# Use of Nanotechnology in Solar PV Cell

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*Abstract*— **The solar cell industry has grown quickly in recent years due to strong interest in renewable energy and the problem of global climate change .Cost is an important factor in the success of any solar technology. Today's solar cells are simply not enough efficient and are too expensive to manufacture for large-scale electricity generation. However, potential advancements in nanotechnology may open the door to the production of cheaper and slightly more efficient solar cells. Nanotechnology has already shown huge breakthroughs in the solar field. Quantum dots have the potential to change the world. They are a form of solar cell that is completely beyoznd anything you might imagine. Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost. PVs based on CdTe, CuInGaSe (CIGS), CuInSe (CIS), and organic materials are being developed with the aim of reducing the price per watt even if that means sacrificing conversion efficiency and reliability. Utilizing nanotechnology in inexpensive solar cell would help to preserve the environment.**

*Index Terms*— **Nanotechnology, Quantum dots, Breakthroughs**

## I. Introduction

Conventional solar cells have two main drawbacks: efficiencies and their expensive manufacturing cost. The first drawback, inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy then it will pass through. If it has more energy than the band gap, then that extra energy will be wasted as heat. These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell.

Nano particles are motes of matter tens of thousands of times smaller than the width of a human hair. Because they're so small, a large percentage of nano particles' atoms reside on their surfaces rather than in their interiors. This means surface interactions dominate nano particle behavior. And, for this reason, they often have different characteristics and properties than larger chunks of the same material.

Nano-structured layers in thin film solar cells offer three important advantages. First, due to multiple reflections, the effective optical path for absorption is much larger than the actual film thickness. Second, light generated electrons and holes need to travel over a much shorter path and thus recombination losses are greatly reduced. As a result, the absorber layer thickness in nano-structured solar cells can be as thin as 150 nm instead of several micrometers in the traditional thin film solar cells. Third, the energy band gap of various layers can be made to the desired design value by varying the size of nano particles. This allows for more design flexibility in the absorber of solar cells.

Thin film is a more cost-effective solution and uses a cheap support onto which the activecomponent is applied as a thin coating. As a result much less material is required (as low as 1% compared with wafers) and costs are decreased. Most such cells utilize amorphous silicon, which, as its name suggests, does not have a crystalline structure and consequently has a much lower efficiency (8%), however it is much cheaper to manufacture .

Comparison of different photovoltaic cell shown in table -1

## II. Nanotechnology Boosts Solar Cells Performance

Current solar cells cannot convert all the incoming light into usable energy because some of the light can escape back out of the cell into the air. Additionally, sunlight comes in a variety of colors and the cell might be more efficient at converting bluish light while being less efficient at converting reddish light. See in Figure 1. Lower energy light passes through the cell unused. Higher energy light does excite electrons to the conduction band, but any energy beyond the band gap energy is lost as heat. If these excited electrons aren't captured and redirected, they will spontaneously recombine with the created holes, and the energy will be lost as heat or light.

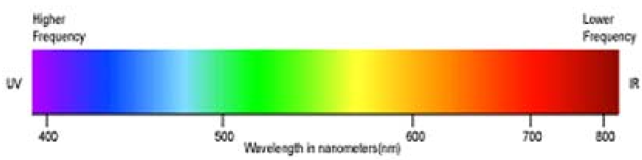


Figure 1. Visible Light Spectrum

In conventional solar cells, ultraviolet light is either filtered out or absorbed by the silicon and converted into potentially damaging heat, not electricity. Ultraviolet light could efficiently couple to correctly sized nanoparticles and produce electricity. Integrating a high-quality film of silicon nanoparticles, 1 nanometer in size directly onto silicon solar cells improves power performance by 60 percent in the ultraviolet range of the spectrum.

In bulk material, the radius is much smaller than the semiconductor crystal. But nanocrystal diameters are smaller than the Bohr radius. Because of this, the "continuous band"

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of electron energy levels no longer can be viewed as continuous. The energy levels become discrete, and quantum confinement is seen to operate. The difference of a few atoms between two quantum dots alters the band gap boundaries. Small nanocrystals absorb shorter wavelengths or bluer light, whereas larger nanocrystals absorb longer wavelengths or redder light. Changing the shape of the dot also changes the band gap energy level as shown in Figure 2.

