

**Development of newer modified electrodes using conducting polymer nano composites for dye sensitized solar cells**



ज्ञान-विज्ञान विमुक्तये

**Submitted to**

**University Grants Commission (UGC)**  
BahadurShah Zafar Marg, New Delhi

**UGC- FINAL RESEARCH PROGRESS REPORT**

**UGC/F.No.40/72/2011 (SR) dated, 05.07.2011**



**Submitted**

**By**

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**UNIVERSITY GRANTS COMMISSION  
BAHADUR SHAH ZAFAR MARG  
NEW DELHI – 110 002**

**PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING  
THE FINAL REPORT OF THE WORK DONE ON THE PROJECT**

1. Title of the project: **Development of newer modified electrodes using conducting polymer nano composites for dye sensitized solar cells.**
  
2. Name and address of the principal investigator: **Dr. T.STALIN**  
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3. Name and address of the institution: **Alagappa University, Karaikudi-03.**
  
4. UGC approval letter no. and date: **F.No.40/72/2011 (SR) dated, 05.07.2011**
  
5. Date of implementation: **01.07.2011**
  
6. Tenure of the project: **Three Years (01.07.2011 to 30.06.2014)**
  
7. Total grant allocated: **Rs. 7, 23,800/-**
  
8. Total grant received: **Rs. 5, 39,800/-**
  
9. Final expenditure: **Rs. 5, 22, 758/-**
  
10. Title of the project: **Development of newer modified electrodes using conducting polymer nano composites for dye sensitized solar cells.**
  
11. Objectives of the project: **Our investigation which aims to develop novel highly conductive polymer-multiwall carbon nanotube nanocomposite counter electrodes for dye sensitized solar cell.**

12. Whether objectives were achieved: **Yes**

13. Achievements from the project:

Dye-sensitized solar cells (DSSCs) have been attracting attention because of their simple structure, low cost, high energy conversion efficiency compared to silicon solar cells (Oregan and Gratzel 1991, Nazeeruddin et al. 1993, Frank et al. 2004, Jayaweera et al. 2008). The DSSC consists of major three important parts: dye -sensitized nano crystalline titanium dioxide (TiO<sub>2</sub>) coated on a transparent glass plate (ITO) act as a photo anode, I<sub>3</sub>/I<sup>-</sup> redox couple containing liquid electrolyte, and platinum coated on a transparent glass plate (FTO) act as a return electrode (Papageorgiou et al. 1997 and Papageorgiou 2004). The counter electrode (CE) in DSSCs acts as an electron injector from the external circuit to the redox electrolyte. The iodide (I<sup>-</sup>) ions present in the redox electrolyte reduce the oxidized dye and the resultant tri iodide (I<sup>3-</sup>) ions are reduced back to I<sup>-</sup> ions at the catalytic site on the CE surface .The problems with platinum are its expensive, inconvenient transportation and limited quantity of the earth (Kay & Grätzel 1996, Murakami et al. 2006, Spath et al. 2003, Okada et al. 2004, Kroon et al. 2007, and Ma et al. 2004). Alternative cheap catalysts and good performance counter electrodes for the DSCs are inexpensive materials, such as carbon black (Murakami et al. 2006), graphene (Roy-Mayhew et al. 2010), carbon nanotubes (Lee et al. 2009), and conductive polymers, like poly pyrrole (Wu et al. 2008), polyaniline (PANI) (Sun et al. 2010) and poly (3, 4-ethylenedioxy thiophene) (Kim et al. 2008, Saito et al.2002, Liu et al. 2010). Among the polymer materials devised, development of the poly (thiophene) derivative, poly ethylenedioxythiophene (PEDOT), has shown significant promise in the challenge at hand. The energy conversion efficiency of DSSCs reached 4.5% when they were put on to composite films of MWCNTs and PEDOT on fluorine doped tin oxide substrates by pulse plating technique to make the counter electrodes. Carbon nanotubes of SWCNTs and MWCNTs, MWCNTs have excellent high mechanical strength, thermal stability and electronic properties. These properties make the MWCNTs good candidates for various applications, such as transistors, batteries, field emission displays and nano scale interconnects.

