Nanotechnology and its Applications in Solar Cells

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Abstract—A major technological challenge for human race in 21st century is the transition from fossil-fuel-based energy economy to renewable (sustainable) energy one. Current solar power technology has little chance to compete with fossil fuels or large electric grids. Today’s solar cells are simply not efficient enough and are currently too expensive to manufacture for large-scale electricity generation. Cost is an important factor in the success of any solar technology. However, potential advancements in nanotechnology may open the door to the production of cheaper and slightly more efficient solar cells. Inexpensive solar cells would also help provide electricity for rural areas or third world countries. The solar cell industry has grown quickly in recent years due to strong interest in renewable energy and the problem of global climate change. Nanotechnology has already shown huge breakthroughs in the solar field. Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost. Utilizing nanotechnology in inexpensive solar cell would help to preserve the environment. This paper provides an overview of the current solar cell technologies and their drawbacks. Then, it explores the research field of nano solar cells and the science behind them. The potential implications that these technologies would have on our society are also discussed.

Keywords—Nanotechnology, Renewable Energy, Solar Cell

I. INTRODUCTION

RENEWABLE energy is increasingly viewed as critical-ly important globally. Solar cells, or photovoltaic, convert the energy of the sun into electricity [1, 2]. Before introducing new solar products which use nanotechnology, it is necessary to explain the basic process that a normal solar cell uses. Conventional solar cells are called photovoltaic cells. These cells are made out of semiconducting material, usually silicon. When light hits the 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 or boron, an electric field can be established. This electric field acts as a diode, because it only allows electrons to flow in one direction [1]. Consequently, the end result is a current of electrons, better known to us as electricity.

In theory all parts of the visible spectrum from near infrared to ultraviolet can be harnessed. The mainstay at present is the silicon solar cell which accounted for 90% of the market in 2004. However these are costly to manufacture and have limited efficiency (around 14% in most production modules, and up to 25% in the lab) [2].

Conventional solar cells have two main drawbacks: they can only achieve efficiencies around ten percent and their expensive manufacturing cost. The first drawback, inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy then it will pass through. If it has more energy than the band gap, then that extra energy will be wasted as heat. These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell [3].

Nano particles are motes of matter tens of thou-sands of times smaller than the width of a human hair. Because they're so small, a large percentage of nano particles' atoms reside on their surfaces rather than in their interiors. This means surface interactions dominate nano particle behavior. And, for this reason, they often have different characteristics and properties than larger chunks of the same material. Nanotechnology (“nano”) incorporation into the films shows special promise to both enhance efficiency and lower total cost[4]. Many nano-structured materials are now being investigated for their potential applications in photovoltaic. Nano-structured layers in thin film solar cells offer three important advantages. First, due to multiple reflections, the effective optical path for absorption is much larger than the actual film thickness. Second, light generated electrons and holes need to travel over a much shorter path and thus recombination losses are greatly reduced. As a result, the absorber layer thickness in nano-structured solar cells can be as thin as 150 nm instead of several micrometers in the traditional thin film solar cells. Third, the energy band gap of various layers can be tailored to the desired design value by varying the size of nano-particles. This allows for more design flexibility in the absorber and window layers in the solar cells [5].

Thin film is a more cost-effective solution and uses a cheap support onto which the active component is applied as a thin coating. As a result much less material is required (as low as 1% compared with wafers) and costs are decreased. Most such cells utilize amorphous silicon, which, as its name suggests, does not have a crystalline structure and consequently has a much lower efficiency (8%), however it is much cheaper to manufacture[6,7]. Consequently, according to the Lawrence
Berkeley National Laboratory, the maximum efficiency achieved today is only around 25 percent [8]. Mass-produced solar cells are much less efficient than this, and usually achieve only ten percent efficiency.

II. RESULTS AND APPROACH

Current solar cells cannot convert all the incoming light into usable energy because some of the light can escape back out of the cell into the air. Additionally, sunlight comes in a variety of colors and the cell might be more efficient at converting bluish light while being less efficient at converting reddish light. Lower energy light passes through the cell unused. Higher energy light does excite electrons to the conduction band, but any energy beyond the band gap energy is lost as heat. If these excited electrons aren’t captured and redirected, they will spontaneously recombine with the created holes, and the energy will be lost as heat or light [9].

A. Improving the Efficiency of Solar Cells by Using Semiconductor Quantum Dots (QD)

One of the starting point for the increase of the conversion efficiency of solar cells is the use of semiconductor quantum dots (QD). By means of quantum dots, the band gaps can be adjusted specifically to allow sun light to pass through, and thus increase the efficiency of the solar cells. These so called quantum dot solar cells are, at present, subject to basic research. As material systems for QD solar cells, III/V-semiconductors and other material combinations such as Si/Ge or Si/Be Te/Se are considered. Potential advantages of these Si/Ge QD solar cells are:

1) Higher light absorption in particular in the infra-red spectral region,
2) Compatibility with standard silicon solar cell production (in contrast to III/V semiconductors),
3) Increase of the photo current at higher temperatures,
4) Improved radiation hardness compared with conventional solar cells.