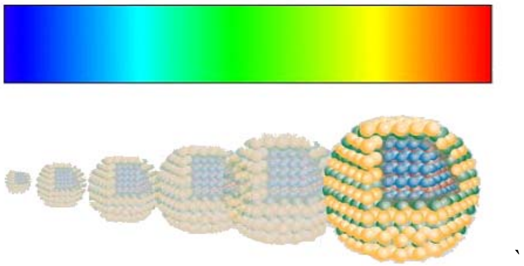

Figure 2. The relationship of size of quantum dot to the light absorbed

To make the improved solar cells, the researchers began by first converting bulk silicon into discrete, nano-sized particles. Depending on their size, the nanoparticles will fluoresce in distinct colors. Nanoparticles of the desired size were then dispersed in isopropyl alcohol and dispensed onto the face of the solar cell. As the alcohol evaporated, a film of closely packed nanoparticles was left firmly fastened to the solar cell.

Solar cells coated with a film of 1 nanometer, blue luminescent particles showed a power enhancement of about 60 percent in the ultraviolet range of the spectrum, but less than 3 percent in the visible range. Solar cells coated with 2.85 nanometer, red particles showed an enhancement of about 67 percent in the ultraviolet range, and about 10 percent in the visible range of the spectrum.

Ultra thin films of highly mono dispersed luminescent Si nanoparticles are directly integrated on polycrystalline Si solar cells. Films of 1 nm blue luminescent or 2.85 nm red luminescent Si nanoparticles produce large voltage enhancements with improved power performance of 60% in the UV/blue range. In the visible, the enhancements are ~10% for the red and ~3% for the blue particles.

Another potential feature of these solar cells is that the nanorods could be 'tuned' to absorb various wavelengths of light. This could significantly increase the efficiency of the solar cell because more of the incident light could be utilized

Single-walled carbon nanotubes to a film made of titanium-dioxide nanoparticles, doubling the efficiency of converting ultraviolet light into electrons when compared with the performance of the nanoparticles alone.

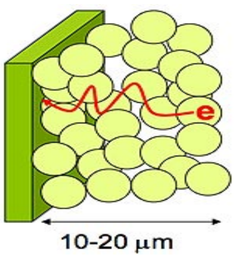


Figure 3. Escape route of electron

Escape route: Electrons created in a nanoparticle-based solar cell have to follow a circuitous path (red line) to reach an electrode. Many don't make it, lowering the efficiency of these cells. Researchers at Notre Dame have used carbon nanotubes to help the electrons reach the electrode, improving efficiency.

Without the carbon nanotubes, electrons generated when light is absorbed by titanium-oxide particles have to jump from particle to particle to reach an electrode. Many never make it out to generate an electrical current. The carbon nanotubes "collect" the electrons and provide a more direct route to the electrode, improving the efficiency of the solar cells.

The CNTs provide better electron ballistic transport property along its axis with high current density capacity on the surface of the solar cell without much loss. The alignment of the CNT with the polymer composites substrate give very high efficiency in photovoltaic conversion. The polymer composites increase contact area for better charge transfer and energy conversion. In this process, the efficiency of solar cell is about 50% at the laboratory scale. The optimum efficiency was achieved with the aligned CNTs with poly 3 - octyl thiophene (P3OT) based PV cell. P3OT has improved the property due to polymer - and nano tubes junctions within the polymer matrix. High electric field within the nano tube splits the exciton to electrons and holes, and enables faster electron transfer with improved quantum efficiency of more than 50%.

*A. Improving the Efficiency of Solar Cells by Using Semiconductor Quantum Dots (QD)*

Another starting point for the increase of the conversion efficiency of solar cells is the use of semiconductor quantum dots (QD). By means of quantum dots, the band gaps can be adjusted specifically to convert also longer- wave light and thus increase the efficiency of the solar cells. These so called quantum dot solar cells are, at present still subject, to basic research. As material systems for QD solar cells, III/V-semiconductors and other material combinations such as Si/Ge or Si/Be Te/Se are considered. Potential advantages of these Si/Ge QD solar cells are:

1) Higher light absorption in particular in the infrared spectral region,
2) Compatibility with standard silicon solar cell production (in contrast to III/V semiconductors),
3) Increase of the photo current at higher temperatures,
4) Improved radiation hardness compared with conventional solar cells.