Recently, carbon nanotubes have been used as CEs in DSSCs and have functioned as catalysts for the I<sub>3</sub> - /I<sup>-</sup> reaction. These CNTs have also been shown to improve the performance of DSSCs For instance; Lee et al. Used chemically polymerized PEDOT and incorporated

MWCNTs in the PEDOT film as CEs, which were coated in stainless steel to achieve better conversion efficiencies. Unfortunately, the chemically prepared PEDOT CEs required complicated fabrication processes. Nonetheless, the electro polymerization method has been successfully used to prepare composite films of polythiophene derivatives and poly anilines with MWCNTs. These homogeneous and well-adhesive polymer films were obtained on fluorine-doped tin oxide (FTO) glass. The surfactant role is important in the preparation of any conjugated polymers in organic medium electrodeposited polymer the metal and glass substrate, thiophene derivatives such as poly3-hydroxy thiophene and 3,4 ethylenedioxythiophene are insoluble in aqueous solutions. The surfactant increase the solubility of the monomer, surface active area as well as increase the polymerization process during the electrodepositing. Many of the surfactant used in the preparation of CEs for DSSCs, but I have selected the three different types of surfactants namely anionic (sodium dodecyl sulfate-SDS), cationic (cetyltrimethylammonium bromide-CTAB) and nonionic (TritonX100) surfactants. The surfactant role was important to the insoluble monomer based electrodeposition preparation methods. In this work, composite films of the PEDOT–MWCNT were made using electro polymerization method on the FTO glass for the CE of a DSSC. The differences in surface morphology and electrode characteristics between the pare PEDOT–MWCNT composite film and surfactant assisted preparation of PEDOT-MWCNT composite films were investigated. Ultimately, the PEDOT-MWCNTs prepared counter electrode was compared with the standard counter electrode of platinum.

## **Experimental and Details**

### **Electrochemical synthesis of the PEDOT-MWCNT nano composite counter electrodes with various surfactants.**

The PEDOT–MWCNT nano composite counter electrodes were prepared by the electrochemical polymerization method. 0.1M EDOT monomer solution was prepared with the addition of 0.1 mg of MWCNTs in de-ionizer water to an equal volume of acetonitrile (10:10 ml). The deposition was carried out at -0.2V to 1.6V. 0.1M LiClO<sub>4</sub> was used as the electrolyte for CV measurements, which contains three different types of surfactant such as the anionic surfactant-sodium dodecyl sulfonate (SDS), the cationic surfactant (CTAB) and the nonionic surfactant (Triton X 100). The Platinum wire and saturated calomel electrode used as the counter and a reference electrode. The resulting working electrodes blue colored films were immediately

rinsed with double distilled water, followed by acetonitrile and acetone at ambient temperature. The Pt coated FTO glass CE was manufactured using an optimized electro-deposition method.

### **Fabrication of dye sensitized solar cell:**

#### **The Photo-anode preparation:**

The TiO<sub>2</sub> (P25, Degussa, India) films on the FTO glass (14Ω cm<sup>-1</sup>) were prepared using the doctor blade method. The films were annealed at 430° C for 45 min and then treated with a 2 ml of Titanium butoxide (TITB) aqueous solution at 80° C for 1 h. Thus the TiO<sub>2</sub> annealed for 45 min at 480° C. The TiO<sub>2</sub> electrode was cooled to room temperature and then immersed in a 0.3 mM solution of cis-bis (isothiocyanato) bis (2,2-bipyridyl-4,4-dicarboxylato) ruthenium (II) bis-tetrabutyl ammonium (N719 dye) in ethanol for 12 h. The TiO<sub>2</sub> film was immersed in sensitizing N719 dye, then washed with ethanol and acetone.

#### **The gel polymer electrolyte preparation:**

The DSSCs was assembled 0.1M Polyethylene oxide (PEO), 0.1 M LiI, 0.1M LiClO<sub>4</sub> and 0.01M Iodine in acetonitrile containing electrolyte. Finally, the electro deposited PEDOT-MWCNTs nano composite used as cathode materials for DSSCs, which is compared with the Pt deposited cathode materials used in dye sensitized solar cell.

#### **The Characterization of PEDOT-MWCNTs counters electrodes for DSSCs.**

The surface morphology of prepared PEDOT-MWCNTs nano composite counter electrodes were characterized by HR-SEM. The structures of the composite electrodes were studied using XPert-Pro X-ray diffractometer with Cu-Kα radiation. The functional group identification of forming composite counter electrodes determines the FT-IR spectra in the range of 400-4000cm<sup>-1</sup>. The electrochemical impedance spectra investigated by the electrical conductivity of PEDOT-MWCNTs counter electrodes (The PGSTAT 30. Eco-Chemi, Netherlands) in the range of 0.01Hz to 10<sup>5</sup> Hz. This instrument equipped with FRA2 software. The cyclic voltammograms were recorded using the PGSTAT30.Eco-Chemi, Netherlands, with a three-electrode system.

