A Review Paper on Infrared Plastic Solar Cell

Shraddha R. Jogdhankar[1], Channappa Bhyri[2]

[1,2] *Department of Instrumentation technology, P D A College of Engineering, Gulbarga, Karnataka, India*

Abstract: As we know we have lived with the sun our entire life and probably most of us take it for granted, we never use it properly. Electricity is the lifeblood of modern civilization and we can get as much as we want from the sun. As coal, gas, oil and nuclear energy fuel prices continue to raise solar energy will become even more cost effective. Solar panels are active solar devices that convert sunlight into electricity. They come in a variety of rectangular shapes and are usually installed in combination to produce electricity. The primary component of a solar panel is the solar cells, or photovoltaic cell having low efficiency and high cost. plastic solar cell technology, is based on conjugated polymers and molecules. Polymer solar cells have attracted considerable attention in the past few years owing to their potential of providing environmentally safe, flexible, lightweight, inexpensive, efficient solar cells. Application of nanotechnology in these plastic solar cells will helps us to make solar energy more economical. Production of plastic solar cells using quantum dots could double the efficiency levels currently possible and reduce costs The transparent solar cells is an advance towards giving windows in homes and other buildings the ability to generate electricity while allowing to view from inside. Currently solar energy's biggest problem is the highest cost compared to other sources. But introduction of plastic solar cells with the nanotechnology in solar energy will increase the efficiency and reduce the cost which will give solution to global crisis. If the solar farms can become a reality, it could possibly solve the planet problem of depending too much on the fossil fuels, without a chance of even polluting the environment.

1. INTRODUCTION

Nanotechnology is the engineering of tiny machines - the projected ability to build things from the bottom up using techniques and tools being developed today to make complete, highly advanced products. It includes anything smaller than 100 nanometers with novel properties. As the pool of available resources is being exhausted, the demand for resources that are everlasting and eco-friendly is increasing day by day. One such form is the solar energy. The advent of solar energy just about solved all the problems. As such solar energy is very useful. But the conventional solar cells mainly due to the construction process and also the materials used in it have a limited number of applications. Latest inventions have opened doors to whole lot of applications that is creeping in to use the solar panels that have been developed out of plastic. In the sector of harnessing renewable form of energy, silicon as an element failed to make a mark in the wide range of applications of solar panels. The use of nanotechnology in the solar cells created an opportunity to overcome this problem, thereby increasing the efficiency. This paper deals with an offshoot in the advancement of nanotechnology, its implementation in solar cells and its advantage over the conventional commercial solar cell

In order to the miniaturization of integrated circuits well into the present century, it is likely that present day, nano-scale or nano electronic device designs will be replaced with new designs for devices that take advantage of the quantum mechanical effects that dominate on the much smaller, nanometer scale . Nanotechnology is often referred to as general purpose technology. That is because in its mature form it will have significant impact on almost all industries and all areas of society. It offers better built, longer lasting, cleaner, safer and smarter products for the home, for ammunition, for medicine and for industries for ages. These properties of nanotechnology have been made use of in solar cells.

2. INFRARED PLASTIC SOLAR CELL

Ever since the discovery (in 1977) of conducting plastic (polymer which feature conjugate double bonds, that enable electrons to move through them), for which prof.Alan heeger was awarded a noble prize, there has been interest in using these materials in fabrication of solar cells. Scientists have invented a plastic solar cell that can turn the suns power into electric energy even on a cloudy day. Plastic solar cells are not new. But existing materials are only able to harness the sun's visible light. While half of the sun's power lies in the visible spectrum, the other half lies in the infrared spectrum. The new material is first plastic compound that is able to harness infrared portion. The plastic material uses nanotechnology and contains the 1stgeneration solar cells that can harness the sun's invisible infrared rays. This breakthrough made us to believe that plastic solar cells could one day become more efficient than the current solar cell.

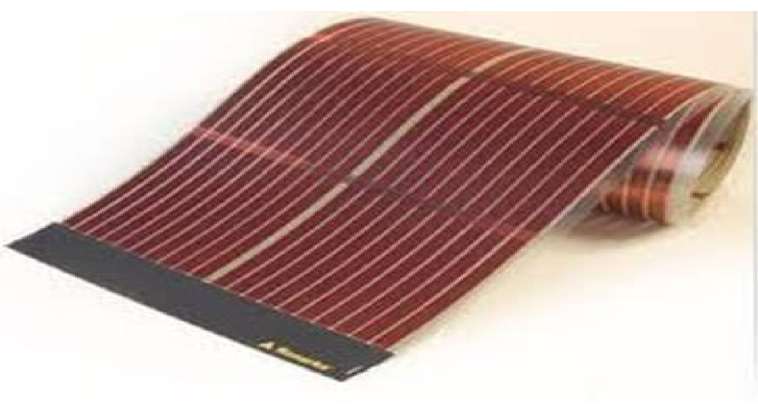

Fig 1: infrared plastic solar cell

The researchers combined specially designed nano particles called quantum dots with a polymer to make the plastic that can detect energy in the infrared. With further advances the new plastic solar cell could allow up to 30% of sun's radiant energy to be harnessed completely when compared to only 6% in today plastic best plastic solar cells. A large amount of sun's energy could be harnessed through solar farms and used to power all our energy needs. This could potentially displace other source of electrical production that produce green house gases like coal. Solar energy reaching the earth is 10000 times than what we consume.