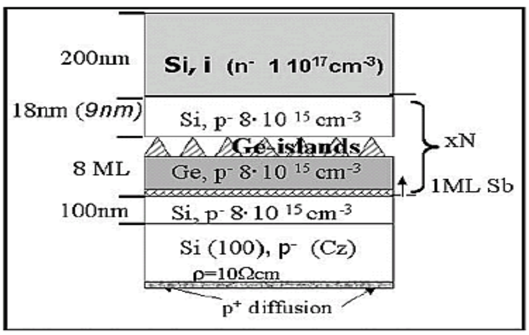


Figure 4. Schematic structure of a Si/Ge QD solar cell with layers Gequantum dots in the active layer of the Si solar cell substrate

## III. Nanotechnology Improve the Solar Cell

Present available nanotechnology solar cells are not as efficient as traditional ones, however their lower cost offsets this. In the long term nanotechnology versions should both be lower cost and, using quantum dots, should be able to reach higher efficiency levels than conventional ones.

To coat the nanoparticles with quantum dots--tiny semiconductor crystals. Unlike conventional materials in which one photon generates just one electron, quantum dots have the potential to convert high-energy photons into multiple electrons. Quantum dots work the same way, but they produce three electrons for every photon of sunlight that hits the dots. Electrons moves from the valance band into the conduction band The dots also catch more spectrums of the sunlight waves, thus increasing conversion efficiency to as high as 65 percent. Another area in which quantum dots could be used is by making so-called a hot carrier cells. Typically the extra energy supplied by a photon is lost as heat, but with a hot carrier cells the extra energy from the photons result in higher-energy electrons which in turn leads to a higher voltage.

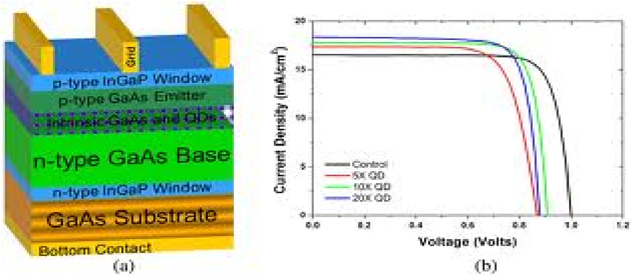


Figure 5. -_a) Quantum-dot (QD)-enhanced solar-cell design concept. (b) Current density-voltage curves for control and 5–20 layer enhanced cells under one sun global air mass 1.5 (AM1.5g) light. These cells did not have antireflective coating. InGaP: Indium gallium phosphide. GaAs: Gallium arsenide.

The transport of electrons across the particle network is the major problem in achieving higher photo conversion efficiency in nanostructured electrode. Utilization of CNT network support to anchor light harvesting semiconductor particles by assisting the electron transport to the collecting electrode surface in DSSC. Charge injection from excited CdS into SWCNT excitation of CdS nanoparticle. When CNTS attached in Cdse & CdTe can induce charge transfer process under visible light irradiation. The enhanced interconnectivity between the titanium dioxide particles and the MWCNTs in the porous titanium dioxide film was concluded to be the cause of the improvement in short circuit current density.

## IV. Cost Reduction by Nano Technology

Conventional crystalline silicon solar cell manufactured by high of using a low temperature process similar to printing. Nanotechnology reduced installation costs achieved by producing flexible rolls temperature vacuum deposition process but nanotechnology . Reduced manufacturing costs as a result instead of rigid crystalline panels. Cells made from semiconductor thin films will also have this characteristic

Nanosolar company have successfully created a solar coating that is the most cost-efficient solar energy source ever. Their Power Sheet cells contrast the current solar technology systems by reducing the cost of production from $3 a watt to a mere 30 cents per watt. This makes, for the first time in history, solar power cheaper than burning coal.