The prepared three surfactant based PEDOT-MWCNT and Pt films were used as the working electrode, a Pt rod was used as a counter electrode and Ag/Ag<sup>2+</sup> electrode was used as reference electrode in an acetonitrile solution containing 0.1M Li, 0.01M and 0.1M LiClO<sub>4</sub> was

used as electrolytes at various scan rates. The DSSCs performance was measured by using the solar simulator (150 W simulator, PEC- L11, PECCELL), under air mass 1.5 and 100 mW cm<sup>2</sup> of the light intensity. The active area of the DSSC devices was measured by using a black mask of 0.5 cm<sup>2</sup>. The photo-electrochemical parameters, i.e., the fill factor (FF) and light-to-electricity conversion efficiency ( $\eta$ ), were calculated by the following equation,

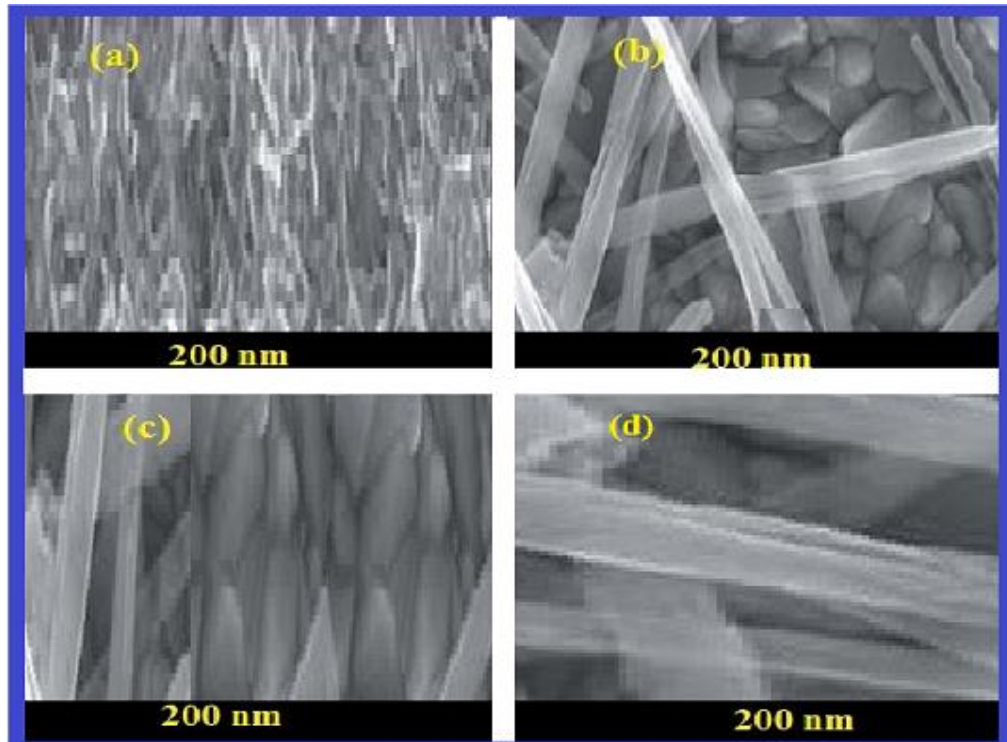
$$FF = \frac{V_{max} \times J_{max}}{V_{oc} \times J_{sc}} \text{ --- eqn (1)}$$

$$\eta (\%) = \frac{V_{max} \times J_{max}}{P_{in}} \times 100 = FF \times \frac{V_{oc} \times J_{sc}}{P_{in}} \times 100 \text{ --- eqn (2)}$$

Here V<sub>max</sub> is the voltage maximum output, J<sub>max</sub> is the current maximum output, V<sub>oc</sub> is the open circuit voltage and J<sub>sc</sub> is short circuit current density. Fill factor may be determined as the ratio of maximum of power to the product of the short circuit current (J<sub>sc</sub>) and the open circuit voltage (V<sub>oc</sub>). Efficiency is determined as the ratio of the maximum power output to force input to the dye sensitized solar cell.

