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Mechanism and Role of Nanotechnology in Photovoltaic Cells and Applications in Different Industrial Sectors

Rashid Mehmood[1], Muhammad Adnan[1*], Muhammad Waseem Imtiaz[2], Muhammad Shahid[2], Muddassar Mehboob[2], Anam Shareef[2], Atifa Irshad[2], Shahid Iqbal[2], Zain Ul Abideen[2]

[1]Centre of Excellence in Solid State Physics, University of the Punjab, Lahore, Pakistan
[2]Department of Physics, University of Agriculture Faisalabad, Pakistan

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***Corresponding author:** Muhammad Adnan
Centre of Excellence in Solid State Physics, University of the Punjab, Lahore, Pakistan

Abstract

Nanotechnology is widely used for the manufacturing of photovoltaic (PV) solar cells. Applications of solar technology are based in two forms; lithium-ion and lead-acid. These cells and batteries have the capacity to store a large amount of energy longer than other ordinary batteries. The mechanism for manufacturing solar cells usually arises from the combinations of layers of single-molecule thick sheets of graphene and molybdenum diselenide. In this fact, one of common example is the fine coating of graphene with zinc oxide nanowires. Solar based cells are incorporated into the modified forms for increasing their synthetic applications. These modified forms are copper indium selenide sulfide quantum dots. Perovskite solar cells are dominating in the scientific community due to their advantages and cheap sources of solar energy. These perovskite solar cells are also composed of different metals and other combinations in order to make them functional for different purposes. The most widely implemented metals are germanium, antimony, titanium and barium. Tin (Sn)-based perovskites allow the movement of ions and electrons and significantly in the surrounding environment. There is also need in the future for valuable and mechanical designing for nanotechnolgy and their usage in industrial and commercial applications.

Keywords: Nanotechnology, photovoltaic (PV) solar cells, lithium-ion, perovskites.

INTRODUCTION

Advances in renewable energy are to be progressed in the field of nanotechnology which is widely used for the manufacturing of photovoltaic (PV) solar cells. These cells have been physically better than those of fossil fuels. One such kind of solar cell is the modern solar panels that have been used for large-scale power grid stations [1, 2]. The most important industrial factor contributing to PV solar technology is large-scale energy production efficiently. Potential developments in the technologies showed the most diverse area to overcome the continuing energy crisis across the globe. The other industrial solar cells are raphene-based solar cells in which a variety of nanoparticles are employed to replace harmful synthetic chemicals. The fine coating of nanoparticles can be applied in the form of nanowires, or quantum dots may be able to increase the efficiency of PV cells [3-5].

Solar cells technology is widely used for covering the in industrial sectors mostly on the base of graphene- based solar cells. But, it depends upon the application of nanoparticles or their size or shape or physical properties affecting the synthesis of industrial demand of solar cells [1, 3, 5]. To make solar cells, the raw materials in the form of silicon dioxide are largely placed into a furnace with an electrical supply, where a carbon arc is applied to release the oxygen. The other applications of solar technology are the solar battery types in two forms; lithium-ion and lead-acid. These cells and batteries have the capacity to store a large amount of energy longer than other ordinary batteries. This type of combination makes extend the use of solar technologies in the industrial sectors [6-8].

A variety of nano-based cells have been combined in the form of sheets or layers for the compact structure of solar cells. These cells have higher capacities to restore energy and can be used for home and industrial applications [5, 8]. There are several attempts to develop the solar cells based on graphene that have been merged for making the compact structure for graphene sheets are separated by lithium carbonate making resulting in the formation of 3D graphene. These cells have a high success rate as compared to ordinary cells. Other advancements are using fine materials in solar cells in the form of metallic parts like copper indium selenide sulfide quantum dots [9-11].

The mechanism for manufacturing solar cells usually arises from the combinations of layers of single-molecule thick sheets of graphene and molybdenum diselenide. It depends on the concentrations of materials employed for their manufacturing. Low concentration usually affects the product and makes them poor quality for industrial processing and other operations. While high concentration usually blocked the chain of final products and makes them render for high appliance operations. In this fact, one of common example is the fine coating of graphene with zinc oxide nanowires. It is expected that this modification could lead to the formation of high-quality materials [1, 3, 7, 8].

