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Recent Developments on Nanotechnology In Solar Energy

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Abstract: One of the biggest challenges for mankind in the century of 21 is use of alternative sources for nonrenewable, limited fossil fuels that tremendously contribute on the problem of global warming. In this challenge, solar energy production is rapidly becoming a vital source of renewable energy being developed as an alternative to traditional sources of power. For improving the efficiency of solar devices various approaches was intended but nanotechnology, a combination of chemistry and engineering, is viewed as new candidate for clean energy applications. Nanotechnology will bring significant benefits to the energy sector, especially to energy storage and solar energy. Improved materials efficiency and reduced manufacturing costs are just two of the real economic benefits that nanotechnology already brings these fields. This paper reviews recent advances on development of nanotechnology in the solar energy devices. Special emphases are given to solar cells based on nanostructure and nanodevices.

Introduction: An adequate and secure supply of energy is essential to the daily live, which needs to be achieved with minimum adverse environmental effects. One of the biggest challenges for mankind in this century is to secure a long term energy supply for sustainable global development . Nowadays our main energy sources for human activity are fossil fuels. Combustion of these fuels causes air pollution, global warming, environmental degradation, ozone layer depletion, biosphere and geosphere destruction and ecological devastation. Consequently, the actual energy production can be considered a harmful industry both in terms of pollution production and environmental impact since the industrial revolution in the 18th century .

Contrarily use of renewable energy sources such as solar, wind, geothermal, ocean thermal and tidal is suitable. Considering the remediation of environmental problems in the development of green processing technologies search is looking into nanotechnology related to renewable energies such as solar, wind and ocean energy could be possible solution to diminishing out dependence on depleting petroleum supplies . Nevertheless, the energy production alternatives are still limited because combining their high costs (manufacturing cost versus efficiency) and the implication on the environment makes these processes unsuitable. Solar energy is emitted from the sun primarily as electromagnetic radiation in the ultraviolet to infrared and radio spectra regions (0.2 to 3µm). The sun has a reasonable constant lifetime with A projected constant radiative energy output of over 10 billions (1010) year.

Nanotechnology, the control of materials and phenomena at scale 1 and 100 nm, hold the key for many of the technological advances in the energy sector. Focusing on the energy domain, nanotechnology has the potential to significantly reduce the impact of energy production, storage and use.

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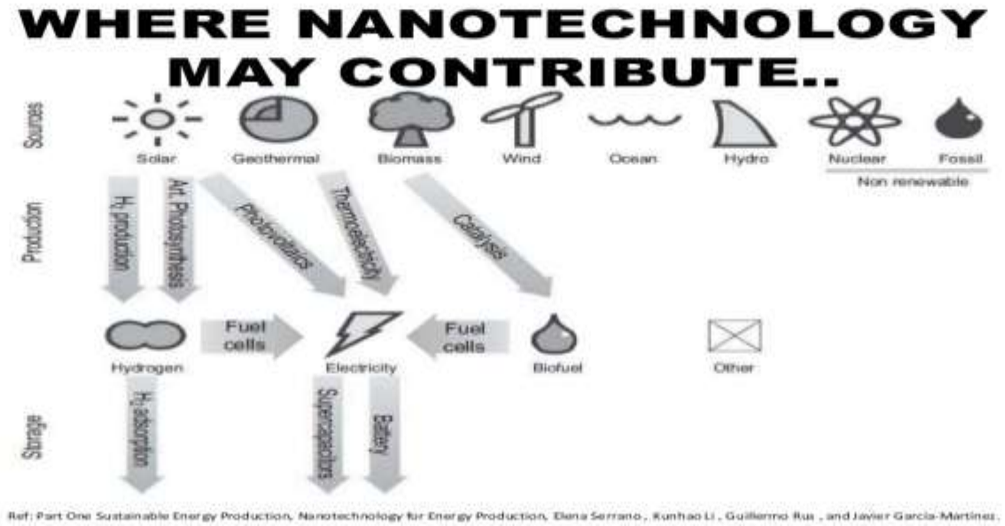

Figure 1.Applications of nanotechnology for the energy production domain.

Nanotechnology involves the miniaturization as well as manipulation of atoms and molecules to control their some physical properties like strength, conductivity, reflectivity, chemical reactivity and etc, which at this scale are so different from the bulk properties. Fundamental properties of nanostructured materials are currently extensively studied because of their potential application in numerous fields which includes electronic devices, opto electronics, optics, tribiology, biotechnology, human medicine and others . Nanostructured materials have enormous surface area per unit weight or volume so that vastly more surface area is available for interactions with other materials around them. According to the roadmap report concerning the use of nanomaterials in the energy sector from6th framework program, the most promising application fields for the energy conversion domain will be mainly focused on solar energy and thermoelectric devices. This paper investigates the utilization of nanotechnology in solar energy with an emphasis on four most important disciplines: . photovoltaic (PV) solar cells, artificial photosynthesis, nanoscale materials used in solar cells and nanofluids applications in solar energy systems. The aim of this study is to look at the role of nanotechnology in solar energy applications and spike the attention of the reader on these current research topics.

