

Nanotechnology based Polymerized Solar Cells and Screen-Printing Technique for Power Generation

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ABSTRACT

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Energy is central to improved social and economic well-being, and is indispensable to most industrial and commercial wealth generation. It is key for improving human welfare and raising living standards. Industrialization of developing countries like India needs more and more power to meet the demand of life amenities. The global demand for energy is increasing drastically. The previous primary sources of energy like fossil fuel, coal, diesel etc which are decreasing day by day due to energy demand and there is a global warming problem also. Even hydro, thermal, biomass, solar, wind energy are not permanent solutions for the rise in demand. So there is a need for non-conventional energy sources to fill the gap in an improved version of power conversion efficiencies. This is fulfilled by organic polymerized solar cells, which have brought and gained the attention of practical large-scale users' minds to meet the energy required for work life.

This paper explains nanotechnology application for energy storing and implementation of polymer technique to the plastic solar cells and also screen-printing technology in the fabrication of organic based bulk heterojunction solar cells.

Keywords : Nanotechnology, Non conventional energy, Solar Cells, Polymer Technology

I. INTRODUCTION

The word nanotechnology is relatively new, but it is not an entirely new field. Nanotechnology is defined as the study and use of structures between 1

nanometer to 100 nanometers in size. It literally means any technology on a nanoscale that has applications in the real world. Nanotechnology has found its presence in almost all fields and even in plastic material fabrication also and that results in the

first solar cells able to harness the invisible, infrared rays from the sun. The breakthrough has led researchers to predict that plastic solar cells are more efficient than current solar cell technology.

Present life style and industrialization leads to rapid increase in need of electrical energy and directed to utilize the sun as a source of electrical energy along with its role as an important source of thermal energy. In photovoltaic devices there are two separate layers, one with an abundance of electrons that functions as a "negative pole," and another with an abundance of electron holes, vacant positively-charged energy spaces that function as a "positive pole". When solar photons or any other light energies are absorbed, which is transferred to the extra electrons in the negative pole, causing them to flow to the positive pole and creating new holes that start flowing to the negative pole, thus producing electrical current which can be used to power other devices.

Conventional semiconductor solar cells are made of polycrystalline silicon or, in the case of the highest efficiency ones, crystalline gallium arsenide is used. The use of these devices has been limited to date because production costs are so high and even the fabrication of the simplest semiconductor cell is a complex process that has to take place under exactly controlled conditions, such as high vacuum and temperatures between 400 to 1,400 degrees Celsius is required. Normal solar panels are rigid, expensive and their size is constrained by manufacturing techniques thus, limits their scalability to large area panels. The group's first crude solar cells have achieved efficiencies of 1.7 percent far less than the 10 percent efficiencies of today's standard commercial photovoltaic. The best solar cells, which are very expensive semiconductor laminates, convert almost 35 percent of the solar energy into electricity. Typical module efficiencies for commercially available screen-printed multi crystalline solar cells are around 12 percent.

II. EASE OF USE

A. Proposed System

Polymers offer the advantage of solution processing at room temperature, which is cheaper and allows for using fully flexible substrates, such as plastics. Thus, replacing the silicon with polymer nanowires would make the solar cell much lighter, and eventually cheaper. The technology takes advantage of recent advances in nanotechnology, specifically the production of nano-crystals and nano-rods as shown in Fig.1. These are chemically pure clusters of 100 to 100,000 atoms with dimensions on the order of a nanometer, or a billionth of a meter.

