Chapter 12
Nanotechnology for Photovoltaic Energy: Challenges and Potentials

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ABSTRACT

Solar radiation is plentiful and a clean source of power. However, despite the first practical use of silicon based solar cell more than 50 years ago, it has not been exploited to its full potential due to the high cost of electrical conversion on a per Watt basis. Many new kinds of photovoltaic cells such as multi-junction solar cells dye –sensitized solar cells and organic solar cell incorporating element of nanotechnology have been proposed to increase the efficiency and reduce the cost. Nanotechnology, in the form of quantum dots, nanorods, nanotubes, and grapheme, has been shown to enhance absorption of sunlight, makes low cost flexible solar panels and increases the efficiency of photovoltaic cells. The chapter reviews the state of current photovoltaic cells and challenges it presents. It also discusses the use of nanotechnology in the application of photovoltaic cells and future research directions to improve the efficiency of solar cells and reduce the cost.

1. INTRODUCTION

Photovoltaic is derived from Photo meaning "light" and voltaic meaning "electric" and is defined as the conversion of sunlight to electricity through a photovoltaic cell (PV). It was first discovered by French physicist Alexandre-Edmond Becquere (1839). The first Solar cell was built by Fritts (1883), who coated the semiconductor selenium with an extremely thin layer of gold to form the junctions (1% efficient). The modern age of solar power technology started when Chapin, Fuller, & Pearson (1954) from Bell Laboratories, discovered that silicon doped with certain impurities was able to generate electricity for satellites. This device originally known as the solar battery is currently

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called Solar cell, exploited the principle of P-N junction. Initially the energy conversion of the cell, was 6% and reached 11% by the year 1957 and 14% by the year 1960 (Pearson, 1957; Rappaport, 1961). Photovoltaic cell is a non –mechanical device usually made from silicon which creates an electron imbalance across the cell and produces direct current (DC) as a result of incident sunlight. To convert DC current into workable alternating current (AC) electricity a device known as power converter is used. Solar energy or solar radiation can also be used for thermal energy source.

The world current energy consumption is 4.1 x 10^{20} Joules/year which is equivalent to a continuous power consumption of 13 trillion watts or 13 terra watts (TW). The earth surface receives an average of 120,000 TW from the sun, ignoring the energy being scattered by the atmosphere and clouds. Thus with Solar cells as low as 10% conversion efficiency, the world's energy needs can be satisfied with solar panels covering 0.16% of earth surface which would supply 20 TW of power. In US it will take 1.6% of the land area to meet the country domestic needs ("Basic Research Needs for Solar Energy Utilization," 2005). According to Pike Research forecasts, the worldwide demand for solar energy will nearly double between 2010 and 2013, reaching 19.3 Giga watts by the end of that period, caused by the shift of solar industry from supply-constrained to demand-driven over the past two years. This shift is driven by a new abundance of polysilicon, as well as the effects of the worldwide financial crisis, and the plunging price of solar modules. This market realignment will set the stage for a new era of solar growth over the next several years ("Global Solar Energy Outlook," 2010).

Photovoltaic energy as an alternative renewable energy source is emerging as a viable solution to energy problems worldwide. Despite its immense potential it is still a long way from becoming the world's major energy source because of many challenges it presents in its implementation. This includes higher cost of making large silicon solar panels and inefficient Solar cells due to inadequate absorption of sunlight and low efficiency of 31% set by Shockley and Queisser (1961) for a single semiconductor junction. The high price for Solar cells is largely due to the use of expensive substrate materials and costly microfabrication processing. The efficiency of thin film photovoltaic cell increased from 10% in 1970 to over 24% in the most recent years by the use of new photovoltaic materials. Ongoing research in photovoltaic energy and new developments in nanotechnology is overcoming some of these challenges. Nanotechnology in the form of nanoparticles, nanowires and nanostrucures has been shown to enhance absorption of sunlight, make low cost flexible solar panels and increase the efficiency of photovoltaic cells beyond Shockly and Queissar (1961) limit by using multiple exciton generation in nanostructures. The advantages of nanotechnology based Solar cells also reduce manufacturing costs as a result of using a low temperature manufacturing process instead of high temperature vacuum deposition process typically used to produce conventional crystalline semiconductor based Solar cells.

The problem of making large and costly silicon solar panels is overcome by making Solar cells so thin that that they can be painted and printed onto rolls of thin film in the form of a foil or spray which can be produced cheaply and quickly. The cell uses alloy of copper called copper Indium Gallium Diselenide (CIGS) and is as efficient as silicon but is cheaper and lighter (Marshall & Bazeley, 2006). A new method of increasing the absorption of sunlight is obtained by combining silicon with low cost plastic which improves the efficiency and reduces the cost of photovoltaic cells. These cells consist of a large number of very small wires made of 2% silicon grown on 98% of plastic substrate. The dimensions of silicon wires range from 30 to 100 μm in length, and 1 μm in diameter. Each wire is coated with antireflective coating so that light can easily penetrate them; bounce around among the forest of silicon wires until it is absorbed. The silicon-wire array has