3. MORPHOLOGY AND DESIGN

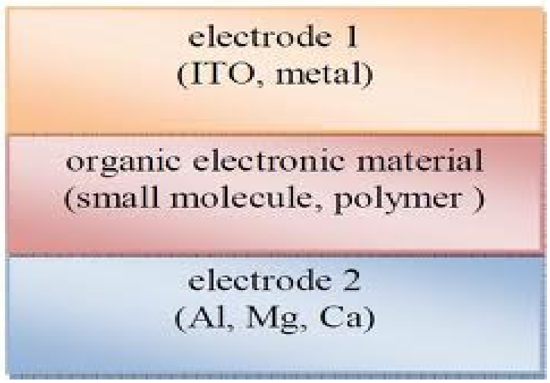

Fig 2: basic structure of plastic solar cell

The plastic solar cell created by the Berkeley research group is actually a hybrid, comprised of tiny nanorods dispersed in an organic polymer or plastic. Figure 2 shows the hybrid plastic solar cells has nanorod/polymer layer sandwiched between two electrodes. The active layer, a mere 200 nanometer thick, is a jumble of nanorods embedded in a semiconducting polymer.

Vacuum evaporation and solution processing techniques are the most commonly used thin film preparation methods in the production of plastic solar cells. Polymers decompose under excessive heat and have too large molar mass for evaporation. Therefore, most polymer-based photovoltaic elements are solution processed at low temperatures. The printing/coating techniques are used to deposit conjugated semiconducting polymers.

Donor-acceptor blends can be prepared by dissolving donor and acceptor components in a common solvent (or solvent mixture) this is called solution processing and Solution processing requires soluble polymers. Blends are deposited by using one of the techniques mentioned above. Sometimes, a soluble monomer is cast as a thin film using a post deposition polymerization reaction afterward. Soluble precursor polymers can also be converted into the final semiconducting form with a post deposition conversion reaction. The advantage of this latter method is that the resulting conjugated polymer thin films are insoluble.

For plastic solar cells, spin-coating, doctor blading, as well as screen-printing methods were applied. Such large scale printing/coating techniques open up the possibility for an upscaling of the production with low-energy consumption.

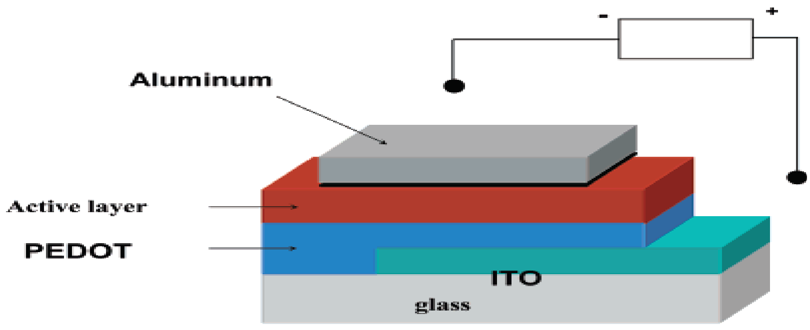

Fig 3: Schematic device structure for polymer/fullerene bulk heterojunction solar cells. The active layer is sandwiched between two contacts: an indium-tin-oxide electrode coated with a hole transport layer PEDOT:PSS and an aluminum top electrode.

The plastic solar cells are fabricated in sandwich geometry. As substrates, transparent, conducting electrodes (for example, glass or plastic covered with ITO) are used. ITO (indium tin oxide) electrodes are transparent and conductive but expensive. Alternatives for ITO are searched for, and nanotube network electrodes potentially work as well. The substrate electrode can be structured by chemical etching. On the transparent conducting substrate, PEDOT:PSS, poly(ethylene-dioxythiophene) doped with polystyrenesulfonic acid, is coated from an aqueous solution. This PEDOT:PSS layer improves the surface quality of the ITO electrode as well as facilitates the hole injection/extraction. Furthermore, the work function of this electrode can be changed by chemical/ electrochemical redox reactions of the PEDOT layer.