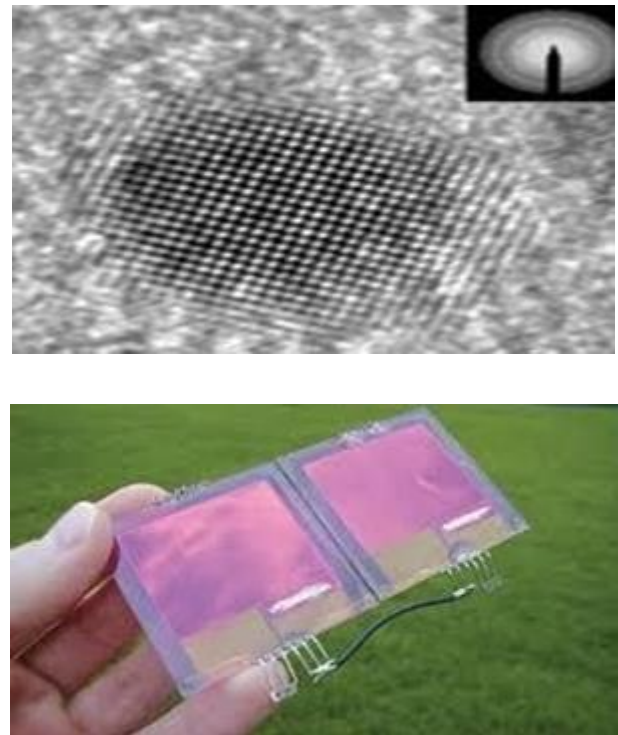


Fig.1 Nano-crystals and Nanorods

Because of their small size, they exhibit unusual and interesting properties governed by quantum mechanics, such as the absorption of different colors of light depending upon their size. We can manufacture nanorods in a beaker containing cadmium solenoid aiming for rods of a diameter – 7

nanometers to absorb as much sunlight as possible. They also aim for nanorods as long as possible in this case for around 60 nanometers. It will play an important role in developing an improved polymer solar cell using non-material additives by combining nanotechnology with plastic electronics.

III. IMPLEMENTATION

The solar cell created is a hybrid, composed of tiny nano rods 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 structure is the most successful structure invented, in which a blend of donor and acceptor with a bicontinuous 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, excitations that is bounded electron-hole pairs are formed, and then the excitations diffuse to the interfaces of the donor/acceptor where the excitations 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 a built-in electric field and then moved to negative and positive electrodes, respectively, and then collected by the electrodes to realize the photon-to-electron conversion. The electronic energy levels of the donor and acceptor in a P3HT/PCBM blend system shown in Fig.2. 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 3.3eV can

be absorbed by the active layer, and the excitations will be formed.

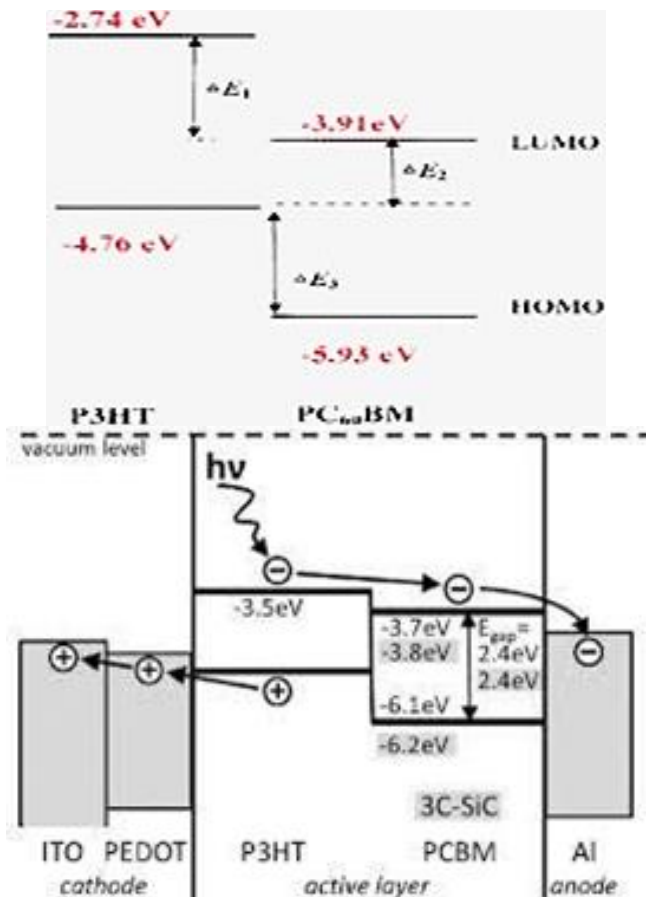


Fig.2 Electronic energy level of P3HT and PC60BM

As 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, the highest occupied and lowest unoccupied molecular orbital of the donor material should be 0.2–0.3eV 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 happen.

