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SOLAR CELL CHARACTERISTICS STUDIES ON POLYMER/TiO_2 POLYMER SOLAR CELL

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ABSTRACT

The polymer photovoltaic cell prepared by of 1,3,5-Triazine-2,4,6-trithiolate (TCA) coordination polymer and titanium dioxide (TiO_2) is studied. Herrin TCA acts as optically active and hole transport layer, TiO_2 as the exciton dissociation surface and copper and silver as electrodes. The power conversion efficiency (PCE) of the cell is 0.11% for 100 mW/cm^2 (AM 1.5) condition in Ag/TiO_2/CuTCA/Cu geometry. Even though the efficiency of the proposed solar cell is low, but the potential of coordination polymers in the photovoltaic application would open a new window.

Key words: Polymer solar cell, coordination polymers, electrochemical polymerization

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1. INTRODUCTION

The efficiency of silicon solar cell has reached almost saturation and many new ideas are implemented to improve the efficiency of polymer solar cell (PSC). Combination of these two, inorganic and organic materials results in a new type of photovoltaics (PV) called hybrid photovoltaic cell. This versatile hybrid technique combines the advantages of inorganic semiconductors such as high charge carrier mobility, reliability and stability with processing flexibility of organic materials. Most of the polymer solar cells employ solution process, because of its several advantages like multilayer deposition (multi junction), both the electron donor and acceptor layer contribute to light absorption, metal nanoparticles (NPs) incorporated polymer nanocomposites enhance efficiency by harvesting the excitons and reducing the resistivity of polymer and reduces the cost by producing cell by printing

technique.[1] Especially, in case of coordination polymer, the electronic properties can be tuned by coordination capability of functional ligands.[2]

The exciton diffusion length in most of the organic semiconductors is 3-10 nm, which is the major obstacle for the efficiency of polymer solar cell. In other words, the excitons generated away from the junction will most probably be recombined rather than harvested. The goal is to bring all excitons to the donor/acceptor interface before having matched recombination within the diffusion length. The blending of donor-acceptor phases intimately together solved the problem and was called bulk-heterojunction (BHJ) solar cells. Once the excitons are part at the interface, the external electrodes collect the charge carriers before they recombine. However, the major drawback of BHJ solar cells is the large interfacial region between the donor and acceptor, which inherently increases the charge recombination and subsequently device dark current.[3] Whereas, In the hybrid devices (exciton solar cells), the polymer absorbs light and creates excitons. The dissociation of generated exciton into separate free charges takes place in the vicinity of the hybrid interface

There is a lot of research interest on hybrid solar cells, whose function is like excitonic solar cells, consisting of metal-oxides and polymers. Widely used semiconducting metal oxides in excitonic solar cells are TiO_2, ZnO, Al_2O_3, CdSe, etc., are categorized under thin films. Generally, metal oxide semiconductors are used as an electron-transport layer between the organic layer and the electrode (cathode). In particular, the titanium dioxide (TiO_2) stands in the forefront as it forms good Ohmic contact to both donors and acceptors in polymer solar cells and shown as a promising acceptor material in hybrid solar cells.[4,5] It is known that TiO_2 is intrinsically n-type semiconductor with high electron affinity, which stems from the position of its conduction bands and enables it to match with the LUMO of most of the organic semiconductors.[6] Compared to organic semiconductors, the electron mobility of metal oxides is much higher, which is highly dependent on stsructure. This mobility improves charge transport in the devices by providing an ultra-quick pathway to an electron.

Coordination polymers (CPs) are studied for solar cell application, because the flexibility in tuning their electronic properties.[2,7] Coordination polymers means compounds in which metal entities linked by inorganic ligands in those polymers.[8] In this work, triazine containing trithiocyanuric acid (TCA, $C_3N_3S_3$) is used which acts as a bridging ligand to form readily polymeric structures with copper transition metal ions forms CuTCA (Cu ions containing polymer or metallopolymers).[8] The simple method of preparation CuTCA film by electrochemical polymerization is explained in early report and they reported that it is a visible light active.[9] The electrical characterization shows it is a p-type semiconductor with high conductivity.[10] This current work demonstrates the photovoltaic performance of hybrid solar cell constructed using TCA. To the best of our knowledge, this is the first report related to coordination polymers for solar cell application.