The active layers are coated using solution or vacuum deposition techniques as mentioned above. The nanorods which are derived from 1-(3-methoxycarbonyl)propyl-1-phenyl-[6,6]-methanofullerene(PCBM) are mixed with a plastic semiconductor called (P3HT) p3ht-poly-(3-hexylthiophene) a transparent electrode is coated with the mixture. An aluminum coating acting as the back electrode completed the device. The nanorods act like wires. When they absorb light of a specific wavelength, they generate an electron plus an electron hole-a vacancy in the crystal that moves around just like an electron. The electron travels the length of the rod until it is collected by aluminum electrode. The hole is transferred to the plastic, which is known as a hole-carrier, and conveyed to the electrode, creating a current.

4. WORKING OF PLASTIC SOLAR CELL

The solar cell created is actually a hybrid, comprised of tiny nanorods dispersed in an organic polymer or plastic. A layer only 200 nanometers thick is sandwiched between electrodes and can produce at present about 0.7 volts. The electrode layers and nanorods/polymer layers could be applied in separate coats, making production fairly easy. And unlike today's semiconductor-based photovoltaic devices, plastic solar cells can be manufactured in solution in a beaker without the need for clean rooms or vacuum chambers.

Plastic solar cell (PSC) structure is the most successful structure invented, in which a blend of donor and acceptor with a bicontinual phase separation can be formed. When the sunlight getting through the transparent electrode is absorbed by the semiconducting donor and acceptor materials in the photoactive layer, excitons (bounded electron–hole pairs) are formed, and then the excitons diffuse to the interfaces of the donor/acceptor where the excitons dissociate into electrons on the lowest unoccupied molecular orbital level of the acceptor and holes on the highest occupied molecular orbital level of the donor. The dissociated electrons and holes are driven by build-in electric field and then moved to negative and positive electrode, respectively, and then collected by the electrodes to realize the photon-to-electron conversion. Figure 4 shows the electronic energy levels of the donor and acceptor in a P3HT/PCBM blend system.

The absorption band of P3HT/PCBM covers the range from 380 to 670 nm, which means that the photons with energy between 2.0eV and 3.3 eV can be absorbed by the active layer, and the excitons will be formed. In order to make better utilization of the sunlight, active layer materials with broad absorption band is required, and for this purpose, more and more low band gap (LBG) materials have been developed and great successes have been made in the past decade.

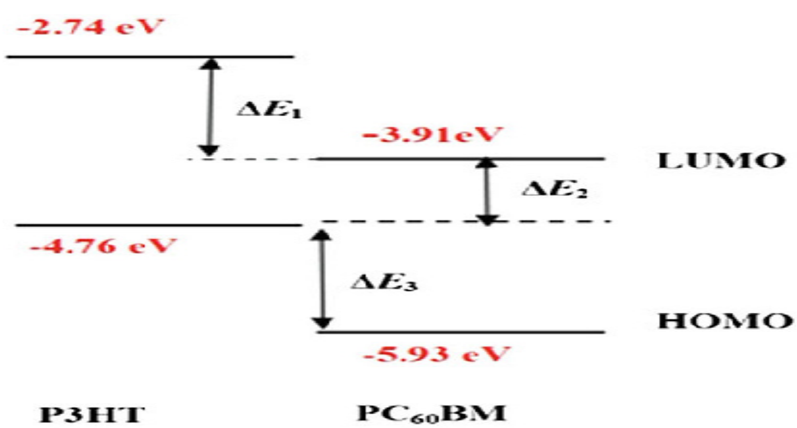

Fig. 4 Electronic energy level of P3HT and PC60BM

Since, the lowest unoccupied molecular orbital and the highest occupied molecular orbital level of P3HT is higher than that of PCBM, the excitons will separate into positive and negative charges at the interface of the P3HT phase and PCBM phase. The negative charge will transport through the lowest unoccupied molecular orbital of PCBM and the positive charge will transport through the highest occupied molecular orbital level of P3HT, and then the charges can be collected by the electrodes. In order to get efficient charge separation, highest occupied molecular orbital level and lowest unoccupied molecular orbital of the donor material should be 0.2–0.3 eV higher than that of the acceptor material, respectively. If the offset is too small, it would be hard to get efficient charge separation; if the offset is too big, much energy loss would be happened. As known, open-circuit voltage (Voc) of BHJ OPV devices are directly proportional to the gap between highest occupied molecular orbital level of the donor and lowest unoccupied molecular orbital of the acceptor. Although, the energy of the photon that can be utilized by the P3HT/PCBM system is higher than 2.0 eV, Voc of P3HT/PCBM based OPV device is typically around 0.6 eV, meaning that more than 70 % energy loss is taking place during the photoelectric conversion process. Therefore, to minimize the energy loss, highest occupied molecular orbital level and lowest unoccupied molecular orbital levels of the donors and the acceptors should be tuned carefully.