## Result and Discussions

### HR-SEM image

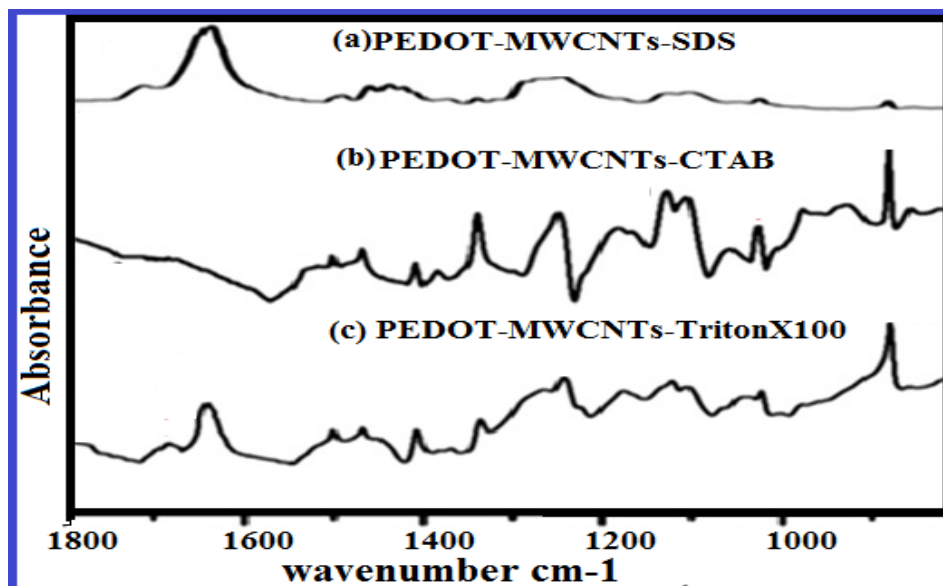


**Fig.1 The HR-SEM images of the simple electrodeposited (a) PEDOT-MWCNT, (b) PEDOT-MWCNT-SDS, (c) PEDOT-MWCNT-CTAB and (d) PEDOT-MWCNT- Triton X 100.**

The HR-SEM images of electrochemical preparation of PEDOT-MWCNT was incorporated the presence and absence of surfactants. Fig.1.(a) the surface morphology was observed on without any surfactant used in the preparation of counter electrode, the addition of surfactants (Fig.1.b-d) was added to the electro deposited PEDOT-MWCNT with increasing the surface roughens and thickness of composite films in the nonionic to anionic surfactant, due to the increased the surface active area or reduced the surface tension of the electrolyte/ electrode interface as well as enhanced the polymerization process. The anionic surfactant of sodium dodecyl sulfate (SDS) used in the preparation of PEDOT-MWCNT nano composite electrode films, it has negative ends of hydrophobic charge species and positive based spies another ends. In these charged spices helped to the reduced the surface tension of electrolyte/electrode interface. Therefore, the uniform thickness, better surface morphology of the nano composite counter electrode formed.

### **FT-IR analysis**

Fig.2. (a-c) shows the FT-IR spectra of PEDOT–MWCNT hybrid films were performed interaction between PEDOT and MWCNTs in the presence of wetting agent (surfactant). The characteristic bands of the MWCNTs were observed at 1716, 1644, 1435, and 1242  $\text{cm}^{-1}$  in broad band. The stretching frequency was noted at 1719  $\text{cm}^{-1}$  that is fitting to the C-O, and C-C- O functional groups in MWCNTs. The presence of surfactants in the PEDOT-MWCNTs composites good interfacial contact between the PEDOT and MWCNTs in the hydrogen bonds, that are bond formed between C-OH and C-O-C groups of PEDOT-MWCNTs.



**Fig.2 The FT-IR spectrum of electro deposited PEDOT-MWCNT-SDS (a), PEDOT-MWCNT-CTAB (b) and PEDOT-MWCNT-TritonX100 (c) based counter electrodes for DSSCs.**

