and enhance power conversion efficiency.

Some nanotechnology-based solar cell producers include Trina Solar, Solargise, Jinko Solar, NextEra Energy, First Solar Inc., Canadian Solar, and Hanwha-Q Cells. India has added about 11.1 GW of solar capacity from January 2021 till November 2021 which is 249% higher than the total installation that occurred in the year 2020.

The Ministry of New and Renewable Energy (MNRE) stated that until November 2022 India will reach the installation capacity of approximately 104GW. Solar energy contributes of about 45% of the total Renewal energy share. Next renewable energy sources are wind energy (38%), biopower (10%), and hydropower (5%). Over the past two decades solar panels becomes more affordable to homeowners, businesses and industries because it helps to save electricity bills without harming the environment. The government is also encouraging people to install solar panels to cut down on the use of fossil fuel.

IV. CONCLUSION

The effects that a low cost, efficient solar cell would have tremendous effect on society. It would help preserve the environment, provide rural areas with electricity, and transform the electronics industry. These would be a result of nanotechnology.

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