5. APPLICATIONS

1. The plastic formulations also open the possibility of printing solar cells onto various surfaces, much as ink printed on news paper
2. Light weight and flexible plastic solar cell panted on back of it could power portable electronics equipments like PDA's laptops and pocket calculator, etc. anywhere we can access solar energy.
3. The new cells also open the possibility of wearable computing devices.
4. Any chip coated in the material could power cell phone or other wireless devices.
5. A hydrogen powered car painted with the film could potentially convert energy into electricity to continually recharge the car's battery.

6. ADVANTAGES

1. They are considered to be **30%** more efficient when compared to conventional solar cells.
2. They are more efficient and more practical in application.
3. Traditional solar cells are bulky panels. This is very compact.
4. Conventional solar cells are only used for large applications with big budgets. But the plastic solar cells are feasible as they can be even sewn into fabric- thus having vast applications.

5. Flexible, roller processed solar cells have the potential to turn the sun's power into a clean, green, consistent source of energy.

7. LIMITATIONS

1. The biggest problem with this is cost effectiveness. But that could change with new material. But chemists have found a way to make cheap plastic solar cells flexible enough to paint onto any surface and potentially able to provide electricity for wearable electronics or other low power devices.
2. Relatively shorter life span when continuously exposed to sunlight.
3. Could possibly require higher maintenance and constant monitoring.

8. CONCLUSION

The prospect that light weight and flexible polymer solar cells can be produced, has spurred interests from research institutes and companies. In the last five years there has been an enormous increase in the understanding and performance of polymer-fullerene bulk hetero junction solar cells. Comprehensive insights have been obtained in crucial materials parameters in terms of morphology, energy levels, charge transport, and electrode materials. Plastic solar cells help in exploiting the infrared radiation from the sun's rays. They are more effective when compared to the conventional solar cell. The major advantage they enjoy is that they can even work on cloudy days, which is not possible in the former. They are more compact and less bulky.

REFERENCES

[1] Nanomaterials: Synthesis, Properties and Applications : Edelstein, A. S., Cammarata, R. C., Eds.; Institute of Physics Publishing: Bristol and Philadelphia, 1996.

[2] The Coming Era of Nanotechnology; 1987. Drexler, K. Eric, Doubleday; New York

[3] Conjugated Polymer-Based Organic Solar Cells:Serap Gunes, Helmut Neugebauer, and Niyazi Serdar Sariciftci, Chem. Rev. 2007, 107, 1324-1338

[4] Modeling the optical absorption within conjugated polymer/fullerene-based bulk-heterojunction organic solar cells: H. Hoppea, N. Arnoldb, N.S. Sariciftcia, D. Meissner, Solar Energy Materials & Solar Cells 80 (2003) 105–113.

[5] Active Layer Materials for Organic Solar Cells, Jianhui Hou and Xia Guo W. C. H. Choy (ed.), Organic Solar Cells, Green Energy and Technology, DOI: 10.1007/978-1-4471-4823-4_2, _ Springer-Verlag London 2013.

[6] Organic solar cells with carbon nanotube network electrodes,Michael W. Rowell,Mark A. Topinka, and Michael D. McGehee, applied physics letters 88, 233506 _2006.

[7] Polymer-based solar Cells: Alex C. Mayer, Shawn R. Scully, Brian E. Hardin, Michael W. Rowell, and Michael D. McGehee, NOVEMBER 2007 | VOLUME 10 | NUMBER 11, *ISSN:1369 7021 © Elsevier Ltd*

[8] Nanomaterials and Energy,Volume 1 Issue NME1,2011,Controlling nanomorphology in plastic solar cells, Carr, Chen, Elshobaki, Mahadevapuram and Chaudhary

[9] A gentle introduction to the next big idea-Mark A. Ratner, Daniel Ratner.

[10] 'plastic solar cells' By Christoph J. Brabec, N. Serdar Sariciftci, and Jan C. Hummelen, Adv. Funct. Mater. 2001, 11, No. 1, February

[11] Visibly Transparent Polymer Solar Cells Produced by Solution Processing, Chun-Chao Chen, Letian Dou,Rui Zhu, Choong-Heui Chung, Tze-Bin Song, Yue Bing Zheng, Steve Hawks, Gang Li, Paul S. Weiss, and Yang Yang, Published online10.1021/nn3029327, 3 july 2012

[12] Polymer solar cells,Gang Li, Rui Zhu and Yang Yang*, Published online: 29 February 2012 | doi: 10.1038/nphoton.2012.11

[13] 2.5% efficient organic plastic solar cells,Sean E. Shaheen, Christoph J. Brabec,a and N. Serdar Sariciftci, applied letters to physics, volume 78, number 6, 5 February 2001/0003-6951/