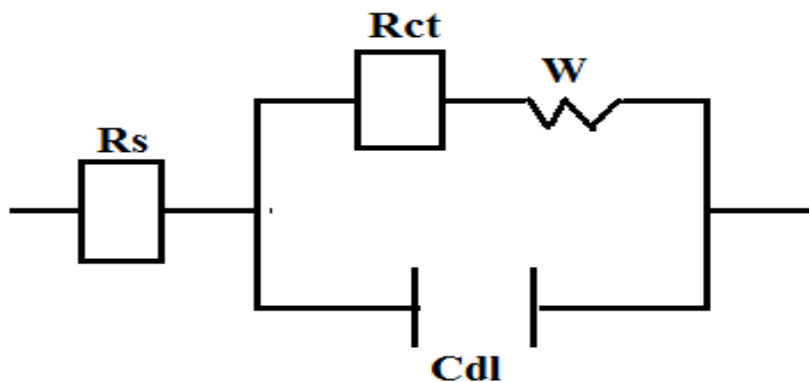
The FT-IR spectrum of the fig.2a PEDOT-MWCNT-SDS hybrid films revealed that the characteristic peaks at 1506, 1470, 1354, 1190, 1020 and 87  $\text{cm}^{-1}$  due to PEDOT the conjugated C- C and C- O stretching vibrations, the symmetrical C- H bending vibration. The peak values at 1690, 1647 and 1244  $\text{cm}^{-1}$  were caused by the absence of anionic surfactant sodium dodecyl sulfate (SDS) in the PEDOT-MWCNT nano composite material. The absorbance peak value decreased the addition of anionic surfactant was added to the PEDOT-MWCNTs, which is revealed that the uniform thickness of the PEDOT-MWCNT film formed using the electro deposited of an anionic surfactant.

### **AC impedance analysis**

The electrical conductivity behavior of prepared nano composites counter electrodes was determined by the AC impedance spectroscopy. The PEDOT-MWCNT nano composite films used as working electrode, platinum wire act as counter electrode and Ag/Ag<sup>2+</sup> used as a reference electrode, in the all the three electrodes assembled in the above diagram. Herein, The Rct is the interfacial charge transfer resistance of PEDOT-MWNCTs (SDS, CTAB and TritonX100) electrodes/electrolyte and electrolyte /Platinum wire, W is Warburg diffusion

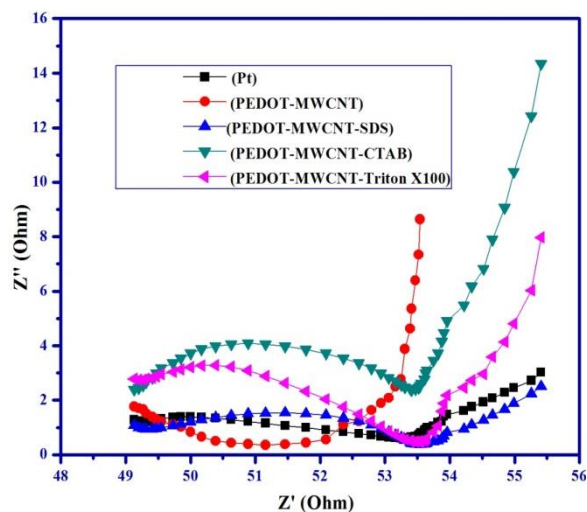


impedance,  $C_{dl}$  is double-layer capacitance and  $R_s$  are the bulk resistance of the electrolyte/electrodes.



**Fig. 3. Diagram of equivalent circuit of the PEDOT-MWCNTs electrode**

The PEDOT-MWCNT nano composite working electrode was immersed in a liquid electrolyte solution containing 0.6M polyethylene oxide (PEO), 0.06M of LiI, 0.06M of LiClO<sub>4</sub>, 0.06M of 1-hexyl-3-methylimidazolium iodide and 0.006M of Iodine. The AC impedance spectra clearly show semicircles in the high-frequency region in the range from 0.01Hz to 100000 Hz for the CE's studied. The higher frequency value of counter electrode was attributed to the interfacial charge transfer resistance ( $R_{ct}$ ) of CE's. The RCT value of anionic surfactant used in the preparation of PEDOT-MWCNT counter electrode was smaller (4.46) compared with other two surfactants used in the electro depositing of PEDOT-MWCNT and Platinum under same preparation condition.

