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Solar energy harvesting with the application of nanotechnology

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ABSTRACT

Nanotechnology is an enabling technology that provides an extensive range of resources to resolve the energy-related problems, as the developing components and appliances are smaller than 100 nm they provide the new ways to catch, store and exchange energy. Every day, the sun shines a huge amount of energy which is generated through a process of nuclear fusion. Even the sun radiates more energy in one second than people have practiced since the beginning of time. It has been noted that the technical potential of solar energy all over the world is many times larger than the current total primary energy demanded. In this study, the solar harvesting technology with the help of nano-materials has been thoroughly studied. The different types of modern solar collecting technologies that use the nano-materials effectively and successfully have been discussed. Among a number of devices, the solar collector, the fuel cell, photocatalysis and solar photovoltaic have used the nanomaterials to increase the efficiency. It is found that by using nanomaterials the incident radiation can be increased by 9 times while the efficiency of the solar collector is 10% higher compared to that of a conventional flat plate solar collector. The generation ways solar cell technologies have been also discussed here. At the end of this article, few challenges in using nanotechnology are also addressed in detail.

Contents

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1. Introduction

It has been nearly half a century since Nobel Prize winner Richard Feynman advocated widespread nano-scale research by delivering his famous speech "There's plenty of room at the bottom" in 1959, through which the nanotechnology concept first captured the world's attention [1]. Feynman described a process by which the ability to manipulate individual atoms and molecules might be developed, using one set of precise tools to build and operate another proportionally smaller set, and so on down to the needed scale.

The term "nanotechnology" was defined by Norio Taniguchi [2] as follows: "nanotechnology mainly consists of the process of separation, consolidation, and deformation of materials by one atom or one molecule". Since that time the definition of nanotechnology has generally been extended to include features as large as 100 nm. Dimensions between 1 and 100 nm are known as the nanoscale i.e., on the scale of 1 billionth to several tens of billionths of a meter as shown in Fig. 1. At the nanoscale, unusual physical, chemical, and biological properties can emerge in materials. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules. Additionally, the idea that nanotechnology embraces structures exhibiting quantum mechanical aspects, such as quantum dots, has further evolved its definition. However, it specifically implies not only the miniaturization but also the precise manipulation of atoms and molecules to design and control the properties of the nanomaterials/nanosystems. These properties are completely different than those possessed by the bulk materials, producing custom-made devices with capabilities not found in bulk materials or in nature, or even to replicate some natural processes that have not been currently achieved through synthetic materials. Also in 1974, the process of atomic layer deposition, for depositing uniform thin films one atomic layer at a time, was developed and patented by Dr. Tuomo Suntola and co-workers in Finland. In the 1980s, the idea of nanotechnology as a deterministic, rather than stochastic, handling of individual atoms and molecules was conceptually explored in depth by Dr. K. Eric Drexler. His vision of nanotechnology is often called "Molecular Nanotechnology" (MNT) or "molecular manufacturing" [3].

Nanotechnology offers, for the first time, tools to develop new industries based on cost-effective and cost-efficient economies, thus seriously contributing to a sustainable economic growth. Focusing on the energy domain, nanotechnology has the potential to significantly reduce the impact of energy production, storage and use. Even if we are still far away from a truly sustainable energy system, the scientific community is looking at a further development of energy nanotechnologies. Energy experts predict that the world would need 30 TW of energy resources by the year 2050 to maintain economic growth [5]. Many scientists believe that the sun is the only candidate that can offer a fully developed solution for the energy crisis. Therefore, solar cells can be considered as a mainstream renewable energy resource once their manufacturing cost has decreased to an affordable level compared with other available energy resources. Parida et al. [6] reviewed different issues concerning solar cell technologies. At this stage, new initiatives on harvesting incident solar radiation with greater efficiency are needed to meet the global clean energy demand. Sequentially, solar cell technologies have evolved into three generations [7]. First generation solar cells are based on a single crystalline semiconductor wafer. Second generation solar cells utilize inorganic thin film structure in the cell assembly. They are cheaper to produce, but the efficiency, which is less than 14% in amorphous thin film solar cells, is lower than the efficiency exhibited by the single junction crystalline solar cell of the first generation that can reach as high as 27%. Theoretically, single junction cells should be able to exhibit a maximum efficiency of ~33% [8], a limit set by Shockley–Queisser thermodynamics. Thus, a new solar cell technology is required in order to achieve efficiencies greater than 33% with lower production cost. The onset of this breakthrough is the third generation solar cells [9]. Currently, the focus is on the third generation solar cells that can deliver economic, highly efficient cells that can emerge as a new technology in the near future as shown in Fig. 2 [10]. The relation between the solar cell production cost per square meter with the solar cell module efficiency and the cost per unit power is shown in Fig. 3 [11].

In this review, firstly we have focused on the applications of nanotechnology for different solar systems and storage systems. Secondly, we have emphasized how nanotechnology significantly contributes to enhance the performance of solar cell technologies. From the overall review, it is articulate that nanotechnology has played a significant role for reaping sustainable energy from solar radiation in different facets. Thus, this review aims to explore the role of nanotechnology in evolving solar energy by reconsidering its constraints.

2. Nanotechnology for harvesting solar energy

From the previous research, it has been shown that nanotechnology is a powerful tool for a host of the solar system in support of efficient, sustainable energy conversion, storage, and conservation, in terms of

- tailoring the interaction of light with materials and enabling the processing of low-cost semiconductors into devices such as photovoltaics.