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Innovative Solar Panels with 60% Efficiency

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Abstract Today's photovoltaic systems are used to generate electricity to pump water, light up the night, activate switches, charge batteries, supply power to the utility grid, and many other applications. Solar batteries are usually made up of semiconductor materials especially silicon. Our innovation in this practical research was adding a floating layer in the form of nanoparticles; which was made up of elements like TiO_2, CdSe, CdTe, Cds and etc. Then we injected the said floating layer into the space between the intermediate layers. Regarding the thickness of composing elements in the floating layer we reached a thickness of 8 to 12 nano meter. Creating quantum dots for electron flow through such holes in order to reach their destination with high speed results in less waste of time and increases the efficiency of the panel to more than 60 percent. This operation makes the resulting panel to be more efficient in comparison to traditional panels. So regarding the production costs, energy output shows better turnover and seems to be more cost-effective. This panel is soft and flexible.

Keywords TiO_2, CdSe, CdTe, Cds, 60% Efficiency

1. Introduction

Today as the traditional and nonrenewable sources of energy like fossil fuels are running out day by day and since they produce lots of pollutions, energy supply has been one of the foremost issues for human societies. Industrial and technologic developments pave the ways to introduce new and applicable innovations and inventions. [1-4]

Among the energy resources the easiestone to access and a free source is solar energy. Such resource utilization requires converting solar radiation (sunlight) to electrical power. This is achieved by means of photovoltaic systems. A photovoltaic system is an arrangement of components with no mobile and chemical mechanisms, designed to supply usable electric power for a variety of purposes, using the Sun (or less commonly, other light sources) as the reference source. In other words energy supply and exploitation in such systems in comparison to fossil fuel sources is more cost-effective and cleaner.

The process of electricity production in photovoltaic systems is easier and less harmful rather than the other usual energy sources. In photovoltaic process, light particles called photons penetrate inside the cells and emit electric current by releasing electrons from silicon atoms. As far as light radiates into the cells electricity is produced. These cells unlike the other batteries do not run out electrons. They are converters which convert solar energy (sunlight) into electricity. The production of electricity by photovoltaic modules is absolutely safe.

Recently the lifelong of solar modules operation was considered 10 years, but benefiting from technologic developments the average operating time for such modules has been increased to 25 years. Most parts of a solar module can be recycled up to 97% of certain semiconductor materials or the glass as well as large amounts of ferrous and non-ferrous metals.

2. Background

Research into photovoltaic technology began over one hundred years ago. In 1873, British scientist Willoughby Smith noticed that selenium was sensitive to light. Smith concluded that selenium’s ability to conduct electricity increased in direct proportion to the degree of its exposure to light. This observation of the photovoltaic effect led many scientists to experiment with this relatively uncommon element with the hope of using the material to create electricity. In 1880, Charles Frits developed the first selenium-based solar electric cell.The cell produced electricity without consuming any material substance, and without generating heat. Broader acceptance of photovoltaic as a power source didn’t occur until 1905, when Albert Einstein offered his explanation of the photoelectric effect. [5]

Einstein’s theories led to a greater understanding of the physical process of generating electricity from sunlight. Scientists continued limited research on the selenium solar cell through the 1930’s; despite its low efficiency and high production costs.In the early 1950’s; Bell Laboratories began a search for a dependable way to power remote communication systems. Bell scientists discovered that silicon, the second most abundant element on earth, was sensitive to light and, when treated with certain impurities, generated a substantial voltage. By 1954 ,Bell developed a silicon-based cell that achieved six percent efficiency.The first non-laboratory use of photovoltaic technology was to power a telephone repeater station in rural Georgia in the late 1950s. National Aeronautics and Space Administration (NASA) scientists, seeking a lightweight, rugged and reliable energy source suitable for outer space, installed a PV system consisting of 108 cells on the United States' first satellite, Vanguard I. By the early 1960s, PV systems were being installed on most satellites and spacecraft.