Mechanism and Role of Nanotechnology

Manufacturing of solar photovoltaic cells also follows the patterns of the transparent conductive layer to the photovoltaic absorber material through the close-spaced sublimation. During that process, laser scribing is performed for making the entire process smooth and efficient [8, 11, 12]. Semiconducting nanowires are manufactured through aerotaxy in which gold nanoparticles are synthetically employed for aiming the generation of energy for large-scale grid stations. Some self-assemblies are applied to align the nanowires on a substrate mainly used in fabricating solar cells and other electrical devices. These devices are used for making useful products in industrial processes without any contamination of the final product. Several chemical contaminants also reinforced the industrial process but troubleshooting and modern cell-running devices are operated [13, 14].

Other mechanisms are followed by the effect of sunlight on the materials used for industrial and other operations. Sunlight; a source of ultraviolet, yellow, and red coming from energy packets called photons. Sunlight falls to the surface of solar panels. These cells absorb the energy from the sun and convert them into other forms such as electrical energy [6, 9]. A solar cell is followed the same patterns as the particular semiconductor electron that transforms sunlight energy directly to electricity through its photovoltaic influence. Different adaptations are needed to make the cheaper and more efficient solar cells but nanotechnology and their small-size nanomaterials are under trials for their industrial and home-based applications. It depends on the nature of materials and their half-life [11, 13, 15].

Nano-Structured Solar Cells

There are several advantages for the use of nanoparticles and their corresponding materials due to their physicochemical properties and the excellent surface-to-area ratio. These properties make them ideal for industrial applications and can be used as nanostructured layers coated on the thin film solar cells leading. The main reason for using nanoparticles appliances is the optical path for light absorption. This is much larger than those ordinary materials that possess poor reflections [4, 8]. While, on the other hand, photovoltaic cells are much more acessible to multiple applications due to their multiple reflections. The other fact in the generation of photo voltaic cells is the light-generated electrons and holes. These electrons and holes makes the contact with other particles in such a way that the absorption layer of solar cells with nanostructured thin films greatly addressed for various nano-size-based solar cells [9, 11, 15].

There are many ways for developing the solar cells with combinations of solar based technologies in which nanosheets or compact combinations makes them designed compared to those of silicon solar cells. The most important adaptation in solar technology is the graphene sheets that are usually separated from the layers of nanosheets through lithium. It results in the formation of 3D graphene where lithium is replaced with dye for sensitized solar cell. This type of solar cells with fine layer sheets are used for industrial and other appliances with wide range of multiple uses emerging devices [11, 14]. In these solar cells, normal duct tape used to peel away layers of graphene using pure graphene. Due to high capacity of the graphene based material, signals may be effectively detected under a microscope after the duct tape component has been dissolved in acetone and dried. Sometimes, high concentrations of acidic solutions in solar cells makes less efficient that increased the level of contaminants. This type of disadvantage significantly lowers the value of solar cells [15-17].

