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Application of Nano-Technology in Industry

Mehran Jalalifar[1]

1. **Islamic Azad University, Fereydan Branch. Isfahan, professor.panahi@gmail.com**

Abstract

The application of renewable energy has increased in the countries of the world considering the need for developing of the countries; so that one standards of the development is application of the energy. This type of energy has contributed more to the energy supply system, day to day. In this challenge, solar energy is rapidly becoming a vital source of renewable energy as a substitute for nonrenewable energy. Different methods have been considered to improve the efficiency of solar devices but nanotechnology is a combination of chemistry and engineering that has been seen as a new interface for clean energy applications. In the field of energy production, it can be mentioned turbines, generators, solar cells, fuel cells, wind turbines, thermoelectric materials and magnetic materials and in the field of energy storage, there are a variety of batteries, super capacitors, lubricants, insulating glasses, etc.

Keywords: Solar Cell, Nanostructures, Solar Energy

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Introduction

The application of renewable energy has increased in the countries of the world considering the need for developing of the countries; so that one standards of the development is application of the energy. This type of energy has contributed more to the energy supply system, day to day. In 2008, more than 120 billion $ was invested in increasing capacity section, construction of power plants and research and development of new energy (1). By the end of 2010, renewable energy in the world has contributed 3.8 percent to global electricity generation (These figures are calculated regardless of water energy, because this type of energy has as much as 15% of the global electricity generation). At present, renewable energy supplies more than 14% of the global primary energy, but unfortunately, our country has not made much contribution, which this issue is a danger to the country's use of fossil fuels (2). Nanotechnology refers to techniques that create extremely fine structures (7-10 to 9-10 meter) by controlling the structure of materials on an atomic and molecular scale. Some phenomena are exacerbated by decreasing the size of the system (3-5). One of these phenomena is the effects of quantum mechanics. For example, the electronic properties of solids vary by decreasing their size. These effects are not observed in macro to micro-size. It also changes some mechanical, electrical, optical, etc. properties compared to macroscopic systems. Materials on nano-scale also exhibit other properties. The equipments are produced using nano-scale materials that have many advantages over different aspects such as durability, life span, cost, performance, etc. compared to typical types. In the last few years, there has been a great deal of hope among scientists to produce high-quality materials (6-8).

In the field of energy production, it can be mentioned the turbines, generators, solar cells, fuel cells, wind turbines, thermoelectric materials, magnetic materials, etc. and in the field of energy storage, there are a variety of batteries, super capacitors, lubricants, insulating glasses etc. (figure 1). Hence, the most important application of nanotechnology in production of new energy converters (such as solar cells and fuel cells) is reducing the environmental pollutants of thermoelectric power plants, filters, and increasing the efficiency of these power plants (by using nano-coatings and nano-magnets), (8-9).

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Figure 1. Application of Nanotechnology in electricity generation industry

If we accept that nanotechnology is the ability to produce new materials, tools and systems by taking control of molecular and atomic levels and using properties of those levels, then it can be found out that it will be inevitable the applications of this technology in various fields, including food, medicine, medical diagnosis, biotechnology, electronics, computers, communications, transportation, energy, environment, materials, aerospace, national security, etc. In such a way that it's hard to imagine a field that does not affect it. The vast applications of this field, together with its social, political and legal implications, have advanced this technology as a cross-cutting and overlapping field (10).

The electricity industry is a dynamic and influential industry due to the role of infrastructure and its close relationship with factors affecting economic growth. The electricity generation sector is the most important and, at the same time, the most expensive section in the electricity industry. Therefore, today there are major challenges in various industries and fields with the introduction of new approaches to this industry. Meanwhile, nanotechnology which has penetrated many industries today, is also playing a role in power plants, (11-13). The key to the success of countries and in enterprises is efficient and high-tech manufacturing. In another word, their goal is to produce a product and provide more value added services. It will not be possible achieving this goal without new knowledge, modern materials and technologies (14-16).

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This paper examines the recent advances in the development of nanotechnology in solar energy devices; special emphasis is given to solar cells based on nanostructures and nanotechnologies.

