Solar Cell Review: The Green Environmental Energy Resource with Nanomaterial

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Introduction:

At present the world is in great need of technologies providing renewable energy. The challenge is how to meet the increasing global energy consumption without sacrificing our future environment. More solar energy strikes the earth in one hour than all the energy consumed on the earth in a year [1]. All wind, fossil fuel, hydro and biomass energy have their origins in sunlight. Solar energy falls on the surface of the earth at a rate of 120 petawatts, (1 petawatt = 1015 watt). This means all the solar energy received from the sun in one day can satisfied the whole world's demand for more than 20 years. Solar energy is clean and renewable. It doesn't emit carbon dioxide during operation. Solar energy provides clean abundant energy and is therefore an excellent candidate for a future environmentally friendly energy source. Solar cells are devices that are able to convert solar energy into electrical energy. The aim of solar cell research is to increase the solar energy conversion efficiency at low cost to provide a cost-effective sustainable energy source.

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 though 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 [2].Conventional solar cells have two main drawbacks: they can only achieve efficiencies around ten percent and they are expensive to manufacture. 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. Scott Aldous, an engineer for the North Carolina Solar Center explains that, "These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell" [2]. Consequently, according to the Lawrence Berkeley National Laboratory, the maximum efficiency achieved today is only around 25 percent . Mass-produced solar cells are much less efficient than this, and usually achieve only ten percent efficiency [3].

Crystalline silicon solar cells are the most widely used solar cells and dominate the market at present. Stable devices and the possibility to use knowledge and technologies from the microelectronics industry have given crystalline solar cells a leading role among other types of solar cells. To meet the demand of reducing material and purification costs thin film solar cells have been developed. First generation solar cells are silicon based photovoltaic cells which still owns 86% of solar cell market. Even though they have high manufacturing cost but they have high efficiency. Second generation solar cells thin film solar cells which are cost effective than first generation silicon solar cells but they have lower efficiency. The advantage of this generation solar cells is their flexibility i.e. they are very light weight and can be used for various applications such as solar panel. Generation solar cells are copper indium gallium selenide, Cadmium telluride (CdTe), amorphous silicon and micro amorphous silicon. The third generation solar cells include non-semiconducting technologies like quantum dot technology tandem/multi junction cells, hot-carrier cells, up conversion and down conversion technologies, and solar thermal technologies [4].

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" [5].

Various type of solar cell has been developed in last past half century, which is more efficient and cost effective. The efficiency of various cells has been given in table 1 given below.

Table1. Efficiency reported for different type of solar cell

Solar cell type	Efficiency	Labortary / Institution
Crystalline Si	24.7	University of New South Wales
Multi Crystalline Si	20.3	Fraunhofer institute of solar system energy
Amorphous Si	10.1	Kaneka
HIT Cell	23	Sanyo corporation
GaAs Cell	26.1	Radboud University Nijmegen
InP Cell	21.9	Spire Corporation
Multi junction Cell	40.8	National Renewable energy Laboratory
CdTe	16.5	National Renewable energy Laboratory
CiGS	19.9	National Renewable energy Laboratory
$CuInS_2$	12.5	Hahn Meitner Institute
DSSC	11.1	Sharp
Organic Solar Cell	6.1	Gwangju Institute of Science and Technology

Discussion:

Earlier development in the solar, with Si as base SiNx deposition $POCl_3$+Al_2O_3 And SiNx deposition synthesis by Low thickness wafer making using perc method with resistivity of 2ohm, the weight is reduce from 4.3g/Wp to 1.5g/Wp and efficiency is maintain at 15.3% [6]. When Single crystal Si and multi crystal Si are synthesis using Boron emitter by Deposition using sole gel, screen printing, and PECVD, the efficiency is vary from 16.3 to 18.75% [7], with Cu/CuO_2/Ti_2O_3/Au in different doping density are used for efficiency enhancement of Si 100 with 5Ω wafer in crystalline form using dc sputter, we get the maximum power from combination with material synthesis carried out at Cu_2O_3 at 600^{0}C in 8cm. sq, dimension gives 95.7w/cm. sq. [8]. When both side passivated surface will develop the large photon tapping by Stacking of material on 0.5Ω and 280um n-type wafer of SiO_2 and Al_2O_3 with e-beam sputtering, the efficiency of crystalline silicon solar cell increase by 20 to 25 % [9]. When both side passivated surface doping with GaIn and GaAs with tilt angle of 2 to 6^0 formed by multiple stacking of material using screen printing with multiple bar from 500^0C to 800^0C annealing, the efficiency created above 25% [10]. When the use of perovskite bismuth ferrite ($BiFeO_3$ or BFO) on ZnO-based solid state solar cells is fabricated using chemical solution methods gives proper solution and high energy. As ZnO has poor chemical stability in acidic and corrosive environments, a buffer-surfactant method is implemented using aminosilane ((3-aminopropyltriethoxysilane or $H_2N(CH_2)3Si(OC_2H_5)_3)$) coating which provide a protective coating on the ZnO nanorods. The aminosilane layer was removed after BFO coating. The solid state solar cells, sensitized by N719, used CuSCN as the hole conductor and were tested under 100 mW cm^{-2}, AM 1.5G simulated sunlight. The photovoltaic performance showed current density improvement from 0.64 mA cm^{-2} to 1.4 mA cm^{-2} and efficiencies from 0.1% to 0.38%[11]. Al doped ZnO nanorods have been successfully synthesized on ITO substrate via solgel dip coating method without using any catalyst. The average diameter of Al doped ZnO nanorods is ~200 nm. The CdS quantum dot sensitized Al doped ZnO solar cell exhibited a power conversion efficiency of 1.5% [12].

Conclusion

Conventional solar cells require relatively pure absorbers to produce electrical current, whereas nanostructured absorbers can circumvent this limitation by enabling collection of carriers in a direction orthogonal to that of the incident light. Such systems have produced test devices having up to 10% efficiency, but typical devices yield 3–5% efficiencies over large areas and have long term stability issues.

Although conventional solar cells based on silicon are produced from abundant raw materials, the high-temperature fabrication routes to single-crystal and polycrystalline silicon are very energy intensive and expensive. The search for alternative solar cells has therefore focused on thin films composed of amorphous silicon and on compound semiconductor heterojunction cells based on semiconductors (e.g., cadmium telluride and copper indium diselenide) that can be prepared by less energy-intensive and expensive routes. A key problem in optimizing the cost/efficiency ratio of such devices is that relatively pure materials are needed to ensure that the photo-excited carriers are efficiently collected in conventional planar solar cell device designs. The use of nanostructures offers an opportunity to circumvent this key limitation and therefore introduce a paradigm shift in the fabrication and design of solar energy conversion devices to produce either electricity or fuels.

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