2. EXPERIMENTAL

2.1. CuTCA Polymer Deposition

1,3,5-Triazine-2,4,6-trithiol trisodium salt solution (TCA) (15%) procured from Sigma-Aldrich and Cu foils (NICE) were used for the preparation of CuTCA thin films by electrochemical methods. Cu foils with a thickness of 0.1 mm and 0.7 cm^2 geometric area was polished with different grades of emery, washed with deionized water and acetone before use. A three-electrode cell setup consisting of copper foil as working electrode, Pt as counter electrode and Ag/AgCl in 0.1 M KCl was used for electrochemical growth of CuTCA thin films. Electrochemical anonodization was carried out with an overvoltage of 50 mV from the open circuit potential for 5 mins. In chemical route for the preparation of CuTCA freshly prepared Copper electrodes were exposed to 7% TCA solution for 30 mins. The detailed

procedure and growth mechanism of the metallopolmers are discussed in earlier report [9]. The electrodes coated with thin films of CuTCA metallopolymers were thoroughly washed with Millipore water and dried for further characterizations.

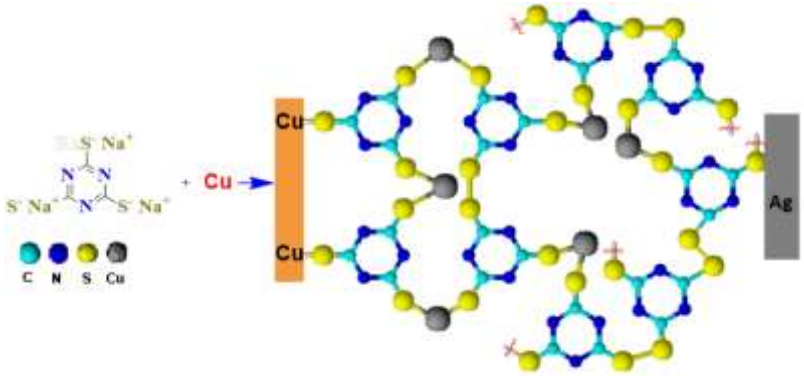

Figure 1 The polymerization mechanism of CuTCA on Cu electrode by electrochemical oxidation.

2.2. Preparation of TiO2 Sol-Gel

TiO_2 sol-gel was prepared by adding 0.2 g of TiO_2 nanopowder which was procured from Sigma-Aldrich having particles size of < P25 nm to 0.2 ml of 0.05 M HNO_3 solution. This colloidal solution was stirred at 120 rpm at room temperature for 30 min, which will form uniform homogenous paste.[11]

2.3. Preparation of Solar Cell

The CuTCA and TiO_2 based solar cell was prepared by spin coating of TiO_2 sol-gel on CuTCA electrode. The TiO_2 gel was spin coated for 60 sec at 2000 rpm then annealed at 100 ^oC for 10-12 min. The silver (Ag) contacts were given on top of TiO_2 layer to get the solar cell structures as Cu/CuTCA/TiO_2/Ag. The prepared solar cell area is about 1 cm^2 as shown in Figure 2. The device was characterized in home-built sample holder having 450 W xenon lamp. Current and voltage (I-V) reading were carried using a computer-controlled Bio-Logic SP-300 potentiostat.

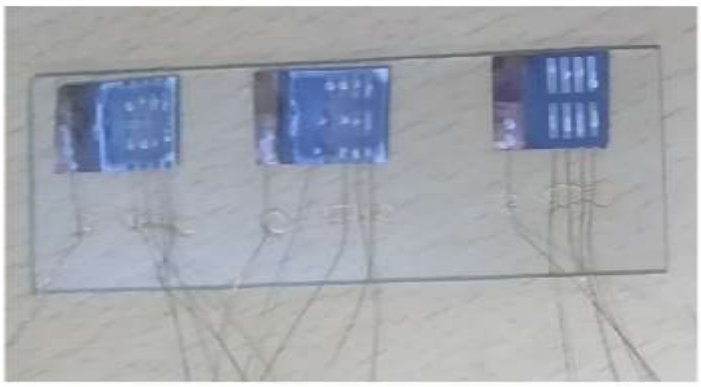

Figure 2 Image of prepared Cu/CuTCA/TiO_2/Ag solar cell.