Discussions and Findings

Application of nanotechnology in the field of energy generation

The solar energy can be used in two ways: 1. using sunlight for direct electricity generation, 2. using solar thermal energy in high temperature power plants for electricity generation and in low temperature power plants for hot water, conditioning of buildings and also for use in solar desalination. In this field, nanotechnology can be very effective in extracting solar energy. It can be increased the efficiency of equipment in two fields of electricity and heat production using this technology (17).

Solar cells: Solar or photovoltaic cells convert solar energy to electricity. Silicon solar cells are the most common type of cells and in 2004 they accounted for 90% of the market. At the same time, their production is costly and their efficiency is limited; in the most efficient of these types of cells, it is used the same single crystal silicon of semiconductor industry. This efficiency is about 14% in most production models and is up to 25% in the lab. On the other hand, at the present, the best solar cells belong to the multi-combinational group of multilayer semiconductor solar cells (currently two or three layers of different conductors) and its highest performance is 34% (18). Examples of these materials are gallium, indium, germanium and their compounds with arsenic, selenium and tellurium. At the same time, the cost of such cells is so high that it is mainly used only for specific applications, such as power supply systems for space satellites. In both cases, the cost of each unit of produced electricity is at least several times of the production of the same amount of electricity with fossil fuels. Therefore, solar energy extraction has the great importance. Iran is located between circuit 25 to 40 degrees north latitude and in the area where solar energy is at the highest levels in terms of solar energy (19). The amount of solar radiation in Iran is estimated to be between 1800 and 2200 kilowatt-hours /square meter per year, which is higher than the average world amount (figure 2). In Iran, it has been annually reported an average of more than 280 sunny days that the solar power obtained in these days is very significant. Today, it has been installed the types of solar power systems in different countries with the proper solar radiation potential, so that its electricity is transmitted to the global network circuit. At present, solar power plants installed around the world produce about 178 GW of

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power and it is predicted that with the removal of barriers, the capacity of solar power installed in the power plants will be exceed 500 GW by 2010.

Solar cell is a semiconductor electronics component that converts sunlight energy directly into photovoltaic electricity. With light from the sun to the semiconductor, the electron moves from the capacity bar to the semiconductor conduction band and generates electron pair of the cavity. Both of them can alone take part in the process of transferring charge in the semiconductor and potential difference generate; so that with the presence of the consumer, the load can be diverted to the orbit (figure 3).

The solar cell efficiency depends on its ability to use as much as possible the incident light. All photovoltaic materials absorb photons with minimum energy or certain wavelengths and anything other than that is not absorbed, or the extra energy is released and wasted in the heat; but nanotechnology seems to have solutions to reduce costs and increase efficiency. New tools such as color-sensitive organic solar cells or grätzel cells use a photosynthesis-like method, in the way that the molecule of color produces electrons by absorbing a light photon; these electrons are transmitted to the titanium dioxide nanoparticles to which the molecules are attached and are transmitted on the electrodes. The cost of producing such devices is about 60% less than silicone cells.