B. Nanotechnology Improves the Solar Cell

Present available nanotechnology solar cells are not as efficient as traditional ones, however their lower cost offsets this. In the long term nanotechnology versions should both be lower cost and, using quantum dots, should be able to reach higher efficiency levels than conventional ones. [10]

To coat the nanoparticles with quantum dot tiny semiconductor crystals. Unlike conventional materials in which one photon generates just one electron, quantum dots have the potential to convert high-energy photons into multiple electrons. Quantum dots work the same way, but they produce three electrons for every photon of sunlight that hits the dots. Electrons move from the valance band into the conduction band. The dots also catch more spectrums of the sunlight waves, thus increasing conversion efficiency to as high as 65 percent. Another area in which quantum dots could be used is by making so-called a hot carrier cells. Typically the extra energy supplied by a photon is lost as heat, but with a hot carrier cells the extra energy from the photons result in higher-energy electrons which in turn leads to a higher voltage [10, 11].

The transport of electrons across the particle net-work is the major problem in achieving higher photo conversion efficiency in nanostructured electrode. Utilization of CNT network support to anchor light harvesting semiconductor particles by assisting the electron transport to the collecting electrode surface in DSSC. Charge injection from excited CdS into SWCNT excitation of CdS nanoparticle. When CNTs attached in Cdse & CdTe can induce charge transfer process under visible light irradiation. The enhanced interconnectivity between the titanium dioxide particles and the MWCNTs in the porous titanium dioxide film was concluded to be the cause of the improvement in short circuit current density. [11]

C. Reduction of the Cost of Solar Cells by Nanotechnology

Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost. 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. These new plastic solar cells achieve efficiencies of only 1.7 percent; however, Paul Alivisatos, a professor of chemistry at UC Berkeley states, “This technology has the potential to do a lot better. There is a pretty clear path for us to take to make this perform much better” [12,13].

Picture of a solar cell, which utilizes nanorods to convert light into electricity, is shown in fig.1.

These new plastic solar cells utilize tiny nanorods dispersed within in a polymer. The nanorods behave as wires because when they absorb light of a specific wave-length they generate electrons. These electrons flow through the nanorods until they reach the aluminum electrode where they are combined to form a current and are used as electricity [12,13].

![Fig. 1 Picture of a solar cell, which utilizes nanorods to convert light into electricity](image)
This type of cell is cheaper to manufacture than conventional ones for two main reasons. First, these plastic cells are not made from silicon, which can be very expensive. Second, manufacturing of these cells does not require expensive equipment such as clean rooms or vacuum chambers like conventional silicon based solar cells. Instead, these plastic cells can be manufactured in a beaker.

Another potential feature of these solar cells is that the nanorods could be ‘tuned’ to absorb various wave-lengths of light. This could significantly increase the efficiency of the solar cell because more of the incident light could be utilized. According to a 2001 report, “The Societal Implications of Nanoscience and Nanotechnology,” by the National Science Foundation, if the efficiency of photovoltaic cells was improved by a factor of two using nanotechnology, “The role of solar energy would grow substantially”[14]. In fig. 2, a diagram of a nano solar cell is shown.

Finally, inexpensive solar cells could also revolutionize the electronics industry. Solar cells could be imbedded into clothing and be ‘programmed’ to work for both indoor light and sunlight.

A comparison of different photovoltaic cells from different directions is given in table 1.

III. CONCLUSION

1) Inexpensive solar cells, which would utilize nanotechnology, would help preserve the environment.

2) Coating existing roofing materials with its plastic photovoltaic cells which are inexpensive enough to cover a home’s entire roof with solar cells, then enough energy could be captured to power almost the entire house. If many houses did this then our dependence on the electric grid (fossil fuels) would decrease and help to reduce pollution.

3) Inexpensive solar cells would also help provide electricity for rural areas or third world countries. Since the electricity demand in these areas is not high, and the areas are so distantly spaced out, it is not practical to connect them to an electrical grid. However, this is an ideal situation for solar energy.

4) Cheap solar cell could be used for lighting, hot water, medical devices, and even cooking. It would greatly improve the standard of living for millions, possibly even billions of people.

5) Flexible, roller-processed solar cells have the potential to turn the sun’s power into a clean, green, convenient source of energy. Even though the efficiency of Plastic photovoltaic solar cell is not very great, but covering cars with Plastic photovoltaic solar cells or making solar cell windows could be generate the power and save the fuels and also help to reduce the emission of carbon gases.

References