Today, over 200,000 homes in the United States use some type of photovoltaic technology. Solar modules contribute power to 175,000 villages in over 140 countries worldwide, producing thousands of jobs and creating sustainable economic opportunities. In 2001 of photovoltaic products global market totaled over 350 megawatts and over $2 billion in the global market. The applications include communications, refrigeration for health care, crop irrigation, water purification, lighting, cathodic protection, environmental monitoring, marine and air navigation, utility power, and other residential and commercial applications. The intense interest generated by current photovoltaic applications provides promise for this rapidly developing technology.

3. Statement of the Problem

Traditionally there are two dominant types of technologies in fabricating solar cells; First Generation and Second Generation. First generation is based on the silicon wafers with 300-400 µm thickness which have crystalline or polycrystalline structure; and is obtained from sliced crystal or resulted from EFG method by means of capillary rise. Second-generation solar cells are usually called thin-film solar cells and made up of layers of semiconductor materials with only a few micrometers thickness around 3-5 µm. Raw materials costs in second generation fabrication is less than past and the size of cells is 100 times larger than the cells fabricated by first generation technology and this is a privilege for bulk fabrication of the second generation cells. But the efficiency of first generation cells, which are the most marketed ones, due to their high quality is more than the efficiency of the second generation cells.[6-9]

It is expected that the difference between the rates of efficiency between these two generations will be reduced during time and the second generation will be replaced by the first generation. In 1961 Queasier and Shockley considering a solar cell as a black body with 300° Kelvin showed that the most rate of efficiency in a solar cell notwithstanding its fabricating technology is 30% which is obtained at energy gap eV1.4 i.e. We obtain Gallium (III) arsenide gap energy. So the efficiency of the solar cells in first and second generations even at their best state will not exceed 30%. The Carnot limitation for converting solar energy to electricity is 95% which is three times bigger than the final efficiency of the first and second generations' cells.

Our innovation in this practical research was adding a floating layer in the form of nanoparticles; which is made up of elements like TiO_2, CdSe, CdTe, Cds and etc. Then we injected the said floating layer into the space between the intermediate layers. Regarding the thickness of composing elements in the floating layer we reached a thickness of 8 to 12 nano meter. Creating quantum dots for electron flow through such holes in order to reach their destination with high speed results in less waste of time and increases the efficiency of the panel to more than 60 percent.

4. Experimental Section

4.1. Materials

The precursors employed in this investigation to prepare CdSe QDs were Cadmium oxide (CdO, Alfa, 99.299%), tetrade-cylphosphonic acid (TDPA, PCI Synthesis), trioctylphosphine oxide (TOPO, Acros, 99%), selenium (Aldrich, 99.7+%), trioctylphosphine (TOP, Aldrich, 92%), and dodecylamine (DDA, Alfa, 96%) - all used as supplied. Mercaptopropionic acid (MPA, 99+% purity) was obtained from Aldrich Chemicals. Titanium (IV) isopropoxide (Aldrich) served as a precursor to prepare TiO_2 colloids. Conducting glass plates (0.8 cm x 4 cm) obtained from Pilkington, USA, were used as optically transparent electrodes (OTE.)

4.2. Preparation of CdSe Nanoparticles

One-pot synthesis was used to synthesize colloidal CdSe QDs.[10] In particular, 0.35 g CdO, 0.3 g TDPA, 1.0 g DDA, and 1.8 g TOPO are placed in a round-bottom flask and heated with vigorous stirring under nitrogen. At ~315 °C, a mixture of 4.0 mL TOP and 0.26 mL 1M TOPSe (Se dissolved in TOP) is injected into the mixture causing a temperature drop to ~245-250 °C. Heating of the solution is sustained, and subsequent growth is carried out at 270 °C. On reaching the desired QD size as determined through UV-vis spectroscopy, [11] heat supplies to the reaction pot is removed and the resultant quantum dots are washed with 3:1 methanol-toluene, centrifuged, and dissolved in toluene for storage.