Electricity production - PV cells:The PV technology converts radiant energy enclosed in light quanta into electrical energy when light fall upon a semiconductor material by causing electron excitation and strongly enhancing conductivity. Devices that perform this process are named solar cell or PV cells. PV technology represents only around 0.04% of the fuel share of world's total primary energy supply . The addition of nanoscale components in PV cells is a way to diminish some restrictions. First, the ability to control the energy bandgap provides flexibility and interchangeability. Second, nanostructured materials enhance the effective optical path and significantly decrease the probability of charge recombination

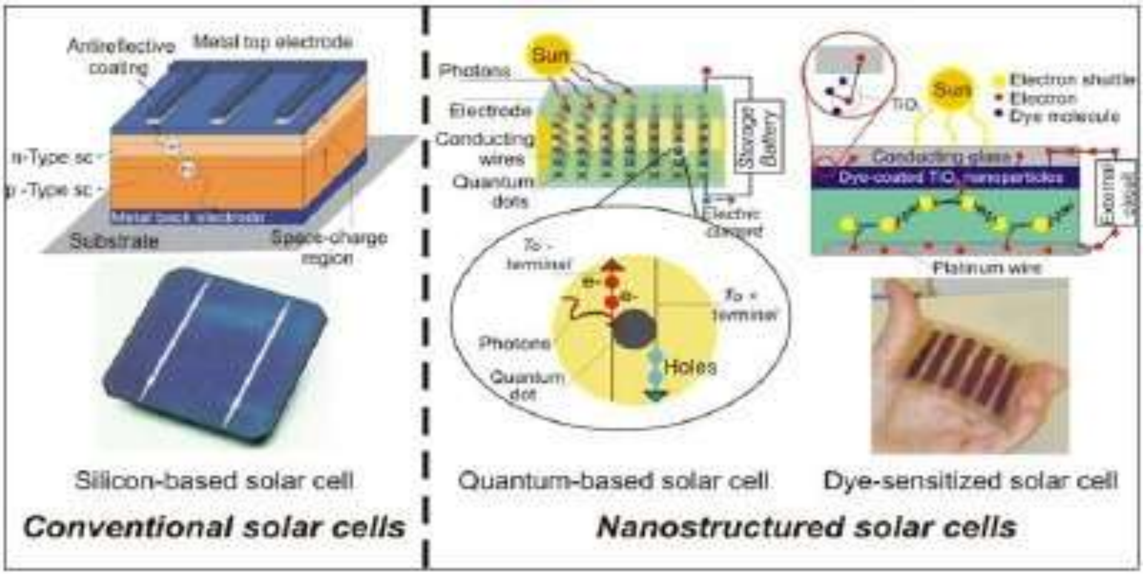

Figure 2 shows the evolution of PV technology: from conventional (silicon-based solar cells) to nanostructured solar cells (quantum-based and dyesensitized solar cells).

The newest technologies, commonly named composite PV technology, mixes conductive polymers or mesoporous metal oxides with high surface areas to increase internal reflections with nanoparticles and, consequently, to make a single multispectrum layer. Several of these layers can be stacked for lower expenses and theoretical efficiency up to 86.5%, unfortunately not achieved in practice Actually, there are some companies working on fourth-generation PVs (i.e., Nanosolar, Nanosys, Konarka Technologies, Inc., etc.) and a great amount of scientific effort is focused on the same approach. However, not enough efficiency has been achieved yet.

In summary, the goal is to notably increase the efficiency and cost ratio, which can be achieved by using materials with different bandgaps, i.e., multilayers of ultra-thin nanocrystalline materials, new dyes or quantum dots, among others. Accordingly, the actual cumulative installed capacity of solar PV is just above 2000MW. Nevertheless, the growing use of PV devices and the considerable improvements in both efficiency and price keeps generating a market that grows 25% per year.

Hydrogen production: artificialphotosynthesis: PV energy can be used to break water molecules into hydrogen and oxygen via the so-called photocatalytic water electrolysis. It means that solar energy can be directly stored in the form of hydrogen. Artificial photosynthesis uses the solar radiation as source of energy for hydrogen production. Water splitting by photocatalysis, also known as artificial photosynthesis, is being actively researched, motivated by a demand for cheap hydrogen which is expected to rise with the new hydrogen economy. Nanotechnology is the tool that can make possible the production of hydrogen from solar energy in a clean, environmentally friendly and low-cost way using photocatalytic water splitting. For this purpose, a variety of semiconductor nanoparticulated catalyst systems based on CdS, SiC, CuInSe2, or TiO2 can be used , the last one being the most promising candidate since it fulfills the above-mentioned requirements. However, this technology is still in the research stage due to the cost associated with its low conversion efficiency.

