The Role of Nanotechnology to enhance solar energy

Krinal Adaki[1], Amar Bariya[2], Maulik Bhavsar[3], Iliyas Belim[4], Krunal Ghodeswar[5] and Pranav Dave[6*]

[1,2,3,4,5]*Gandhinagar institute of Technology, Gandhinagar, Kalol, Gujarat*
[6]*School of Research & Development, National Forensic Sciences University, Gandhinagar-382007, India*

Abstract: *Nanotechnology has tremendous applications in various sectors and also has wide range to implement. Since few years, nanotechnology is widely used to develop new techniques in research. Even though, researchers have interested in this field to develop new materials and applications. Nanoscience has become a diverse and unique field of scientific and technical activity. The reasons are-the unique properties of nanostructures and the outstanding performance of nanoscale devices. At the nanoscale, a material's property can change dramatically, with unique design possibilities and properties; they attract the attention of researchers worldwide. After some of the years, the energy problem will be stand in front of us as recently there are many devices and although humans, who wasted the energy somehow. This paper explains how the concept of nanotechnology can help the world to enhance maximum energy from the device or material. Paper also explains the advantages and disadvantages of Nanotechnology while producing the solar energy. It also describes the brief introduction of promising solar energy.*

Keywords: *Solar cells, solar energy, renewable energy, nanotechnology.*

1. INTRODUCTION OF NANOTECHNOLOGY

The term was coined in 1974 by Norio Taniguichi of Tokyo Science University to describe semiconductor processes such as thin-film deposition that deal with control on the order of nanometers. His definition still stands as the basic statement today: "Nano-technology mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule." One nanometer is a billionth of a meter, or 10^{-9} of meters. Here are a few illustrative examples: [1],[2]

- There are 25,400,000 nanometers in an inch
- A sheet of newspaper is about 100,000 nanometers thick
- On a comparative scale, if a marble were a nanometer, then one meter would be the size of the Earth.

Nanotechnology has been around since the beginning of time. Nature has always routinely used nanotechnology to synthesize molecular structures in the body, such as enzymes, proteins, carbohydrates, and lipids, which form components of cellular structures. However, the formal discovery of nanotechnology has been widely attributed to the American physicist and Nobel Laureate Dr. Richard Phillips Feynman, who presented a paper called There's Plenty of Room at the Bottom on December 29, 1959, at the annual meeting of the American Physical Society at California Institute of Technology. Nanotechnology operates on atoms and molecules on the nano-meter scale, and by controlling the arrays and structure of substances, it exploits the unique characteristics of Nano-size particles to create new, excellent characteristics of substances. The dictionary, definition states that nanotechnology is "the art of manipulating materials on an atomic or molecular scale specially to build microscopic devices." Other definitions include the US government which states that "Nanotechnology is research and technology development at the atomic, molecular or macromolecular level in the length scale of approximately 1-100 nm range, to provide a fundamental understanding of phenomena and materials at the Nano-scale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size" [3],[4]. Nanotechnology is a truly multidisciplinary field involving chemistry, physics, biology, engineering, electronics, social sciences, etc., which need to be integrated together to generate the next level of development in nanotechnology. Fuel cells, mechanically stronger materials, Nano biological devices, molecular electronics, quantum devices, carbon nanotubes (CNTs), etc. have made use of nanotechnology. In a recent report of the National Science Foundation to the President's Office of Science and Technology Policy it was stated that "Nanoscience and technology will change the nature of almost every human-made object in the next century" [5].

1.1. Areas that nano- technology promises to affect

Pharmacy

It may be possible to create biomolecules that carry out "pharmacy in a cell" release cancer-fighting nanoparticles or chemicals in response to a distress signal from an afflicted cell [4].

Information Storage:

Ultrafine dye particles often yield higher quality inks in terms of color, coverage, and colorfastness. Also, ''nano pens'' (atomic force microscope tips) can write letters with features as small as 5 nm. Nanoparticles have already found their way into modern audio and videotapes and disks, which are dependent on magnetic and optical properties of fine particles. Further advances will be made with smaller and smaller size and with control of magnetic coercively and optical absorption, so that much denser storage media should be possible [6].

Refrigeration

On a small scale it has been demonstrated that an entropic advantage can be gained in magnetic particle field reversal. Thus, upon application of a magnetic field, the entropy of a magnetic species changes and if adiabatic conditions are maintained, the application of the field will result in a temperature change. This ΔT is the magnetocaloric effect, and the magnitude of this effect depends on the size of the magnetic moment, heat capacity, and temperature dependence of the magnetization. If nanoparticles with large magnetic moments and adequate coercivity can be obtained, the magnetocaloric effect may allow refrigeration on a practical scale. The promise of magnetic nanoparticles refrigerators, with no need for refrigeration fluids (Freons, HFC, etc.), has enticed many researchers, and success would mean tremendous benefits for society and the environment. Chemical/Optical Computers Organized two-dimensional or three-dimensional arrays of metal or semiconductor nanoparticles exhibit special optical and magnetic properties. These materials hold promise in numerous applications in the electronics industry, including optical computers [7]. Harder Metals Nanoparticulate metals when compressed into solid objects exhibit unusual surface hardness, sometimes as high as five times that of the normal microcrystalline metal. Film Precursors Similar to their use in inks, nonaqueous metallic colloidal solutions have proven useful as precursors for thin metallic film formation when used as spray paint. Gilding of silver artifacts with gold has been accomplished with gold–acetone colloids [8].