A. Design of Polymerized Solar Cells

The plastic solar cell created by the Berkeley research group is actually a hybrid, composed of tiny nano rods dispersed in an organic polymer or plastic. Fig.3 shows a schematic diagram of a hybrid "plastic" solar cell with a nanorod / polymer layer sandwiched between two electrodes. The middle layer, a mere 200 nanometers thick, is a jumble of nanorods embedded in the semiconducting polymer. They mixed the nanorods with a plastic semiconductor, called P3HT – poly-(3- hexylthiophene) – and coated a transparent electrode with the mixture. The thickness, 200 nanometers – a thousandth the thickness of a human hair – is a factor of 10 less than the micron- thickness of semiconductor solar cells. When nanorods 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 the aluminum electrode collects it. Thus, an aluminum coating as shown in Fig.5 acting as the back elec rode completes the device. The hole is transferred to the plastic, which is known as a hole-carrier, and conveyed to the electrode, creating a current.

The electrode layers and nanorod/polymer layers could be applied in separate coats, making production easy. Further, using rod-shaped nano-crystals rather than spheres provided a directed path for electron transport to help improve solar cell performance. These types of hybrid solar cells are reported to achieve a monochromatic power conversion efficiency of 6.9 percent, one of the highest ever reported for a plastic photovoltaic device.

B. Nanorod / Polymer Technology

The plastic solar cell designed is actually a hybrid, composed of tiny Nanorod dispersed in an organic polymer or plastic. Fig.3 shows a schematic diagram of a hybrid "plastic" solar cell with a Nanorod/polymer layer sandwiched between two electrodes.

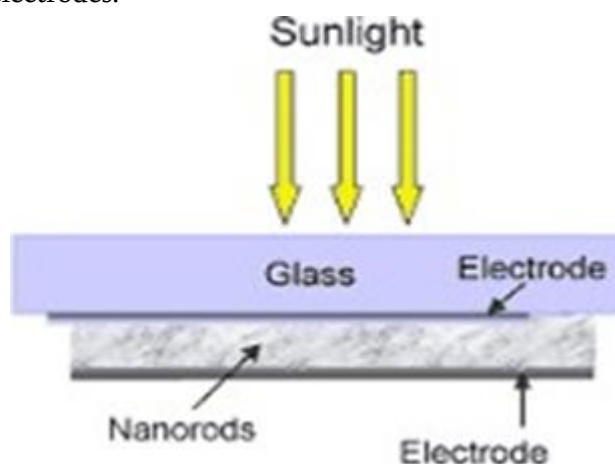


Fig.3 Schematic diagram of a hybrid "plastic" solar cell with a nanorod/polymer layer

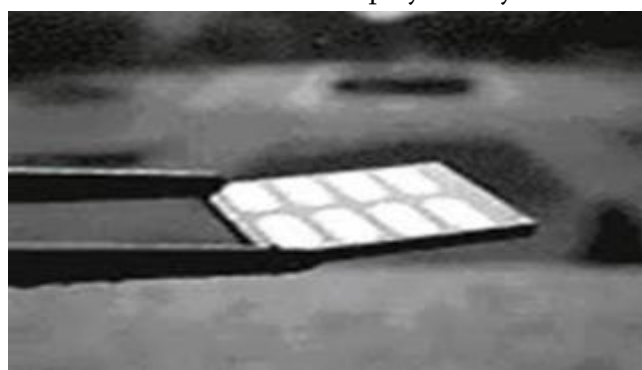


Fig.4 Panel of eight plastic solar cells based on inorganic nanorods and semi conducting Polymers.

The shiny ovals are the aluminum back electrodes of the individual solar cells. The middle layer, a mere 200 nanometers thick, is a jumble of nanorods embedded in the semi conducting polymer. Nano rods are mixed with a plastic semiconductor, called P3HT - poly- (3-Hexylthiophene) and coated a transparent electrode with the mixture. The thickness,200 Nanometers - a thousandth the thickness of a human hair - is a factor of 10 less than the micron thickness of semiconductor solar cells.