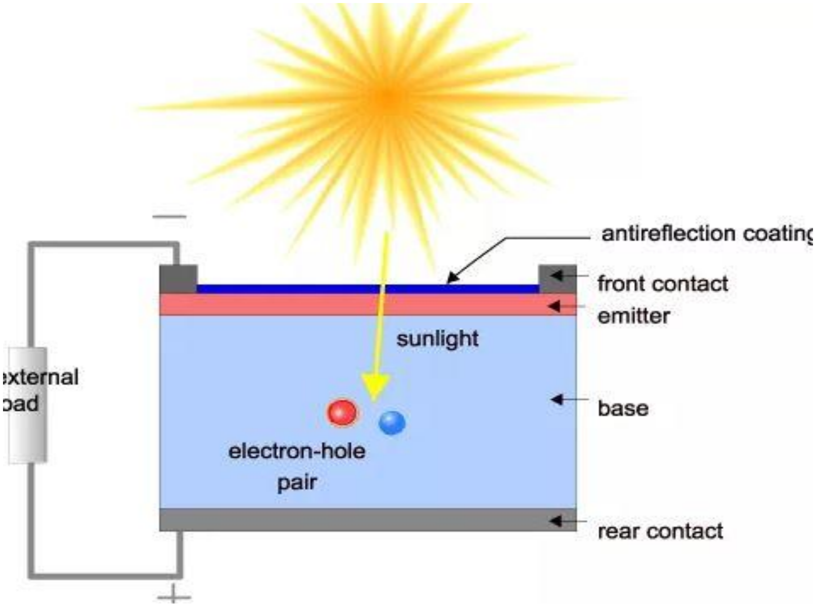

Fig. 1: Shows the mechanism and nature working of solar cells

Solar based cells are incorporated into the modified forms for increasing their synthetic applications. These modified forms are copper indium selenide sulfide quantum dots. While, quantum dots containing various metals like lead, chromium and nickel are toxic and highly expensive and have been replaced with the copper indium selenide sulfide quantum dots. These quantum-based dots are tremendous uses due to their narrow band gap, and high absorption coefficient [8, 12, 16].

Recently, compatible materials are much attracted to the technology of solar cell which is made from a single sheet of molybdenum diselenide. While, similar to quantum dots, molybdenum diselenide based designs are highly efficient and resist environmental changes. These types of solar cells are much more valuable in designing of much as conventional solar cells. It has applications in transistors, photo-detectors, and photovoltaics. Due to its layered structure and the unique nature of selenium, molybdenum diselenide has been widely used in lubricants and energy storage devices. These metallic-based solar cells gained the chemical and physical value of industrial applications [16-18].

Semiconducting nanowires are made with coating of single or combinations of nanoparticles in terms of nanotechnology where self-assemblies are applied to align the nanowires on a substrate. This type of combination is used for coating the large number of solar cells aligns in a series of solar batteries [11, 14, 18]. Sometimes, silver nanoparticles also used for enhancing the value of products with thin-film solar cells and photoelectrochemical water-splitting systems. While, other nanotechnology based applications of solar cells are based on fluorescent nanofibers and have been more compact over traditional cells. These solar cells are used for different industrial applications and more compatible materials to be designed in such a way that power generation-based cells are most leading over conservational cells [17- 20].

With the increasing of industrial demand of nanotechnology-based products, nano-based semiconductor quantum dots are employed for solar cells in different sectors. These nano based semiconductor quantum dots are working on the principles of band gaps that are the main design and vital part specifically to convert also longer-wave light and thus increase the efficiency of the solar cells. These semiconductor quantum dots are made through metallic combinations of various elemental compositions [19, 22]. The most important metals are Si/Ge or Si/Be Te/Se are considered. This metallic combination is advantageous over traditionally used ordinary cells with low uptake of electrons. Thus, nanotechnology advances leads the more valuable demand in energy production through semiconducting nanowires microscopic light sources for optical computing. These nanowires are much better over photovoltaic cells due to their shorter length considered one-dimensional structures as nanowires [21-24].

Perovskite solar cells are dominating in the scientific community due to their advantages and cheap sources of solar energy. These perovskite solar cells are also composed of different metals and other combinations in order to make them functional for different purposes. The most widely implemented metals are germanium, antimony, titanium and barium [1, 7, 9]. The usage of perovskite solar cells provides significant advances in renewable energy, especially solar photovoltaic as an alternative to conventional power generation sources. These perovskite solar cells are also environmentally friendly and reduced the risk of pollution. Nanotechnology increases the storage of solar energy nanoscale that can improve the processing and transmission of solar energy. While, other ordinary cells are causing the contamination of hazardous metals and thus replaced with nano based cells and nanowires [16, 18, 20].