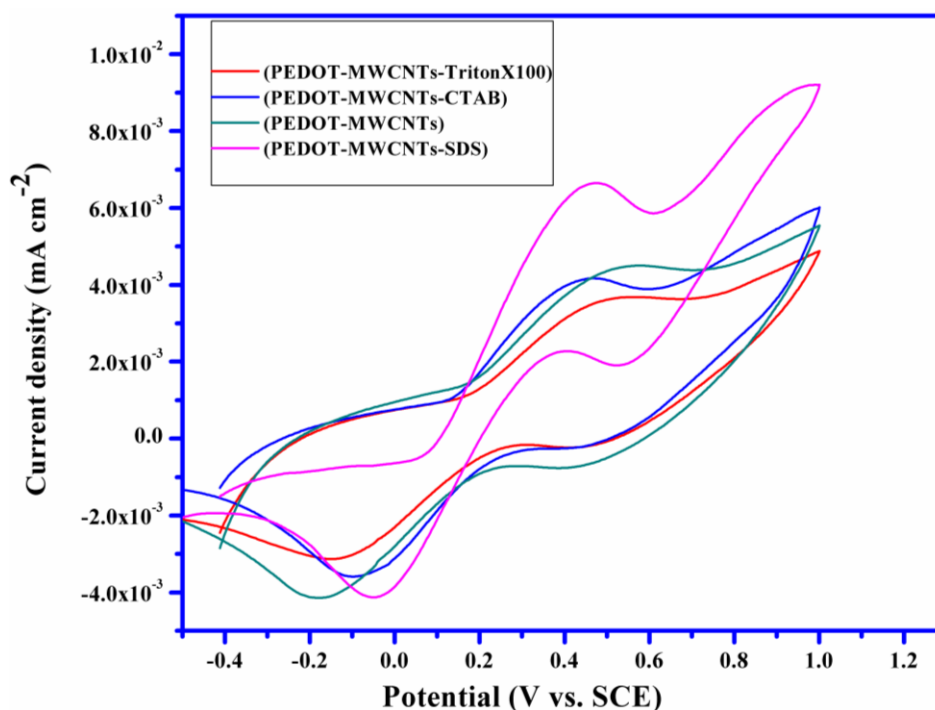


**Fig.4 AC impedance curve of Pt, PEDOT-MWCNT and its three different types of surfactant used in the electrodeposition preparation of nano composite working electrodes.**

This phenomenon indicated that the lower interfacial charge transfer resistance occurred at the interface between the PEDOT–MWCNT-SDS counter electrodes and electrolyte, due to the anionic surfactant of the sodium dodecyl sulfonate increased the monomer dissolution, good absorption behavior of the working electrode surface during the polymerization process and also give the higher the surface active area of the working electrode. Therefore, these results were attributed to the effect anionic surfactant using the preparation of PEDOT-MWCNT-SDS nano composite counter electrode film has a high electrical conductivity compared with two types of the surfactant used the preparation of PEDOT-MWCNT and Platinum.

#### **Electrocatalytic activity of PEDOT-MWCNTs counters electrodes with various surfactants.**

The cyclic voltammogram of the Pt, PEDOT-MWCNT and three different types of the surfactant used in the preparation of PEDOT-MWCNT-SDS, PEDOT-MWCNT-CTAB and PEDOT-MWCNT-Triton X 100 films were shown in fig. 5. The Cyclic Voltammetry of the samples was measured using a three electrochemical cell consisting of as prepared electrode used as working electrode, platinum used as a counter electrode and saturated calomel electrode used as a reference electrode dipped in 0.1M LiI, 0.1M LiClO<sub>4</sub> and 0.01M Iodine electrolyte solution. This system to determine the electro catalytic activity of dye sensitized solar cell.