4.3. TiO_2/CdSe Films

TiO_2 powder (3.5 g; P-25, mostly in anatase form) from Degussa is thoroughly mixed with 4.5 /uL of titanium isopropoxide in 15 mL of ethanol using a homogenizer for 1 h in an ice bath. The paste was then coated on OTE electrodes by the doctor-blade technique. The resulting film thickness was 8 um. The films prepared with this method are referred to as OTE/TiO_2 (NP) lectrodes.

Cut pieces (0.8 cm x 4 cm) of titanium foil (0.25 mm in thickness, >98% from Aldrich) were degreased by sonication in isopropanol for 1 h. The titanium foil was placed in an electrochemical cell equipped with a platinum mesh counter electrode and a power supply. Ammonium fluoride (0.25 M) in formamide (5 wt % water) was used as an electrolyte.[12] A constant voltage of 20 V was applied between the two electrodes for 16 h to obtain a 8 um thick TiO_2 nanotube array. The nanotubes have an average outer diameter of 90 nm and a tube thickness of 12 nm. The arrays prepared by this method are referred to as Ti/TiO_2-(NT) electrodes.

5. How a Photovoltaic Cell Works

5.1. Step 1

A slab (or wafer) of pure silicon is used to make a PV cell. The top of the slab is very thinly diffused with an “n” dopant such as phosphorous.On the base of the slab a small amount of a “p” dopant, typically boron, is diffused. The boron side of the slab is 1,000 times thicker than the phosphorous side. Dopants are similar in atomic structure to the primary material. The phosphorous has one more electron in its outer shell than silicon, and the boron has one less. These dopants help create the electric field that motivates the energetic electrons out of the cell created when light strikes the PV cell.[13]

The phosphorous gives the wafer of silicon an excess of free electrons; it has a negative character. This is called the n-type silicon (n = negative).The n-type silicon is not charged—it has an equal number of protons and electrons—but some of the electrons are not held tightly to the atoms. They are free to move to different locations within the layer.The boron gives the base of the silicon a positive character; because it has a tendency to attract electrons. The base of the silicon is called p-type silicon (p = positive). The p-type silicon has an equal number of protons and electrons; it has a positive character but not a positive charge.

5.2. Step 2

Where the n-type silicon and p-type silicon meet, free electrons from n-layer flow into the p-layer for a split second, then form a barrier to prevent more electrons from moving between the two sides. This point of contact and barrier is called the p-n junction.

When both sides of the silicon slab are doped, there is a negative charge in the p-type section of the junction and a positive charge in the n-type section of the junction due to movement of the electrons and “holes” at the junction of the two types of materials. This imbalance in electrical charge at the p-n junction produces an electric field between the p-type and n-type silicon.

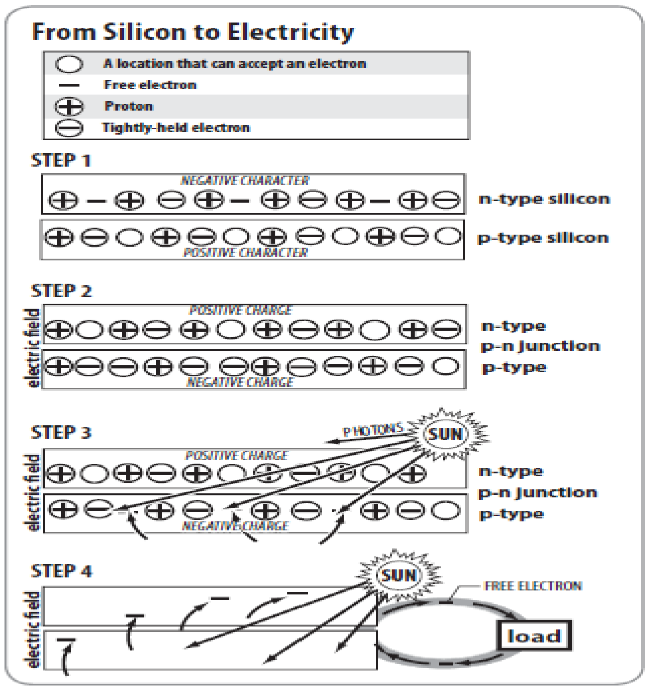
5.3. Step 3

If the PV cell is placed in the sun, photons of light strike the electrons in the p-n junction and energize them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-type silicon and repelled by the negative charge in the p-type silicon. Most photoelectron collisions actually occur in the silicon base.