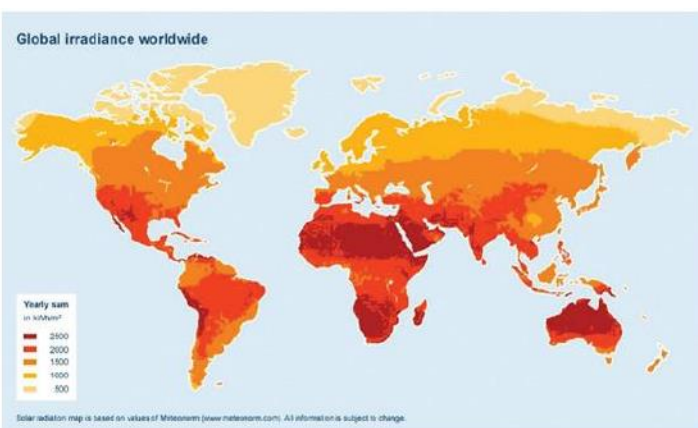

Figure 2. Global radiation level in different countries and in Iran

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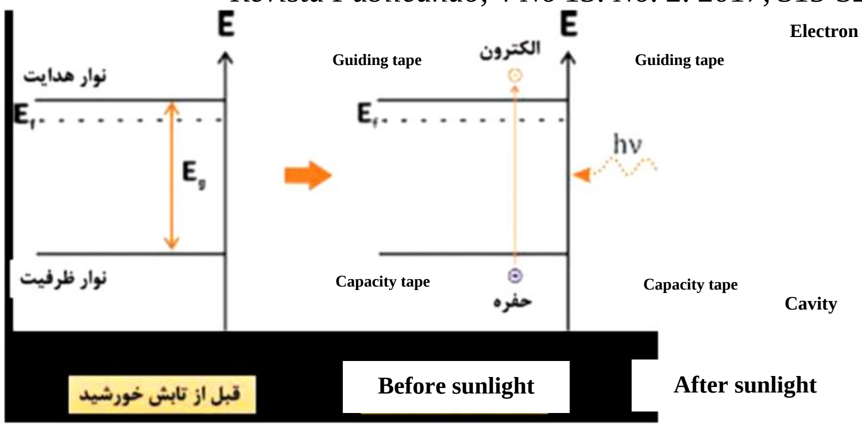

Figure 3. The mechanism of electron production and cavity

At the same time, their efficiency is low (its laboratory models are up to 10%). Semiconductor polymers are another substitute. The mechanism of these polymers is similar to organic semiconductors; That is, these polymers have wide bands with a structure similar to silicon and require an input energy to transport electrons from non-conductive bands to the conducting band or the band gap. But at the same time, they do not have high return. Scientists think that quantum dots are the most effective. This is because they can be adjusted to absorb any wavelength of the visible spectrum by resizing (or combining) these points. They also have higher energy efficiency due to their small size and release three electrons for each photon Instead of an electron released in existing silicon technologies (20).

Solar cell electrical characteristics: The most important electrical characteristics for cell measurement include: VOC open circuit voltage: Voltage under zero current density, JSC Short circuit current: One cell current density at applied zero voltage, FF efficiency factor

$FF = (J_{max} \times V_{max})/(J_{sc} \times V_{oc})$, efficiency $\eta = P_{out}/P_{in} = (P_{max}/P_{light}) \times FF = (J_{sc} \times V_{oc})/P_{light}$.

The introduction of nanotechnology in the solar cell industry:

Nanotechnology has had a positive impact on solar cell performance in many ways such as: Increasing the absorption and trapping of sunlight, providing new nanoscale-based structures for solar cells, using nano-fluids to improve the performance of solar systems, application of photocatalytic based on nanotechnology in solar cells, application of nano-coatings, application

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of nanotechnology in power cooling systems, nanoparticles, a suitable solution to increase solar cell efficiency (21).

Hybrid photovoltaic cells based on a combination of nanocrystals and polymers have a significant potential for reducing the cost of converting sunlight to electrical energy. Colloid nanocrystal semiconductors such as polymers are synthesized by chemical methods from the soluble phase and possess superior properties of inorganic semiconductors, such as wide spectral absorption spectra and high mobility of the carriers. The use of nanostructures in the active layer of the solar cell is very useful as a receiver or in electrodes as a carrier collector (22).

Titanium-based pigment hybrid solar cell: In these solar cells, the cell function can be improved by replacing inorganic nanoparticles or quantum dots instead of pigmentation. Titania impregnation with nanostructures is effective in improving solar cell efficiency; for this purpose, titanium has been impregnated with nanostructures including gold nanoparticles, zinc celandine quantum dots and carbon nanotubes and it has been studied the effect of this impurity on improving the performance of a solar cell consisting of zinc phthalocyanine pigments and titanium nanocrystals. The circuit-current voltage, short-circuit current density, efficiency factor and cell efficiency for this type of cell are shown in Table 1 (23).

Table 1. Parameters measured from pigment solar cells by dipping Titania nanocrystals

Nanoparticles	Gained development	η (%)	FF (%)	Jsc (mAcm-2)	Voc (v)
Without impurity	---	0.22	31.1	3.37	0.21
Gold nanoparticles	218%	0.7	34.5	5.79	0.35
zinc celandine quantum dots	205%	0.67	28.9	4.83	0.48
Carbon nanotube	123%	0.49	36.1	5.03	0.27

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Polymer solar cell based on zinc oxide and titanium nanotube: In this structure, zinc oxide nanotube is used as an electron transport layer and Titanium nanotube hybrid is used as an active layer. The carrier layer provides a route for collecting and transporting the carriers to the electrode. The thinner nano-monomers of titanium penetrated into the polymer have a large polymer-coated surface and improve the separation of exits and the transport of carriers. Three tools with different configurations were made for comparison, the information is given in Table 2, (table 2).