When nano rods 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 the aluminum electrode collects it. Thus, an aluminum coating as shown in Fig.4 acting as the back electrode completes the device. The hole is transferred to the plastic, which is known as a hole-carrier, and conveyed to the electrode, creating a current. The electrode layers and nanorod/polymer layers could be applied in separate coats, making production fairly easy. Further, using rod-shaped nano-crystals rather than spheres provided a directed path for electron transport to help improve solar cell performance. These types of hybrid solar cells are reported to achieve a monochromatic power conversion efficiency of 6.9 percent, one of the highest ever reported for a plastic photovoltaic 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 the aluminum electrode. The hole is transferred to the plastic, which is known as a hole-carrier, and conveyed to the electrode, creating a current.

C. Screen-printing Techniques

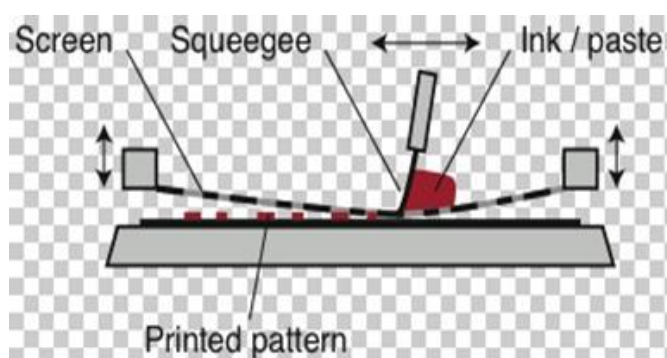


Fig.5a Structure of bulk hetero-junction solar cell

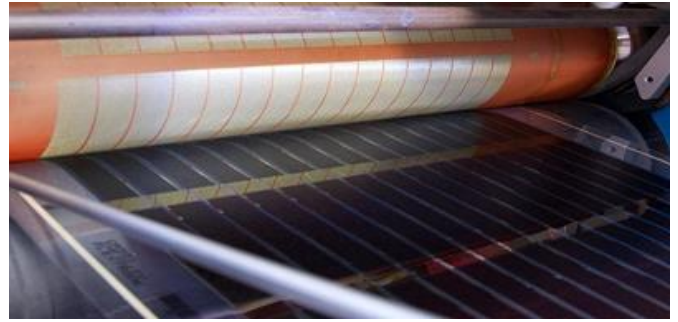


Fig.5b Screen printing process

Screen-printing is a commonly used industrial technique for fast, inexpensive deposition of dye films over large areas. Hence it is an ideal technology for large-scale fabrication of polymer-based solar cells. Also screen-printing allows patterning to easily define which areas of the substrate receive deposition. This is important for instance, for fabricating a photovoltaic device that is integrated onto a substrate containing other electronic devices. Also, in the production of a large area energy collection system, it is necessary to fabricate many individual solar cells that are wired together. Using screen printing, individual's devices can easily be defined on the same substrate in order to optimize the power generation of the entire system.

However, in this case, the printed films were not smooth and the screen footprint was visible to the naked eye. Here, we use screen printing to deposit an ultra thin and smooth active layer in a bulk hetero junction photovoltaic device, consisting of a conjugated polymer/fullerene blend, with a thickness of 40 nm and root-mean-square (rms) surface roughness of 2.6 nm.

The structure of the bulk-hetero junction solar cell is shown in Fig.5(a).. A description of the screen printing process, depicted in Fig.5(b) follows. During deposition, the screen is placed a few millimeters above the surface of the substrate.

IV. WORKING OF THE PROJECT

FABRICATION OF BULK HETEROJUNCTION PLASTIC SOLAR CELLS BY SCREEN PRINTING

In the present work, we demonstrate the implementation of screen printing technology in the fabrication of an organic-based bulk heterojunction solar cell. Screen printing is a commonly used industrial technique for fast, inexpensive deposition of dye films over large areas.