There are several disadvantages of Pb-based perovskites as lead is the toxic form of metal causing environmental pollution. It has more affinity to bind with the ions and electrons and significantly locks their movement in the surrounding environment. The light-absorbing layer in perovskite solar cells contains a small amount of lead [18, 21]. Encapsulating of solar cells does not stop lead from leaking likely to become damaged by severe weather conditions. Perovskites have satisfactory intrinsic stability but becomes unstable under high temperature and varying conditions of pressure. These unpredicted limitations left a gap for new designing of lead replacement nanoparticles compact photovoltaic cells that effectively allows the ions and electrons. There is also need nanotechnology based cells replacing ordinary solar cells as lead in ordinary cells predominately causing hazards problems and nanotechnology helps to clean the environmental pollution [22-25].

It has been found that tin (Sn)-based perovskites are more helpful in solving the issues faced in the case of Pb- based perovskites. Tin (Sn)-based perovskites allow the movement of ions and electrons and significantly in the surrounding environment. These tin (Sn)-based perovskites are widely used for industrial purposes due to their cheap fabrication cost, excellent performance, and environmental friendliness [19, 20]. Thus, tin-based perovskites show similar optoelectronic properties and small exciton binding energy and take advantage of the parts of the solar spectrum that silicon PV material. These cells are more needed to design in combinations of nano based cells with high effectiveness as compared to other solar cells [25-28].

One of the most important parameters affected the the efficiency of the photovoltaic cell is the temperature that also influences on solar properties. It is found that surface passivation and structural and interface engineering also important in improving the stability of the photovoltaic cells. Explosive thermal emission is another major problem in ordinary cells that have been resolved through nanotechnology. In traditional solar cells, photocarriers relax from their initial energetic position to the band edge by thermal emission process before they can be extracted out from the devices [29-32].

Hot carrier solar cells are utilized in order to minimize wastage of energy also managing the solar energy in effective ways. Nanotechnology is also applied for improving the unique properties of nanostructures is responsible for balancing the heat release and cooling system. It is important to much interest in identifying key players and profiling their differential emphases in nano-enhanced thin film solar cells research. Nanostructured solar cells also used to enhance the light-harvesting capability and increase efficiency. Mesoscopic solar cell composed of different layers fabricated with nanoparticles and non-vacuum processing renders a significant reduction of the fabrication cost [27, 32, 33].

CONCLUSION

Photovoltaic cells are widely used for different purposes due to their efficient mode of working and directly transforming energy into electricity from the sun often use in generating electricity, and powering machines. They have also other uses due to the formation of nanostructures and are compatible with mechanical parts and have also been used in consumer products, such as electronic toys, handheld calculators, and portable radios. There is also need in the future for valuable and mechanical designing for nanotechnolgy and their usage in industrial and commercial applications.

REFERENCES

1. Salem, M. R., Elsayed, M. M., Abd-Elaziz, A. A., & Elshazly, K. M. (2019). Performance enhancement of the photovoltaic cells using Al2O3/PCM mixture and/or water cooling-techniques. *Renewable Energy*, *138*, 876-890.
2. Landi, B. J., Castro, S. L., Ruf, H. J., Evans, C. M., Bailey, S. G., & Raffaelle, R. P. (2005). CdSe quantum dot-single wall carbon nanotube complexes for polymeric solar cells. *Solar Energy Materials and Solar Cells*, *87*(1-4), 733-746.
3. Chen, L. C., Chen, C. C., Liang, K. C., Chang, S. H., Tseng, Z. L., Yeh, S. C., ... & Wu, C. G. (2016). Nano-structured CuO-Cu2O complex thin film for application in CH3NH3PbI3 perovskite solar cells. *Nanoscale research letters*, *11*(1), 1-7.
4. Tsukazaki, A., Ohtomo, A., Onuma, T., Ohtani, M., Makino, T., Sumiya, M., ... & Kawasaki, M. (2005). Repeated temperature modulation epitaxy for p-type doping and light-emitting diode based on ZnO. *Nature materials*, *4*(1), 42-46.
5. Burschka, J., Pellet, N., Moon, S. J., Humphry-Baker, R., Gao, P., Nazeeruddin, M. K., & Grätzel, M. (2013). Sequential deposition as a route to high-performance perovskite-sensitized solar cells. *Nature*, *499*(7458), 316-319.
6. Landi, B. J., Raffaelle, R. P., Castro, S. L., & Bailey, S. G. (2005). Single-wall carbon nanotube–polymer solar cells. *Progress in photovoltaics: research and applications*, *13*(2), 165-172.
7. Panchabikesan, K., Swami, M. V., Ramalingam, V., & Haghighat, F. (2019). Influence of PCM thermal conductivity and HTF velocity during solidification of PCM through the free cooling