5.4. Step 4

A conducting wire connects the p-type silicon to an electrical load, such as a light or battery, and then back to the n-type silicon, forming a complete circuit. As the free electrons are pushed into the n-type silicon they repel each other because they are of like charge. The wire provides a path for the electrons to move away from each other. This flow of electrons is an electric current that travels through the circuit from then-type to the p-type silicon.

In addition to the semi-conducting materials, solar cells consist of atop metallic grid or other electrical contact to collect electrons from the semi-conductor and transfer them to the external load, and a back contact layer to complete the electrical circuit.



With all this in view, if we use a capacitor instead of conducting wire, current flow from capacitor generates energy and in this way the energy of light photons is converted to electricity. For example, in present methods from among each 100 electrons finally 8 to 15 of them reach the destination and produce DC electricity while after achieving this kind of electricity 70% of it is converted to AC.[14]

A quantum dot is a nano crystal made of semiconductor materials that are small enough to display quantum mechanical properties. Specifically, its excitons are confined in all three spatial dimensions. The electronic properties of these materials are intermediating between those of bulk semiconductors and of discrete molecules. Quantum dots were discovered in a glass matrix by Alexei Ekimov and in colloidal solutions by Louis E. Brus. The term "quantum dot" was coined by Mark Reed.[15]

The ability to tune the band gap is what makes quantum dots desirable for solar cell use. Quantum dots are particles of semiconductor material that have been reduced below the size of the Exciton Bohr-radius, and due to quantum mechanics considerations, the electron energies that can exist within them become finite, like existing energies in an atom. In fact, quantum dots have often been referred to as "artificial atoms". These energy levels are tunable by changing the size of quantum dots, and in turn define the band gap. The dots can be grown over ranges of size, allowing them to be tuned across a wide variety of band gaps without changing the underlying material or construction techniques. In typical preparations employing wet chemistry, the tuning is accomplished by varying the duration or temperature of synthesis.

The emergence of Nano structure products hascreated new prospective facing the materials science. Because of the fine size and the high performance of these products the quantum rules have gained more attention. When the size or dimension of a thing frequently changes from large dimensions to very small sizes, at first the characteristics do not change then smaller changes take place and when the size reaches under 100 nm great changes take place in the characteristics. These set of materials which possess a size under 100nm are called nano materials. If in these materials just one dimension is minimized to nano scale while the other two dimensions remain large we reach a structure called 'quantum well'. If two dimensions are minimized to a nano scale and the other one is still large we reach a structure called 'quantum wire'. At the end of the process of minimization where all three dimensions reach a scale under the nano size, 'quantum dot' is obtained. In other words we can say that quantum dots are zero-dimensional structures. Quantum dots can be categorized according to metals like nickel, cobalt, platinum, gold and semiconductors like cadmium telluride (CdTe), cadmium selenide (CdSe) and cadmium sulfide (CdS). The usual size of these materials is between 2 to 20 nm, but according to some studies their size may even be smaller than 10 nm. Quantum dot structures have a vast applicability in different technological fields. One of these fields which have recently been paid significant attention to, is applying such structures innano structure solar cells which in turn not only results in reducing the cost of fabrication, but also increases the conversion efficiency.[16]

The optic and electronic features of metal and semi-conductornano crystals depends largely on their size. Therefore, it is required to implement specific methods for semiconductor quantum dots synthesis.