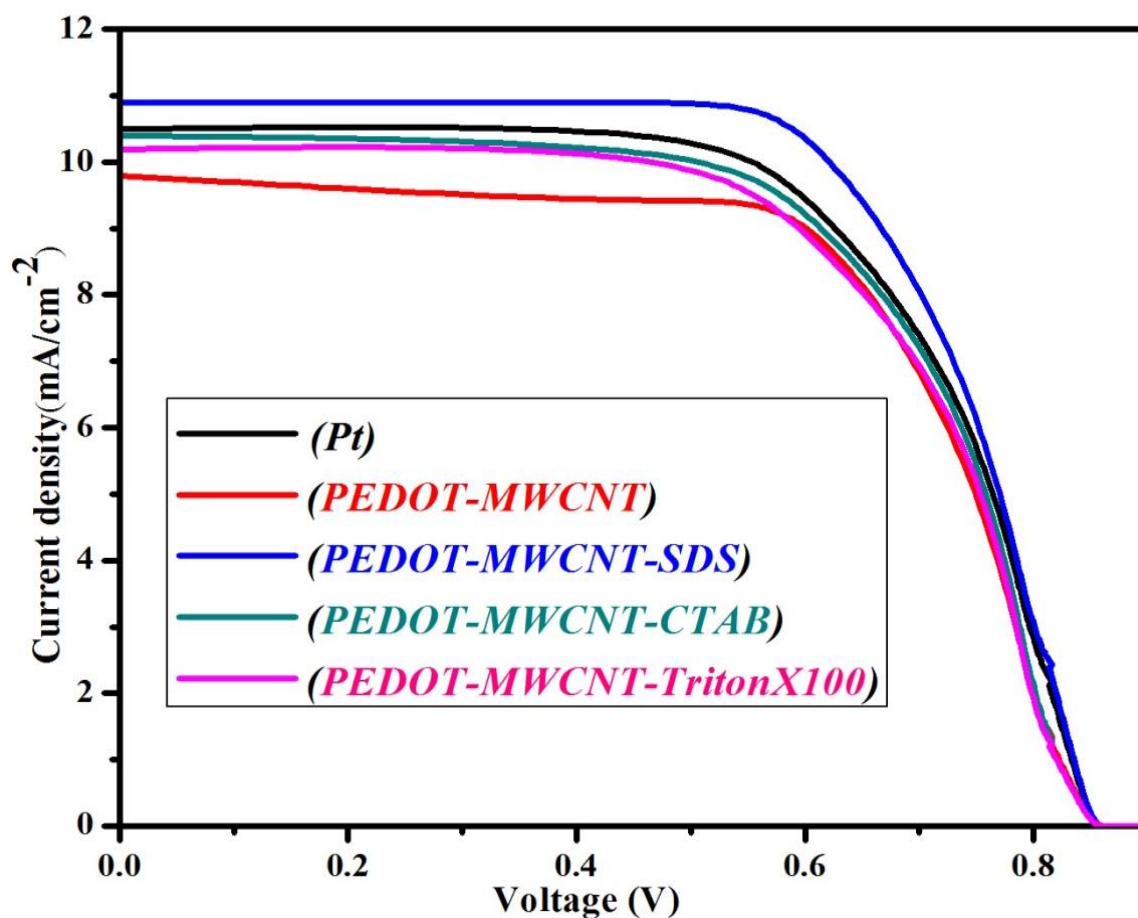
**Fig.5. The cyclic voltammogram (CV) of the Pt, PEDOT-MWCNT, PEDOT-MWCNT-SDS, PEDOT-MWCNT-CTAB and PEDOT-MWCNT-Triton X100.**

The PEDOT-MWCNT–SDS used in preparation of the nanocomposite counter electrode has higher electrocatalytic activity, because used in anionic surfactant of sodium dodecyl sulfate gave the higher surface active area and enhanced the electrochemical polymerization of poly (3,4-ethylenedioxy thiophene), which is confirmed in the electrochemical polymerization fig. 6. Therefore, the electrocatalytic activity of resulted the CV curve gives variation in the bath the two oxidation and reduction peak potential values, the first oxidation potential was set apart to the I<sub>3</sub><sup>-</sup> ions produced or oxidized form values, the second oxidation potential was higher which is attributed to the faster re-reduction of the tri-iodide ion into iodide ions.

We can conclude that the electrocatalytic activity of PEDOT-MWCNTs-SDS have higher compared to the other surfactant, Pt and pure CEs, due to the formation of strong electrostatic interaction between the EDOT<sup>+</sup> Cation radical and DS<sup>-</sup> anion. The lower oxidation potential was related to the higher dissolution behavior of monomer in organic media takes place in two steps: in the first step, an adsorbed layer of oxidized EDOT appears at the surface of the electrode and the second one EDOT species diffusing close to the electrode/electrolyte dimmers or oligomers formed during the first step are oxidized.