Tool (*I*): (ZnO / P3HT) based on the pure polymer film of the layer deposited on the zinc oxide nanotube. The tool (II) with configuration (ZnO / P3HT: TiO2) has shown a 6-fold increase in the density of the collecting current from the cell compared to instrument (I) due to the presence of Titanium nanotube. The tool (III) with the configuration (ZnO / TiO2 / P3HT: TiO2), showed a higher density of current than tool (II). This increase can be attributed to the addition of the Titanium nanotube layer which prevents the electrons returning to the polymer and recombination with the holes. The presence of Titanium nanotube in the structure of the zinc oxide / polymer hybrid will improve the performance of the solar cell due to increased surface and effective transmission route (24).

Table 2: Parameters Measured from Different Tools of the Hybrid Solar Cell Based on Zinc Oxide Nanotube

Type of tools	Voc (mV)	Jsc ($mAcm^{-2}$)	FF (%)	ɳ (%)
I	335	0.3	40	0.04
II	385	1.96	39	0.29
III	400	2.2	35	0.31

Hybrid solar cell with telluride cadmium nanotube: efficiency development of hybrid solar cells was achieved through the combination of cadmium Telluride / poly (3-hexafytofen) nanotube as an active layer. These tools showed open-circuit voltage v 0.7, short circuit current mA 5.7, efficiency factor 0.4 and efficiency of 1.7% (Fig. 4). The results show that the use of nanotubes

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results in better optical absorption, more effective separation of exitons and electron transfer in a direction perpendicular on the film surface (25).

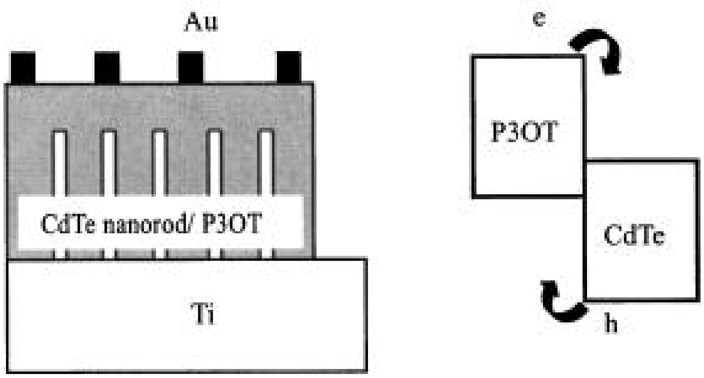

Figure 4. Polymer/cadmium talluride nanotube hybrid solar cell structure 3. Octyl-thiophene

Polymer solar cell based on nanostructured zinc oxide, in the reverse-structured polymer solar cell, when only a layer of zinc oxide buffer was used as the electron transport layer, 1.64% efficiency, open circuit voltage 0.49 and short circuit current 9.59 were reported. In the same way, the synthesis of zinc oxide nanotube on the zinc buffer layer developed cell parameters; so that it was reported the efficiency of 2.44%, open circuit voltage 0.48 and short circuit current of 14.99%, (26).

Nanofluid, a convenient way to transfer heat and reduce temperature in solar systems

The nanofluids are a solid-liquid compound in which metal or non-metallic nanoparticles are suspended in the base fluid. Suspended nanometer particles such as silicon oxide, titanium oxide, copper oxide, nickel metal nanoparticles or carbon nanotubes and graphene generates the displacement characteristics and transfer the fluid heat, which can greatly enhance the heat transfer. Since the cooling of the solar cells has the particular importance, the use of nanofluids makes it possible to transfer more heat from the solar cell to the outside and increase the efficiency and longevity of solar cells. In addition, nanofluids are also used in solar thermal systems (Figure 5).