In addition, screen printing allows patterning to easily define which areas of the substrate receive deposition. This is important, for instance, for fabricating a photovoltaic device that is integrated onto a substrate containing other electronic devices. Also, in the production of a large area energy collection system, it is necessary to fabricate many individual solar cells that are wired together. Using screen printing, individual devices can be easily used in order to optimize the power generation of the entire system. In industrial processes, films fabricated with screen printing usually have a thickness greater than 0.5 μm . During deposition, the screen is placed a few millimeters above the surface of the substrate.

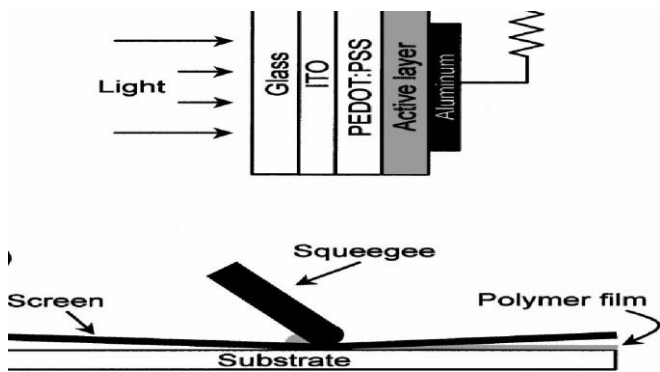
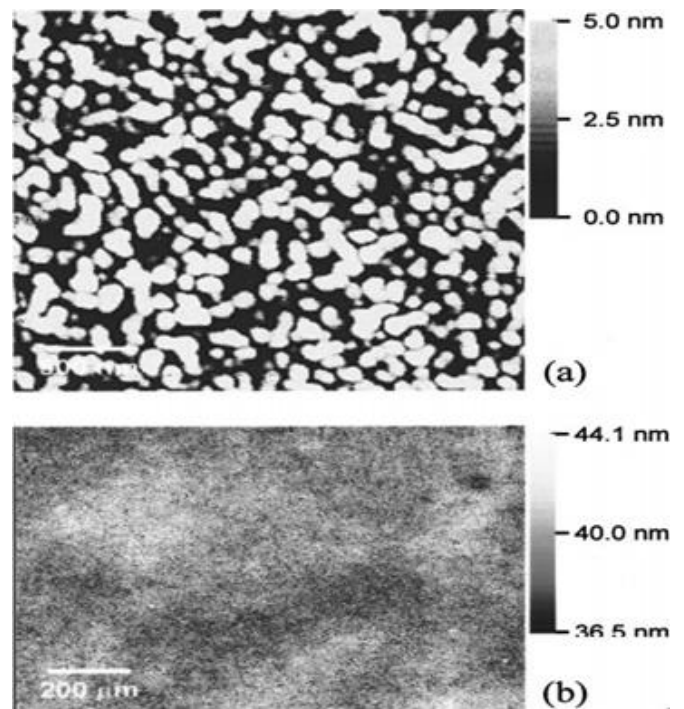


Fig.6 Schematic diagrams of the device structure of the bulk heterojunction solar cell connected to an external resistive load and the screen printing technique.

V. RESULT AND DISCUSSION

The short-circuit current, open-circuit voltage, fill factor, and power conversion efficiency are 3.16 mA/cm^2 , 841 mV, 0.44, and 4.3%, respectively. The temperature of the device during measurement was approximately 25 $^{\circ}\text{C}$.

Fig.7 Plot of the current density ~absolute value! versus voltage for the solar cell operated in the dark ~filled squares! and under illumination ~hollow squares! by monochromatic light with a wavelength of 488 nm and an intensity of 27 mW/cm^2 . "squeegee" is then swept with a velocity of several centimeters per second across the surface of the screen, momentarily contacting it to the substrate. At this point, solution flows from the screen to the surface of the substrate. As the squeegee then passes over a region, the screen separates from the substrate, leaving behind a solution that dries to yield a continuous film. short-circuit conditions is approximately 90% at an incident wavelength of 488 nm.



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