concept–A parametric study. *Journal of Energy Storage*, *21*, 48-57.

8. Rehan, M. A., Ali, M., Sheikh, N. A., Khalil, M. S., Chaudhary, G. Q., ur Rashid, T., & Shehryar, M. (2018). Experimental performance analysis of low concentration ratio solar parabolic trough collectors with nanofluids in winter conditions. *Renewable Energy*, *118*, 742-751.
9. Tiwari, G. N., & Tiwari, A. (2016). Solar Cell Materials, Photovoltaic Modules and Arrays. In *Handbook of Solar energy* (pp. 123-170). Springer, Singapore. DOI: 10.1007/978-981-10-0807-8
10. Aldous, S. (2005). How Solar Cells Work. *How Stuff Works*, 22.
11. Sun, K., Ritzert, N. L., John, J., Tan, H., Hale, W. G., Jiang, J., ... & Lewis, N. S. (2018). Performance and failure modes of Si anodes patterned with thin-film Ni catalyst islands for water oxidation. *Sustainable Energy & Fuels*, *2*(5), 983-998.
12. Catchpole, K. R., & Polman, A. (2008). Plasmonic Solar Cells. *Optics Express*, 16(6). Focus Issue on Solar Energy edited by Alan Kost, University of Arizona.
13. Reo, Y., Zhu, H., Go, J. Y., In Shim, K., Liu, A., Zou, T., ... & Noh, Y. Y. (2021). Effect of monovalent metal iodide additives on the optoelectric properties of two-dimensional Sn-based perovskite films. *Chemistry of Materials*, *33*(7), 2498-2505.
14. Jiang, X., Chen, S., Li, Y., Zhang, L., Shen, N., Zhang, G., ... & Xu, B. (2021). Direct surface passivation of perovskite film by 4-fluorophenethylammonium iodide toward stable and efficient perovskite solar cells. *ACS Applied Materials & Interfaces*, *13*(2), 2558-2565.
15. Ball, J. M., Lee, M. M., Hey, A., & Snaith, H. J. (2013). Low-temperature processed meso-superstructured to thin-film perovskite solar cells. *Energy & Environmental Science*, *6*(6), 1739-1743.
16. Li, C., Qiu, J., Zhu, M., Cheng, Z., Zhang, J., Xiang, S., ... & Zhang, Z. (2022). Multifunctional anionic metal-organic frameworks enhancing stability of perovskite solar cells. *Chemical Engineering Journal*, *433*, 133587.
17. Green, M. A. (2003). Third Generation Photovoltaics: Ultra-High Efficiency at Low Cost, Springer-Verlag, Berlin. Hoogwijk, M. M. (2004) On the global and regional potential of renewable energy sources. Science Technology and Society. Utrecht University, Utrecht.
18. Rafols, I., & Meyer, M. (2010). Diversity and network coherence as indicators of interdisciplinarity: case studies in bionanoscience. *Scientometrics*, *82*(2), 263-287.
19. Shah, A., Torres, P., Tscharner, R., Wyrsch, N., & Keppner, H. (1999). Photovoltaic technology: the case for thin-film solar cells. *science*, *285*(5428), 692-698.
20. Li, L., Fan, M., Brown, R. C., Van Leeuwen, J., Wang, J., Wang, W., ... & Zhang, P. (2006). Synthesis, properties, and environmental applications of nanoscale iron-based materials: a review. *Critical Reviews in Environmental Science and Technology*, *36*(5), 405-431.
21. Shan, B., Vanka, S., Li, T. T., Troian-Gautier, L., Brennaman, M. K., Mi, Z., & Meyer, T. J. (2019). Binary molecular-semiconductor p–n junctions for photoelectrocatalytic CO2 reduction. *Nature Energy*, *4*(4), 290-299.