3. RESULT AND DISCUSSION

The device is exposed to solar radiation through TiO_2 layer. The excitons will be generated in the polymer close to the polymer/TiO_2 junction under light. The generated excitons then diffuse to interface of polymer/TiO_2 where they will dissociate into free charges by the built-

in voltage.[1] The electrons reach to Ag through the TiO_2 layer and holes to Cu through polymer. The curtail parameters of solar cells are open-circuit voltage (V_{oc}) and short circuit current (I_{sc}). The open-circuit voltage is the potential at which current in the external circuit is zero. The short circuit current (I_{sc}) is the current generated in the solar cell in its short circuit condition.

The I-V data in figure 3 shows that, the device results open-circuit voltage of 0.161 V. The V_{oc} of a hybrid solar cell is basically driven by the bandgap of the donor-acceptor materials.[12] This is the difference between electrons potential energies in the acceptor conduction band (CB and the holes present in the highest occupied molecular orbital (HOMO) of the donor (E^D_{HOMO} - E^A_{LUMO} = bandgap). The factors those effect the V_{oc} are the large band offset among the donor and acceptor materials (is due to the dark or injected current), carrier recombination (either at the electrodes or in the bulk), incomplete splitting of the quasi-Fermi levels determined by the incident light intensity, chemical potential pinning to poorly optimized electrodes and increasing annealing temperature.[5,13–15] V_{oc} The V_{oc} in our device is low it may be because of low bandgap and it can be increased by optimized tuning of the relative HOMO/CB gap between the polymer and metal oxide film.

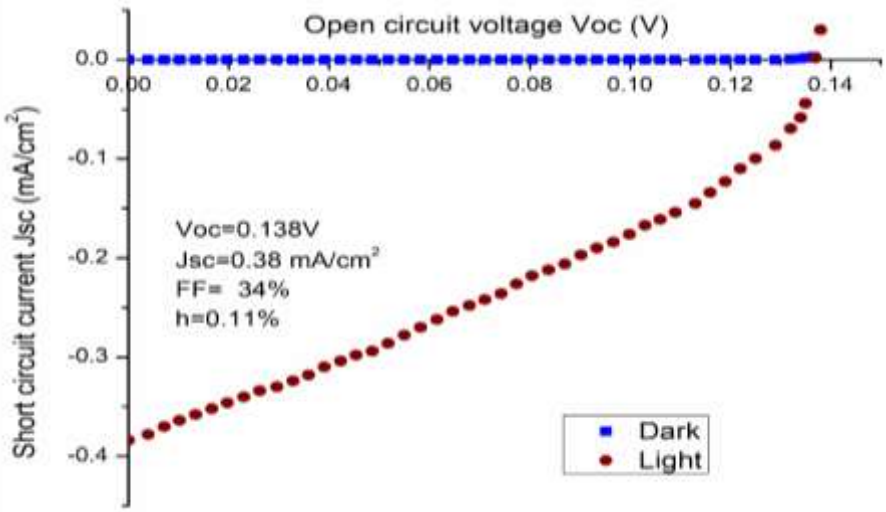

Figure 3 Current- voltage characteristics of curves of proposed solar cell.

The short circuit current is produced by generation and collection of carriers under illumination. The short circuit current of proposed solar cell exhibit 0.431 mA/cm^2 .as shown in figure 3. The I_{sc} is mainly driven by the material capacity to absorb solar spectrum and efficient charge carrier's collection. In this proposed solar cell the value of Isc is low, it may be due to carrier transport dynamics of polymer (bandgap, energy levels, mobility and traps).[16] The effective absorption of solar light improves the efficiency of the solar cell also.

The ratio of the maximum power (P_{mp}) delivered by the solar cell to the product of short circuit current and open-circuit voltage ($FF=P_{mp}/V_{oc}I_{sc}$) is the fill factor (FF) which is also a crutial parameter to decide the efficiency of the solar cell. The determined FF of our solar cell is 28.2%. Finally, the solar cells are characterized for Power conversion efficiency (PCE). The common misbelief is that the exciton binding energy affects the PCE of organic solar cells because it is substantially larger for organic materials. However, this energy plays no role in the efficiency calculations.[12] The PCE delivered by the solar cell is calculated as 0.196% which is given by $\eta = (V_{oc} \times J_{sc} \times FF)/P_{in}$. All the measured parameters of proposed solar cell are listed in table 1.

Table 1 Measured photovoltaic parameters of Ag/TiO_2/CuTCA/Cu solar cell.