Nanoscale materials for solar cell : Nanoscale materials (nanomaterials) are defined as the substances where at least one dimension is less than approximately 100 nm. Due to their small dimensions, nanomaterials have large number of surface or interfacial atoms, resulting in more surface dependent material properties. Nanomaterials can be in zero dimension (e.g. Quantum dots or QD), one dimension (e.g. surface films, nanowires and nanotubes), two dimensions (e.g. strands or fibres), or three dimensions (e.g. particles). They can exist in single, fused, aggregated or agglomerated forms with spherical, tubular, and irregular shapes. Common types of nanomaterials include nanotubes, dendrimers, quantum dots and fullerenes.

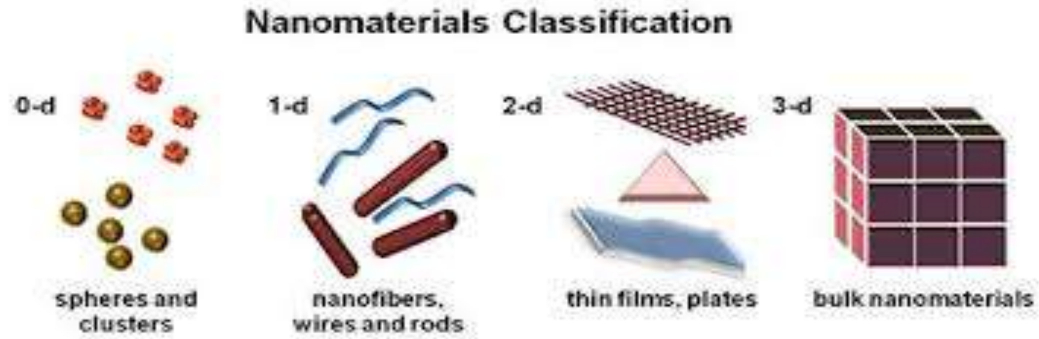

Figure 3.Classification of Nanomaterials (a) 0D spheres and clusters, (b) 1D nanofibers, nanowires, and nanorods, (c) 2D films, plates, and networks, (d) 3D nanomaterials .

Nanomaterials and nanostructures possess promising potential to enhance the performance of solar cells by improving both light trapping and photocarrier collection. Meanwhile, these new materials and structures can be fabricated in a low-cost method, facilitating cost-effective production of PVs. Performance of a PV device largely relies on both photon absorption and photocarrier collection. Therefore, in design of a PV device with decent energy conversion efficiency, both factors have to be optimized. Nevertheless, there requirements in optimizing optical absorption and carrier collection can be in conflict. For any photosensitive material to be developed in the future, the quality control capable of achieving homogeneous photo activity is expected to be a key factor. The materials are classified as thin films, such as inorganic layers, organic dyes, and organic polymers that are deposited on supporting substrates. Embedded QDs in a supporting matrix by a “bottom up” approach is configured as nanocrystals. Si is the only material that is well researched in both bulk and thin film forms. There are many new alternatives to Si photocells, such as copper indium gallium selenide (CIGS), CdTe, dyesensitized solar cells (DSSCs) and organic solar cells . Among these new materials, semiconducting polymers are gaining much attention because of their large parameter space and inherent simplicity of device fabrication, and thus warrant further investigations . The inexpensive purification or synthesis of nanomaterials, deposition methods for the fabrication of thin film structures and easy process control in order to achieve a large-area production with inacceptable performance tolerances and high lifetime expectancy are still the main challenges for fabrication of solar cells. Therefore in attaining the main objectives of PVs, the efficiency of solar cells should be improved without any compromise on the processing cost of these devices.

Nanotechnology incorporation into the films shows special promise in enhancing the efficiency of solar energy conservation and also reducing the manufacturing cost. Its efficiency can be improved by increasing the absorption efficiency of the light as well as the overall radiation-to-electricity. This would help to preserve the environment, decrease soldiers carrying loads, provide electricity for rural areas and have a wide array of commercial applications due to its wireless capabilities. The solar energy has to be properly channelized to meet the energy demand in the developing countries and solar cell industry can reach greater heights by the incorporation of third generation solar cell devices and panels based on nanostructures . In this regard, nanotechnology with capability of tailoring materials for defined purpose may create abundant nanostructures.