22. Beard, M. C., Ip, A. H., Luther, J. M., Sargent, E. H., & Nozik, A. J. (2014). Quantum confined semiconductors for enhancing solar photoconversion through multiple exciton generation. In *Advanced concepts in photovoltaics* (pp. 345-378). Cambridge: Royal Society of Chemistry.
23. Li, T., Wu, Y., Liu, Z., Yang, Y., Luo, H., Li, L., ... & Tan, H. (2022). Cesium acetate-assisted crystallization for high-performance inverted CsPbI3 perovskite solar cells. *Nanotechnology*, 3, 236-242.
24. Reinders, A., Verlinden, P., van Sark, W., & Freundlich, A. (2017). *Photovoltaic Solar Energy: From Fundamentals to Applications*, 1st ed.; Wyley: Coventry, UK.
25. Swick, S. M., Gebraad, T., Jones, L., Fu, B., Aldrich, T. J., Kohlstedt, K. L., ... & Marks, T. J. (2019). Building Blocks for High-Efficiency Organic Photovoltaics: Interplay of Molecular, Crystal, and Electronic Properties in Post-Fullerene ITIC Ensembles. *ChemPhysChem*, *20*(20), 2608-2626.
26. Richter, A., Benick, J., Feldmann, F., Fell, A., Hermle, M., & Glunz, S. W. (2017). n-Type Si solar cells with passivating electron contact: Identifying sources for efficiency limitations by wafer thickness and resistivity variation. *Solar Energy Materials and Solar Cells*, *173*, 96-105.
27. Deng, W., Chen, D., Xiong, Z., Verlinden, P. J., Dong, J., Ye, F., ... & Altermatt, P. (2015). 20.8% PERC solar cell on 156 mm× 156 mm P-type multicrystalline silicon substrate. *IEEE journal of photovoltaics*, *6*(1), 3-9.
28. Zuo, L., Jo, S. B., Li, Y., Meng, Y., Stoddard, R. J., Liu, Y., ... & Jen, A. K. Y. (2022). Dilution effect for highly efficient multiple-component organic solar cells. *Nature Nanotechnology*, *17*(1), 53-60.
29. Chiang, S. E., Lin, P. C., Wu, J. R., & Chang, S. H. (2022). Improving the photovoltaic performance of inverted perovskite solar cells via manipulating the molecular packing structure of PCBM. *Nanotechnology*, *34*(1), 015401.
30. Thakur, D., Chiang, S. E., Yang, M. H., Wang, J. S., & Chang, S. H. (2022). Self-stability of un-encapsulated polycrystalline MAPbI3 solar cells

via the formation of chemical bonds between C60 molecules and MA cations. *Solar Energy Materials and Solar Cells*, *235*, 111454.

31. Alarcón-Altamirano, Y. A., Miranda-Gamboa, R. A., Baron-Jaimes, A., Ortiz-Soto, K. A., Rincon, M. E., & Jaramillo-Quintero, O. A. (2022). Boosting photovoltaic performance for Sb2S3 solar cells by ionic liquid-assisted hydrothermal synthesis. *Nanotechnology*, *33*(44), 445401.
32. Cuesta, V., Singh, M. K., Gutierrez-Fernandez, E., Martín, J., Domínguez, R., de la Cruz, P., ... & Langa, F. (2022). Gold (III) Porphyrin Was Used as an Electron Acceptor for Efficient Organic Solar Cells. *ACS applied materials & interfaces*, *14*(9), 11708-11717.
33. Talebi, H., & Emami, F. (2022). Broadband plasmonic absorption enhancement of perovskite solar cells with embedded Au@ SiO2@ graphene core–shell nanoparticles. *Semiconductor Science and Technology*, *37*(5), 055002.