In this research for quantum dots synthesis we used interlacing growth of clusters on a surface. There are different variables in this method which leads to the emergence of different branches in this field. What seems necessary is the accumulation of the crystalline films (or a film in crystalline state with atomic size) in a vapor or liquid phase. This method encompasses a wide range of quantum dots and by means of it through providing suitable arrangements we can reach an appropriate and regulated situation.

First of all we arranged nano particles according to a specific formula and under the especial laboratory conditions. This structure is a modified sample of sensitive photovoltaic cells fabricated from TiO_2 nano crystals and color molecules. In cells which have been sensitized by quantum dots, the color molecules are replaced by quantum dots. A significant potentiality of these cells is quantum dots high efficiency which is the result of compact ionization (Reverse Auger Effect). Meanwhile these dots are injected between Eva layers and groups of cells. This material is in liquid form and in addition to preparing the quantum dots for free electrons flow from silicon wafer, releases electron and in this way efficiency is achieved over 60%. Three chemical formulas which results in such a phenomenon are;

CdSe +hν ¬¬----->CdSe (e + h) ----->CdSe +hν

CdSe (e) + TiO_2 ----->CdSe + TiO_2(e)

CdSe (h) + Red ----->CdSe + Ox

This method decreases the loss of free electrons during their flowtowards destination. After matching the wafers in tabber string phase and before matching the modules, between module 1 and 2 (adjacent modules) gelatinous fluid is used to increase the panel flexibility. Although TiO_2 is among the forbidden industrial gases, by enclosing this gas in isolating interface we prevented from any problems. This liquid is almost gray and is injected by means of nanoparticle injection device.

5.5. Benefits of Innovation

1. This product has a high efficiency and occupies less space than the other solar panels in previous generations.
2. It can be used in military and aerospace industries and has applicability in different other industries.
3. Use of clean generative energy with no fuel consumption and more energy saving in less time.
4. Preventing from solar energy waste.
5. Avoiding the high costs of electricity generation in dams and encountering ecosystem changes.
6. Preventing from the diffusion of greenhouse gases via generating electricity using fossil fuels and endangering ozone layer.
7. Preventing from great use of renewable resources; according to an accredited American institution, Iran owns gas and oil resources just for the next 50 years.
8. Commercialization of this product is very valuable and can result in significant exchange gain annually.
9. Producing one KB electricity in this way is cheaper than the other traditional ways or better to say it costs nothing, because all the production costs are paid by private sections.
10. The extra electricity produced in this system can be

used as the input electricity for other resources.

6. Applications

1. Household daily power supply.
2. Electricity supply for some industrial devices and machines.
3. Electricity supply for outposts.
4. Electricity supply for CCTV Cameras.
5. Laptop and cell phone charge.
6. Electricity supply for energy boxes.
7. Application in military industries to fabricate ballistic missiles.
8. Application in supplying field hospitals' and temporary camps' electricity in disasters like earthquake and flood.

7. Summary and Practical Application of the Final Product

By installing this product in specified locations and assembling accessories like storage batteries, LED lamps and electricity inverters to reach AC power, panel enables photon absorption and electron diffusion by means of silicon wafers. In this way electrons move in a high speed at nanosecond pace and passes through the wells, reach the junction box and enter the power sources or electric transmission cables as DC power. If lamps and other accessories are tunable to use DC power they will be triggered quickly. Otherwise about 70 to 80% of such power is converted to AC electricity to be operative. Storage with high efficiency in less time with proposed innovation is possible and it produces about 12 to 14 hours lightening during the night.

Available panels currently consist of first and second generations. With producing the gray liquid and injecting nanoparticles between intermediate layers we reached efficiency above 60 to 70%. This in turn increases the efficiency of solar panel with semiconductor silicon wafer technology 3 to 4 times more than current rates. After injecting nanoparticles, Eva layers turn into gray color and a second generation panel changes its nature to a third generation panel.

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