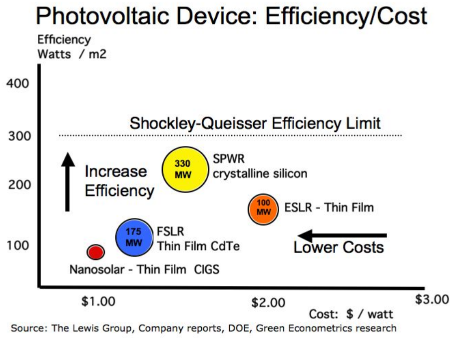


Figure 6. Cost/Efficiency Tradeoff

Photovoltaic devices are limited in their practical efficiencies governed by the thermodynamic limits and production costs that involve tradeoffs in materials, production processes, and PV device packaging. The Lewis Group as a result of higher efficiency or lower production provides a thorough illustration of the efficiency trends for various PV devices materials such as crystalline silicon used in semiconductors as well as the new approaches to thin film PV including amorphous silicon, cadmium telluride (CdTe), copper indium deselenide (CIS) and copper indium gallium deselenide materials (CIGS). These thin film material could offer substantial PV devices price reductions costs.

## V. Application of Nanotechnology use Solar Cell

1) Inexpensive solar cells, which would utilize nanotechnology, would help preserve the environment.
2) Coating existing roofing materials with its plastic photovoltaic cells which are inexpensive enough to cover a home's entire roof with solar cells, then enough energy could be captured to power almost the entire house. If many houses did this then our dependence on the electric grid (fossil fuels) would decrease and help to reduce pollution.
3) Nanotechnology in solar cells would also have military implications. The U.S. Army has already hired Konarka Technologies to help design a better way to power their soldiers' electrical devices. According to Daniel McGahn, Konarka's executive vice president, "A regular field soldier carries 1.5 pounds of batteries now. A special operations has a longer time out, has to carry 140 pounds of to create inexpensive and reasonably efficient solar equipment soldier, 60 to 70 pounds of which are batteries "If nanotechnology could be used cells, it would greatly improve soldiers' mobility.
4) Inexpensive solar cells would also help provide electricity for rural areas or third world countries. Since the electricity demand in these areas is not high, and the areas are so distantly spaced out, it is not practical to connect them to an electrical grid. However, this is an ideal situation for solar energy.
5) Cheap solar cell could be used for lighting, hot water, medical devices, and even cooking . It would greatly

improve the standard of living for millions, possibly even billions of people.

6) Flexible, roller-processed solar cells have the potential to turn the sun's power into a clean, green, convenient source of energy Even though the efficiency of Plastic photovoltaic solar cell is not very great, but covering cars with Plastic photovoltaic solar cells or making solar cell windows could be generate the power and save the fuels and also help to reduce the emission of carbon gases.

TABLE – 1 COMPARISON OF DIFFERENT PHOTOVOLTAIC CELL

| Sub-Types | Mono-crystalline | Poly-crystalline | CdTe | CIGS | a-Si | Multi Junction |
|---|---|---|---|---|---|---|
| | Purity 99.99999% | Purity 99.99999% | low temperature sensitivity | captures large spectrum | Amorpho us Silicon | GaAs/CIS a-Si/mc-Si |
| Description | Crystalline silicon wafers | | Semiconductor is deposited directly on glass | | | |
| Module Efficiency | High | | Low | | | |
| Performance under heat | Performance degrades with higher temperatures | | Up to 60% lower heat coefficient than crystalline silicon modules, making it a good choice in hot climates. | | | |
| Space required per kWp | Polycrystalline: 10m² - 30m² depending on cell spacing Mono crystalline : > 8m² | | Glass-glass laminate ~ 25m² | | | |
| Degradation | Degradation | | Degradation | | | |
| Direct or diffuse light | Direct or diffuse light | | Direct or diffuse light | | | |
| Amount of photovoltaic material needed | Poly silicon: 8g/W | | CdTe : 0.22g/W | | | |
| Efficiency (production ) | 15-20% | 13 - 15% | 10% | 12% | 7% | 36% |
| Efficiency (lab) | 25% | 21% | 16% | 20% | 10% | 40% |

## VI. CONCLUSION

Nanotechnology (“nano”) incorporation into the films shows special promise to both enhance efficiency of solar energy conservation & reduce the manufacturing cost. Although the nanotechnology is only capable of supplying low power devices with sufficient energy, its implications on society would still be tremendous. It efficiency by increasing the absorption efficiency of light as well as the overall radiation-to-electricity would help 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

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