Int.J.HIT.TRANSC:ECCN.Vol.7: Issue 2A (2021) Page 31-34 ISSN: 0973-6875

Available Online at www.hithaldia.in/locate/ECCN

ORIGINAL CONTRIBUTION

TiO_2 BASED DYE SENSITIZED SOLAR CELL USING NATURAL DYE EXTRACTED FROM BLACKBERRY

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ABSTRACT

Dye sensitized solar cells (DSSC), mainly highly meso-porous TiO_2 based DSSC plays a leading role for alternative type Gratzel solar cell. In TiO_2 based DSSC, mesoporous TiO_2 adsorb significant amount of dye molecules due to its high surface to low volume ratio. These dye instantly absorb the sunlight, immediately injects a charge into TiO_2 that creates instant charge separation between TiO_2 and dye. In case of TiO_2 based solar cell, the bandgap edge levels are suitably adjusted with respect to the Dyes and electrolytes. One such natural blackberry dye can give significant contribution in higher efficiency, and it’s lower cost and better scalability may also be long term replacement of other dye. In this paper, the relation of TiO_2 with different types of dye combination along with the device performance, future prospective will be discussed.

KEYWORDS: Mesoporous TiO_2, Dye Sensitized Solar Cell,, Blackberry dye, Hole Transporting Material

1. INTRODUCTION

The demand for global energy increases everyday and is predicted to be about 30 TW by 2025. After the oil crisis in 1973, energy supply has become a priority issue for industries, companies, governments, social and ecological groups and for consumers too. The highly developed western societies are now in desperate need of cheap, easy-scalable, non-polluting and clean source of energy. Renewable energy sources have chance to provide an optimal solution to the global energy problem. Amongst them, photovoltaic (PV) offers a reliable, clean and easy-scalable way for heat and electricity generation by transforming the energy received from the sun. PV also provides cost-effective solutions to the energy crisis in developing countries by not only providing electricity for household applications but also for water pumping systems. Utilization of the solar energy is one of the promising and safe alternatives to address this huge energy demand. Low cost solar cells have been the subject of intensive research work for the last three decades. Amorphous semiconductors were announced as one of the most promising materials for low cost energy production. However, dye sensitized solar cells (DSSCs) emerged as a new class of low cost energy conversion devices with simple manufacturing procedures. One of the most used natural pigments in DSSCs are anthocyanins. Anthocyanin is one of the natural pigments, frequently found in leaves, fruits, flowers, berries and tubers (1,2**)** is very good alternative as a photosensitizer in DSSCs (3,4**)** and extracted from leaves, roots, berries and even insects etc. at a low cost extraction process., which are Anthocyanin pigments have no metal components; are non-toxic and can be obtained at low cost (5-**12)**

2. DEVICE ARCITECTURE

A **dye-sensitized solar cell** (**DSSC**) is a low-cost solar cell belonging to the group of thin film solar cell. It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a photo-electrochemical system. The cell is composed of four elements, namely, the transparent conducting and counter

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conducting electrodes, the nano-structured wide band gap semiconducting layer, the dye molecules (sensitizer), and the electrolyte. The DSSC has a number of attractive features; it is simple to make using conventional roll-printing techniques, is semi-flexible and semi-transparent which offers a variety of uses not applicable to glass-based systems, and most of the materials used are low-cost. The dye extracted from blackberry has shown a monochromatic incident photon to current efficiency (IPCE) ranging from 40% to 69%. Short circuit photocurrent density (J_{sc}) up to 8.8 mA/cm^2, and open circuit voltage (V_{oc}) ranging from 316 to 419 mV, were obtained from these natural dyes under 100 mW/cm^2 (AM 1.5) simulated sunlight.

3. WORKING PRINCIPLE

Nanocrystalline TiO_2 is deposited on the conducting electrode (photo-electrode) to provide the necessary large surface area to adsorb sensitizers (dye molecules). Upon absorption of photons, dye molecules are excited from the highest occupied molecular orbitals **(HOMO)** to the lowest unoccupied molecular orbital **(LUMO).** Once an electron is injected into the conduction band of the wide band gap semiconductor nano-structured TiO_2 film, the dye molecule (photo-sensitizer) becomes oxidized. The injected electron is transported between the TiO_2 nanoparticles and then extracted to a load where the work done is delivered as an electrical energy. Electrolytes containing I^-/I_3^- redox ions is used as an electron mediator between the TiO_2 photoelectrode and the carbon coated counter electrode. Therefore, the oxidized dye molecules (photosensitizer) are regenerated by receiving electrons from the I^- ions redox mediator that get oxidized to I_3^- (Tri-iodide ions). The I_3^-substitutes the internally donated electron with that from the external load and reduced back to I^-ion. The movement of electrons in the conduction band of the wide bandgap nano-structured semiconductor is accompanied by the diffusion of charge-compensating cations in the electrolyte layer close to the nanoparticle surface. Therefore, generation of electric power in DSSC causes no permanent chemical change or transformation.