Environmental/ Green Chemistry

- Solar Cells: Semiconductor nanoparticles, with size-tuneable bandgaps, hold the potential for more efficient solar cells for both photovoltaics (electricity production) and water splitting (hydrogen production) [4].

- Remediation: Photoexcitation of fine particles of semiconductors leads to electron–hole pairs that are useful for both oxidation and reduction of pollutants, for use in decontaminating water [4].

- Water Purification: Reactive metal fine powders (Fe, Zn) show high reactivity toward chlorocarbons in an aqueous environment. These results have led to the successful implementation of porous metal powder–sand membranes for groundwater decontamination [5].

- Destructive Adsorbents: Nanoparticulate metal oxides exhibit high intrinsic surface reactivities and high surface areas, and strongly chemisorb acidic gases and polar organics. Since dissociative chemisorption is usually observed, these new materials have been dubbed ''destructive adsorbents,' and are finding use in anti-chemical/biological warfare, in air purification, and as an alternative to incineration of toxic substances [5].

1.2. Role of nanotechnology in solar energy conversing

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 are 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 [9].

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 [10].

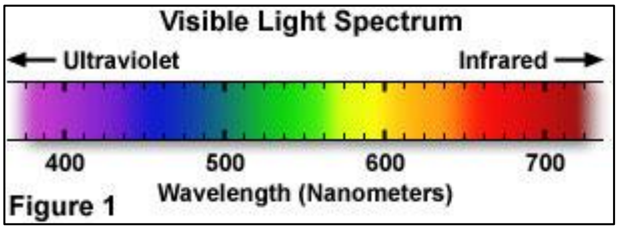

Fig-1 Nanotechnology boosts solar cells performance

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 are not captured and redirected, they will spontaneously recombine with the created holes, and the energy will be lost as heat or light. 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 Nano-particles and produce electricity. Integrating a high-quality film of silicon Nano-particles, 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 Nano-crystal diameters are smaller than the Bohr radius. Because of this, the "continuous band "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 Nano-crystals absorb longer wavelengths or redder light. Changing the shape of the dot also changes the band gap energy level as shown in figure-2 [10],[11].

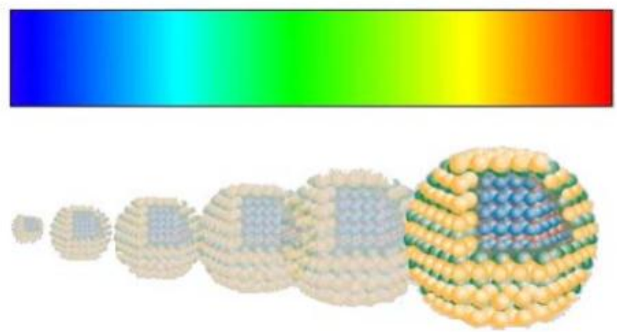

Figure 2. The relationship of size of quantum dot to the light absorbed

Fig-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 Nano-particles will fluoresce in distinct colors. Nano-particles 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 Nano-particles 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, which 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 Nano-particles are directly integrated on polycrystalline Si solar cells. Films of 1 nm blue luminescent or 2.85 nm red luminescent Si Nano-particles 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 Nano-rods 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 [12].

Efficiency of Solar Cells by using semiconductor Quantum Dots (QD)

The increase of the conversion solar cell efficiency 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: [13]

1) Higher light absorption 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.

Utilization of Carbon nanotube

Utilization of CNT network supports to anchor light harvesting semiconductor particles by assisting the electron transport to the collecting electrode surface in DSSC. Charge injection excited from 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 [10].

Merits in Nano silicon Solar Cells

As research has continued to support the incorporation of nanotechnology and solar technology, the use of resonant colloidal nanoparticles has been shown to improve the performance of halide perovskite solar cells that are derived from organometals. Furthermore, resonant metallic nanoparticles, when incorporated into these solar cells, have successfully increased light absorption and charge separation to ultimately improve the efficiency of applied solar panels. To avoid the potential reactivity of the metallic nanoparticles with the perovskite halides, a recent study applied photocurrent and fill-factor enhancements to organometal halide perovskite solar cells that also contain resonant silicon nanoparticles between its active layers. This study found that the overall efficiency of the solar cells improved by as much as 18.8%, whereas fill factor, which is a parameter that determines the maximum power that can be obtained from the solar cell, increased by a staggering 79% [12].

Reduction of the Cost of Solar Cells by Nanotechnology

Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost. Chemists at the University of California, Berkeley, have discovered a way to make cheap plastic solar cells that could be painted on almost any surface. These new plastic solar cells achieve efficiencies of only 1.7 percent. Picture of a solar cell, which utilizes nanorods to convert light into electricity, is shown in fig-3 [13].