V_{oc} (V)	Jsc (A cm-2)	Vmp (V)	Imp (A cm-2)	FF (%)	η (%)
0.161	0.431	0.101	0.194	28.2	0.196

4. CONCLUSION

This work was devoted to the study of hybrid inorganic-organic solar cell made by CuTCA polymer and TiO_2. 1,3,5-Triazine-2,4,6-trithiol trisodium salt (TCA) was coated on Cu foils to get CuTCA thin films by electrochemical methods. TiO_2 was deposited on CuTCA film by spin coating to get Cu/CuTCA/TiO_2/Ag solar cell geometry. The solar cell exhibit power conversion efficiency of 0.196% with V_{oc} as 0.161 and I_{sc} as 0.431 in 1000 Wm^{-2} condition.

REFERENCES

[1] A.J. Moul, L. Chang, C. Thambidurai, R. Vidu, P. Stroeve, (2012) Hybrid solar cells: basic principles and the role of ligands, J. Mater. Chem. 22, 2351–2368.

[2] Z. Gonzalo Givaja, Pilar Amo-Ochoa, Carlos, J.G. and Felix, (2012) Electrical conductive coordination polymers, Chem. Soc. Rev. 41, 115–147.

[3] C. Goh, S.R. Scully, M.D. Mcgehee, (2007) Effects of molecular interface modification in hybrid organic-inorganic photovoltaic cells, J. Appl. Phys. 101, 114503.

[4] I. Abayev, A. Zaban, F. Fabregat-Santiago, J. Bisquert, (2003) Electronic conductivity in nanostructured TiO2 films permeated with electrolyte, Phys. Stat. Sol. (A). 196, 5–7.

[5] S. Chen, J.R. Manders, S.W. Tsang, F. So, (2012) Metal oxides for interface engineering in polymer solar cells, J. Mater. Chem. 22, 24202–24212.

[6] V.C. Anitha, A.N. Banerjee, Sang Woo Joo, (2015) Recent developments in TiO2 as n- and p-type transparent semiconductors: synthesis, modification, properties, and energy-related applications, J Mater Sci. 50, 7495–7536.

[7] X. Wang, K. Maeda, A. Thomas, K. Takanabe, G. Xin, J.M. Carlsson, K. Domen, M. Antonietti, (2009) A metal-free polymeric photocatalyst for hydrogen production from water under visible light, Nature Materials. 8, 76–80.

[8] J.C. Chudy, J.A.W. Dalziel, (1975) Metal Complexes of 1,3,5-Triazine-2,4,6-Trithiol, J. Inorg. Nucl. Chem. 37, 2459–2461.

[9] R.S. Vishwanath, S. Kandaiah, (2016) Chemically Immobilized Triazine Based CuIIS3C3N3 Metallopolymer on Copper as a Photocathode for Photoelectrochemical Hydrogen Evolution, J. Electrochem. Soc. 163, H402–H409.

[10] K. Deepak, A. Roy, P. Anjaneyulu, S. Kandaiah, S.L. Pinjare, (2017) Charge transport mechanism in p-type copper ion containing triazine thiolate metallopolymer thin film devices, J. Appl. Phys. 122101, 164504–164103.

[11] D. Kishore Kumar, M.H. Hsu, A. Ivaturi, B. Chen, N. Bennett, H.M. Upadhyaya, (2019) Optimizing room temperature binder free TiO 2 paste for high efficiency flexible polymer dye sensitized solar cells, Flex. Print. Electron. 4, 015007.

[12] B.A. Gregg, (2005) The Photoconversion Mechanism of Excitonic Solar Cells, MRS Bulletin. 30, 20–22.

[13] B.A. Gregg, (2003) Excitonic Solar Cells, J. Phys. Chem. 107, 4688–4698.

[14] B.C.J. Brabec, A. Cravino, D. Meissner, N.S. Sariciftci, T. Fromherz, M.T. Rispens, L. Sanchez, J.C. Hummelen, (2001) Origin of the Open Circuit Voltage of Plastic Solar Cells, Adv. Funct. Mater. 11, 374–380.

[15] C.M. Heller, I.H. Campbell, D.L. Smith, N.N. Barashkov, J.P. Ferraris, (1997) Chemical potential pinning due to equilibrium electron transfer at metal/C60-doped polymer interfaces, J. Appl. Phys. 81, 3227–3231.

[16] H. Lee, C. Lee, H.J. Song, (2019) Influence of electrical traps on the current density degradation of inverted perovskite solar cells, Materials. 12, 1–7.