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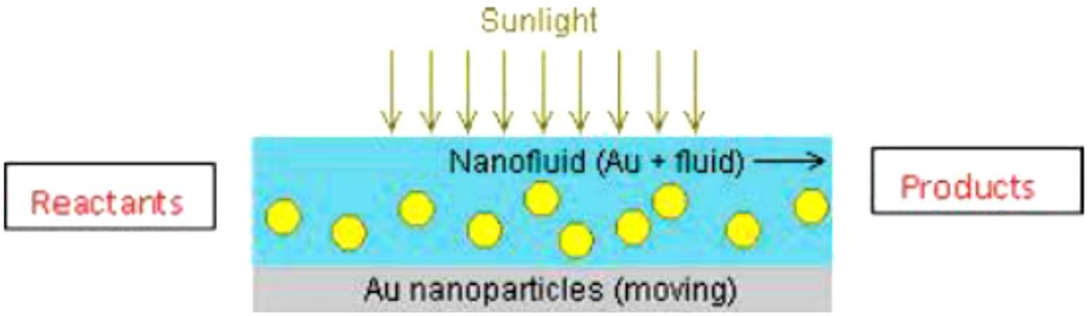

Figure 5: Nanofluid layout, nanoparticles in the base fluid environment

Photocatalyst application based on nanotechnology in solar cells

Photocatalytics are usually semiconducting solid oxides that generate a pair of electrons in the photons by absorbing them. Types of nano-photocatalytics such as titanium dioxide, zinc oxide, cadmium sulfide etc. have been used. The problem with these photocallists is the absorption of short wavelengths of the sun light. Accordingly, their efficiency is reduced and costs rise. It has been combined them together to solve this problem. Another application of nanofootocatalists in solar cells in addition to increase the absorption range and directing it to visible light, is development and accelerate of the electron transfer to the electrodes, thereby reducing the resistance of the cells; In this case, the recombination of the electrons with the cavities is reduced and the generated electrical current increases and energy conversion efficiency improves (10).

Application of Nanotechnology in Power Saving Systems

Rechargeable batteries and supercapacitors

One of the problems in solar power generation systems is the instability and irregular production. Power generation in these systems is subject to environmental conditions such as weather conditions, temperature, and hours of sunlight. For this reason, constant and uniform generation is not possible in these systems. Therefore, a storage device such as a battery is necessary to eliminate power generation changes when using it. Typical batteries have a lot of weight and volume and low efficiency and their replacement cost a lot to the consumer. Among the new generation of batteries, lithium batteries have been considered. Nanotechnology is also widely used in this area (27).

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The most important difference between ordinary cells and lithium batteries is the use of organic solvents instead of water as an electrolyte solvent. Lithium-ion battery provides lithium-ionic communications between two electrodes and it exchange the electron in two electrodes in the charge and discharge mode (Fig. 6). One of the main problems of liquid electrolytes is high electrical resistance due to the use of organic solvents. Nanomaterials are used to improve electrolyte performance. The use of powders, especially in the form of nanoparticles, of compounds such as aluminum oxide, silicon oxide and zirconium oxide to non-aqueous electrolyte can increase the conductivity up to 6 times. The research process leads to the generation of solid polymer electrolytes instead of liquid electrolytes of first generation lithium batteries.

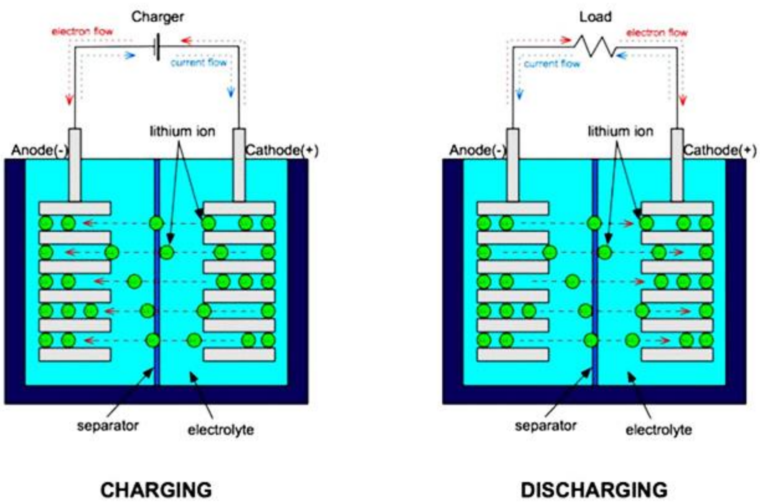

Figure 6: Lithium battery charging and discharging mode schematics

Different materials are required in rechargeable batteries, for cathode that the main lithium is accumulated when the battery is drained and the anode that emits different lithium ions when the battery is evacuated. Since the power density is compatible with the available lithium content, the volume change in each of the electrodes during the discharge charge cycle can be high. For this purpose, researchers are developing nanocomposites of metal oxide nanoparticles for the cathode that the use of these leads to a higher density of lithium intercalation, better propagation and electrical conductivity of the cathode. Also, the use of carbon materials and metal alloys in the anode has the tensile strength of the anode and adapts to the increase in volume changes during the charge cycle. The surface of the supercapacitors electrode determines their energy density. Therefore, scientists are developing nanocrystalline materials, carbon nanotubes and