Fig-3 Solar cell unit

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. These new plastic solar cells utilize tiny nanorods dispersed within in a polymer. The nanorods behave as wires because when they absorb light of a specific wavelength, they generate electrons. These electrons flow through the nanorods until they reach the aluminum electrode where they are combined to form a current and are used as electricity [14],[15].

2. MERITS & LIMITATIONS OF NANOTECHNOLOGY IN SOLAR ENERGY CONVERSION (ENERGY SECTOR)

Merits of nanotechnology in solar energy [5]

- Lower manufacturing costs and more flexibility in manufacturing.
- Easy to manufacture and it does not require special arrangements.
- Inexpensive solar cells, which would utilize nanotechnology, would help preserve the environment.
- 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.
- 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.
- 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.
- 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.
- As the properties of light absorption and stability, titanium has been developed in making solar cell cheaper.
- In these nano wires has been tuned for absorbing the photons, so that it can be used even in indoor lighting and maximum energy can be used.

Limitations of nanotechnology in solar cells [7],[8]

- They are not strong enough for natural calamity.
- The manufacturing of nanotechnology is a difficult process which needs high precautions.

- As on today the cadmium problem, toxicity remains. That leads Disposal of panel will be a great problem.

- Mass production of nanotechnology material is still in its infancy. As far as we can tell, it is still expensive and developing it can cost a lot of money. Moreover, Nanotechnology is likely to cause important changes in many economic areas. Once the availability of nanomaterials increases, more and more markets will feel their impact. Some technologies and materials may become obsolete, and this may lead company to go out of business. Nanotechnology may even result in job losses.

3. CONCLUSION

Energy has its specific features & conditions like wind energy can be employed in the only region where the wind speed is better, Solar energy is employed at regions where the atmosphere is regularly sunny instead of cloudy/rainy, these every specific energy has its specific conditions and the best alternative suited is opted to generate electricity. The percentage of implementing renewable energy is gradually increasing these days, as it is totally free resource from the nature and can never be in scarce. The nanotechnology introduced in solar energy gives a huge benefit to the world as it boosts the performance of solar cells. As per the study of nanotechnology is used in solar energy with its gradually increasing efficiency and flexibility, it can be said that the electricity required to power the world would be on a vast scale in future countries like USA, Japan, Canada & Germany has already started taking initiative to rely on solar energy.

REFERENCES

[1] J. Huang, R. S. Pickart, R. X. Huang, P. Lin, A. Brakstad, F. Xu,Sources and upstream pathways of the densest overflow water in the Nordic Seas,Nat. Commun.11(2020) 1-48.

[2] K. Subramani, A. Elhissi, U. Subbiah, W. Ahmed, Introduction to nanotechnology, Nanobiomaterials Clin. Dent.3(2019) 3–18.

[3] Bharathidasan, Solar Cells and Nanotechnology, Journal of electrical and electronics engineering.1(2003) 473–476.

[4] N. Nabhani, M. Emami, Nanotechnology and its Applications in Solar Cells, International Conference on Mechanical and Industrial Engineering.1 (2013) 1–4.

[5] V. K. Sethi, M. Pandey, P. Shukla, Use of Nanotechnology in Solar PV Cell, Int. J. Chem. Eng. Appl.3 (2011) 77–80.

[6] R. P. Allaker, Z. Yuan, Nanoparticles and the control of oral biofilms, Elsevier Inc.,University of London, UK, 2019, pp 243-275.

[7] H. J. Wagner, Introduction to wind energy systems, EPJ Web Conf.148 (2017) 1–16.

[8] G. M. Joselin Herbert, S. Iniyan, E. Sreevalsan, S. Rajapandian, A review of wind energy technologies, Renew. Sustain. Energy Rev.11 (2007) 1117–1145.

[9] M. A. Perea-Moreno, E. Samerón-Manzano, A. J. Perea-Moreno, Biomass as renewable energy: Worldwide research trends, Sustain.11(2019) 1-19.

[10] M. Castillo, G. Morales, L. A. Loyola, The alkaloids of L. paniculatum and the structure of paniculatine, Can. J. Chem.54 (1976) 2900–2908.

[11] I. E. Agency, WORLD ENERGY BALANCES, Natl. Guidel. Infect. Prev. Control Viral Hemorrhagic Fevers,Asia,2020.

[12] A. Kumar, HYDROPOWER ENGINEERING, Gov. of Uttarakhand, Roorkee, 2008.

[13] A. J. Perea-Moreno, M. J. Aguilera-Ureña, F. Manzano-Agugliaro, Fuel properties of avocado stone. 186 (2016) 358–364.

[14] A. A. Muresan, S. Attia, Energy efficiency in the Romanian residential building stock: A literature review, Renew. Sustain. Energy Rev.74(2017) 349–363.

[15] A. J. Perea-Moreno, A. García-Cruz, N. Novas, F. Manzano-Agugliaro, Rooftop analysis for solar flat plate collector assessment to achieving sustainability energy, J. Clean. Prod.148 (2017) 545–554.