4. MATERIALS

Maqui (Aristotelia Chilensis) and blackberry (Rubus Glaucus) extracts have important role as photosensitizer on the DSSCs for study the photovoltaic performance. The TCO (ITO, ZnO:Al, SnO_2:F etc.) coated glass with sheet resistance of 8 ohm/square are used as front electrode. A paste of titanium dioxide was used (Ti-Nanoxide D). The catalyst tested was based on platinum. Few sealing materials are used to join the electrodes and a liquid electrolyte filled in the space between the two electrodes.

5. PREPARATION OF NATURAL DYE

The anthocyanin extracts can be obtained from blackberry. The fruits are dried at 45^{0}C, and 0.5 g of dried fruit can be macerated with 5 mL of distilled water. Filter papers are used to extract the juice. The extracts are protected from exposure to light and stored at 5^0 C. Anthocyanin extract solution is diluted at different concentrations especially, one at 750 and another at 1500 mg anthocyanin/L. The diluted solution is used as sensitizer.

6. ROLE OF HOLE TRANSPORTING LAYER

In general, hole transporting layer (HTL) plays following roles: (i) it extracts and transports the holes in the active layer to the electrode; (ii) it acts as an energy barrier to prevent the transfer of electrons to the anode; (iii) it improves the devices stability by reducing possible degradation and corrosion; (iv) it can help to make proper matching of all HOMO and improve the open circuit voltage (V_{oc}) of DSSC devices [13-14].

Organic hole transporting material (HTMs) such as P_3HT, PTTA, PEDOT:PSS, spiro-OMeTAD, and inorganic HTMs such as copper-based materials (CuO_x, CuSCN, CuI, etc.), nickel-based materials (NiO_x), and two-dimensional layered materials (MoS_2, WS_2, etc.). Organic spiro-OMeTAD is the most popular HTM for high-performance of DSSC based solar cell and works efficiently in combination with some additives, like 4-tert-butylpyridine (tBP) and bis (trifluoromethane) sulfonimide lithium salt (Li-TFSI**) [15].** Dopant-free HTMs such as PEDOT:PSS [poly (3,4-ethylenedioxythiophene): polystyrene sulfonate] and P_3HT [poly(3-hexylthiophene-2,5-diyl)] have also been developed.

7. ROLE OF TiO_2

Titanium oxide (TiO_2) has found extensive use in a great variety of applications among which electrode materials for dye-sensitized solar cells. The polymorphs of TiO_2, rutile, anatase and brookite exhibit specific physical properties, band gap, electronic surface states. For many applications the size of particles was an important parameter because it determines the surface to volume ratio, which greatly influences many properties. TiO_2 anatase was the most used phase for photovoltaic applications and brookite seems potentially interesting. Nanometric particles of the three polymorphs were synthesized in aqueous medium in order to compare the electronic properties of these materials for photovoltaic devices.

8. ROLE OF BLACKBERRY

Blackberries contain a strongly light--absorbing dye molecule called anthocyanin, and these dyes can be extracted and used in a dye--sensitized TiO_2 solar cell to absorb light and then convert the light into electrical energy. Blackberry is a natural dye which has no toxic effects in comparison with the industrial samples.

9. CONCLUTIONS

In conclusion, high efficiency DSSC can be prepared using an anthocyanin-enriched extract mixture. Blackberry extracts has crucial effect on the DSSC efficiency depending upon the following factors (i) anthocyanin concentration; (ii) impregnation time; and (iii) dye type. The optimal conditions to prepare solar cells were obtained using the variables dye type of maqui/blackberry, anthocyanin concentration of 1500 mg/L and impregnation time of 8 h. The dye-sensitized solar cells prepared under optimized conditions showed 0.34% of DSSC efficiency. The impregnation time, however, does not impact on the DSSC efficiency. Anthocyanin concentration and dye type have a stronger influence on the DSSC efficiency. The dye mix (maqui and blackberry) shows better performance UV–Vis absorption spectrum range than either the maqui or blackberry dye working alone. The mixed dye provides more efficient incident photon-to-electron conversion. The mix of the anthocyanin extract has good ability to bind TiO_2 due to high surface coverage of TiO_2 nanoparticles**.** Anthocyanin concentration improves the number of bound dye molecules and the photocurrent. In the meantime, the bound anthocyanins helps to insulate the TiO_2 from the electrolyte, reducing the dark current and raising V_{OC}.

Acknowledgement: The author would like to acknowledge DST and CSIR - Govt. of India for providing financial support to arrange R&D infrastructure for continuous advanced research activity to train undergraduate students using this infrastructure for outcome of skilled human resources for our country.

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