With these nanostructured materials it is possible to receive increased electron diffusion length, decreased back recombination, and physical effects such as photon localization. Thus a decrease in the energy loss would likely lead to an improvement in the solar cell efficiency . The nanowire geometry provides potential advantages over thin-film solar cells in every step of the photoconversion process. These advantages include reduced reflection; extreme light trapping, improved band gap tuning, facile strain relaxation, and increased defect tolerance. These benefits are not expected to increase the maximum efficiency above standard limits; instead, they reduce the quantity and quality of material necessary to approach those limits, allowing for substantial cost reductions

Nanofluids for solar energyapplications: By the fast growth of universal population, solar energy is obtaining worldwide interest as an appropriate alternative which is fully environmentally kind. Heat transfer enhancement in solar equipments is one of the significant issues in energy economy and design goals. Low efficiency of systems utilizing solar energy is an important issue; so, using high efficiency technologies in gathering solar radiation is a significant solution. One of the efficient techniques is to replace the working fluid with a fluid which contains nanometer-sized particles (1–100 nm in one dimension) that called nanofluid. Adding nanometersized particles to a fluid was initially investigated by Choi in 1995 , in which the results revealed better thermal conductivity. Hence, nanofluid is a good alternative to enhance the efficiency of solar systems.

Recently, researchers have become interested in the utilization of nanofluids in collectors, water heaters, solar cooling systems, solar cells, solar stills, solar absorption refrigeration systems, and a combination of different solar devices due to higher thermal conductivity of nanofluids and the radiative properties of nanoparticle. There are so many challenging matters on this area. How to select appropriate nanofluids in solar applications is a key issue. The effectiveness of nanofluids as absorber fluids in a solar device strongly depends on the type of nanoparticles and base fluid, volume fraction of nanoparticles, radiative properties of nanofluids, temperature of the liquid, size and shape of the nanoparticles, pH values, and stability of the nanofluids .

Based on the literatures, the enhanced thermal conductivity of nanofluids is the main cause of efficiency increment in solar systems but a higher nanoparticle volume fraction does not always causes the efficiency enhancement. The conclusions on the effect of nanoparticle size for solar collector efficiency are adversary , which needs more experimental research to do on this factor. Employing nanofluids in solar systems includes many environmental and economical advantages such as reducing of CO_2 emission through enhancing the efficiency, also less emission in manufacturing process of nanofluid based collectors.

Utilizing nanofluids in solar systems depends on various parameters such as particle size, polydispersity of particles, agglomeration and so on. The limitation of nanoparticles is the most important challenge in this issue since their specifications are not accurate. For this reason, promotion in the particle production and costs reduction is crucial for the studies related to nanofluid applications. Regarding the insufficient experimental studies thermoelectric cells, on a number of solar systems such as parabolic trough systems, solar ponds or PV thermal systems, more information are needed to confirm the operation of these systems using nanofluids.

Conclusion: This work focused on the description of nanotechnology application in solar systems. The most important fields of nanotechnology in solar energy include PV based on nanomaterials, hydrogen production, nanoscale materials and nanofluids for solar energy applications. The growing interest in applying nanoscale materials for solving the problems in solar energy conversion technology can be enhanced by the introduction of new materials such as quantum dots, multilayer of ultrathin nanocrystalline materials and the availability of sufficient quantities of raw materials. Through better nanomaterials, PV solar cells are increasing their efficiency while reducing their manufacturing and electricity production costs at an unprecedented rate.

Hydrogen production, storage and transformation into electricity in fuel cells are being benefited from more efficient catalysts for water splitting, better nanostructured materials for higher hydrogen adsorption capacity and cheaper simpler fuel cells. Nanofluids have been utilized to improve the efficiency of several solar thermal applications.

Theoretical and experimental studies on solar systems proved that the system performance enhances noticeably by using nanofluids. This review article is an attempt to elucidate the advantages and disadvantages of nanotechnology application in the solar system. **References**: [1] Alonso, D.M, Wettsein , S.G, dumesic , J.A, Bimetallic, 2012, catalyst for upgrading of biomass to fuels and chemicals. Chem. Soc. Rev. 41 (24), 8075- 8098. [2] NRDC, Benchmarking air emissions of utility electric generators in the eastern U.S. [3] Office of technology assessment, 1994, Studies of environmental costs of electricity, OTA –RTI- 134.washington, DC: U.S. government printing office [4] Rowe RD, Lang CM, Chestnut LG , Latimer D , Rae D , Bernow SM, et al, ESEERCO ,1995 , New York state environmental externalities cost study. New York; Oceana publications [5] Khan FI, Hawboldt K, Iqbal MT, 2005, life cycle analysis of wind- fuel cell integrated system. Renewable energy, 30: 157..