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aerogels, all of which have a high surface-to-surface ratio. At the same time, since supercapacitors use a small amount of electrolyte, the surface of each electrode should be designed to make sure that the interactions between the electrode and the electrolyte ion are optimal. Many supercapacitors use organic electrolytes, and therefore, the size of their anions and cations varies greatly. Therefore, the surface structure of each electrode should have nanoparticles with different dimensions (28).

Research and development in this sector are very close to the market; so that experts believe that nanotechnology will have a significant impact in this area over the next few years. Advanced batteries and supercars are expected to be priced well on the market due to the high demand for portable power supplies.

Self-cleaning and anti-fouling nano-coatings, protecting and increasing efficiency

One of the factors reducing the efficiency of solar cells is environmental factors such as light reflection from the solar cell surface is the cloudy weather and obstacles created by light passage like sediment layers on the solar cell floor. The advancement of technology and the fabrication of nano-layers with anti-reflection and self-reflection properties increases solar power generation to solve this problem. Nano-coatings made up of titanium oxide nanoparticles that, can destroy organic pollutants such as hydrocarbons by absorbing sunlight, is able to keep the solar cell levels clean and prevent them from becoming dirty by eliminating fossil fuel pollution. Thus, sunlight is more intense to the surface of the cell, and the process of producing electrons and cavities continues with more efficiency. In addition, by using nanotechnology, the properties of hydrophobicity of the glass surface can be changed in such a way that water does not tend to wet the surface so that the sediment effects of the salts will remain on the surface of the glass. Since the electron-throat production in semiconductor cells is proportional to the light intensity of the sun, therefore, the removal of the reflected sunlight by the solar cell-protective glass and moving it to the semiconductor surface is one of the ways to increase power (figure 7), (29).

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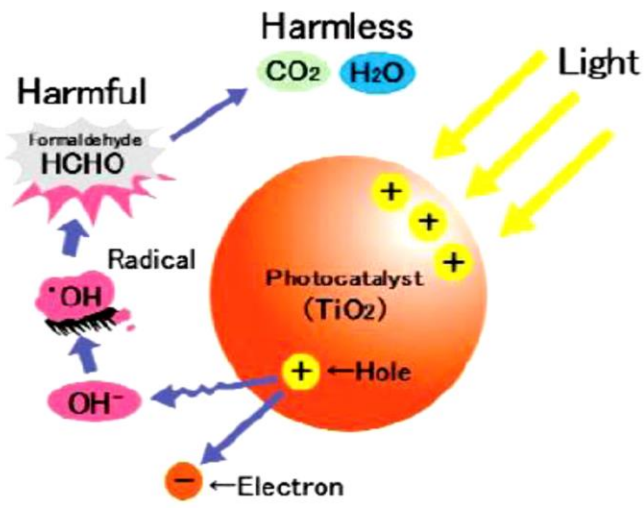

Figure 7: Performance of a photocatalyst nanoparticle in self-cleaning process

Conclusion

In this paper, with a full description of the process of nanotechnology solar energy generation, it has been studied many important applications of nanotechnology in solar energy. In recent years, the interest in the use of nanoscale materials to solve problems in solar energy conversion technology can increase the efficiency of the device, as well as reduce the cost of energy generation. The proper use of this technology leads to increase the absorption and trapping of sunlight, improve the performance of solar systems, application of Photocatalytics based on nanotechnology in solar cells, application of nano coatings and application of nanotechnology in cooling systems. Shortly, it can be said that the use of nanotechnology to build and improve the functioning of solar cells is currently in the research phase, however commercialization of this technology can be considered as a significant turning point in the solar cell industry due to very high potential that this field has shown in improving solar cell performance.

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