**DSSCs performance of three different types of surfactant based PEDOT-MWCNT nano composite counter electrodes.**

The PEDOT-MWCNTs shows the great electro catalytic activity for re-reduction and regeneration of the I<sub>3</sub><sup>-</sup> to I<sup>-</sup> in the redox electrolytes for dye sensitized solar cells. Many workers developed in the PEDOT-MWCNTs and their composite counter electrodes to improve the electrical energy conversion efficiency of the DSSCs. We demonstrated that the poor water soluble of EDOT monomer was incorporated with the nano structured many walled carbon compounds for the purpose of various surfactants used the electrochemical preparation of composites to form uniform thickness and investigated as their applications in counter electrodes for DSSCs



**Fig.6. I-V curves of the electro-deposited Pt, PEDOT-MWCNT, PEDOT-MWCNT-SDS, PEDOT-MWCNT-CTAB and PEDOT-MWCNT-Triton X100 nano composite counter electrodes.**

Fig. 6. Shows the I-V curves of the DSSC cells that were made using Pt, PEDOT-MWCNT and three different types of surfactant based preparation of PEDOT- MWCNT-SDS and/or CTAB, TritonX100 materials. The detailed photovoltaic performances of those cells are shown in Table.1.

The DSSC device using PEDOT-MWCNTs along as a counter electrode shows a relatively high efficiency of 7%. When the as-made-up of electro deposited PEDOT- MWCNT-SDS nano composites were applied as the CE, the efficiency was improved compared to other types of dye sensitized solar cells. The outcomes indicate that the negatively charged end species containing Sodium dodecyl sulfate (SDS) attached to the positively charged species containing PEDOT in PEDOT-MWCNTs used for the preparation of the nano composites counter electrode for DSSCs, which is increasing the contact area of the electrodes. The highest efficiency of 7.13%

was obtained for PEDOT-MWCNT-SDS CEs based DSSCs. This efficiency was equal to when using Pt as counter electrode for dye sensitized solar cell. The PEDOT-MWCNT-SDS has the highest short-circuit photo-current density ( $J_{sc}$ ),  $10.98\text{mA}/\text{cm}^2$  and highest open-circuit voltage ( $V_{oc}$ )  $0.848\text{ mV}$ . The optimized photon into electrical energy conversion efficiency ( $\eta$ ) of the DSSCs was achieved to 7.13% when the sodium dodecyl sulfate (anionic surfactant) film used the polymerization process. This is higher than the cationic (6.96%), nonionic (6.73%) surfactants based preparation of PEDOT-MWCNT nano composite counter electrodes and Platinum based counter electrode (7.08%).

**Table.1. I-V Characterization of Pt, PEDOT-MWCNT and three different types of surfactant used in the preparation of PEDOT-MWCNT nano composite counter electrodes.**

Counter electrodes used in DSSCs	Short circuit current density ( $J_{sc}$ )	Open circuit voltage( $V_{oc}$ )	Fill Factor (FF)	Efficiency $\eta$ (%)
<b>Platinum (Pt)</b>	10.50	0.843	0.680	7.08
<b>PEDOT-MWCNT</b>	9.82	0.827	0.460	6.53
<b>PEDOT-MWCNT-SDS</b>	10.98	0.848	0.682	7.13
<b>PEDOT-MWCNT-CTAB</b>	10.34	0.829	0.642	6.96
<b>PEDOT-MWCNT-TritonX100</b>	10.20	0.828	0.638	6.73

## Conclusion

The PEDOT-MWCNT and the addition of three different type's f surfactant based counter electrodes were prepared and characterized. An anionic surfactant used the preparation CE was granular-stick like structure was observed in the HR-SEM pictures. FT-IR analysis was conformed in the strong electrostatic interaction between the electrolyte and electrode surfaces of CEs. The highest electrical conductivity of the sodium dodecyl sulfate added to PEDOT-MWCNT nano composite counter electrode and decreases the  $R_{ct}$  value of  $5.79 \times 10^3\text{ S}/\text{cm}$  at

room temperature. The electrocatalytic activity of the SDS used in the preparation the PEDOT-MWCNTs showed the faster regeneration of iodide to tri-iodide in the redox couple compared with Pt and other surfactant based CEs. The DSSCs performance of the anionic surfactant based CEs gave best sunlight to electrical energy conversion efficiency of 7.13%, which is even higher than the Pt, pure PEDOT-MWCNT and the other two types of surfactant based CEs.

#### 14. Summary of the findings:

- ❖ The electropolymerization of EDOT monomer and surfactants dissolved in the equal volume of double distilled water and acetonitrile solvents in 1:1ratio. PEDOT is one of the most stable CPs available, combining a low onset oxidation potential ( $E_{ox}$ ) of the monomer and moderate band gap (approximately 1.6–1.7 eV) as well as high electrical conductivity ( $>100 \text{ S cm}^{-1}$ ).
- ❖ These properties have made PEDOT applicable in many fields such as antistatic coatings, cathodes in capacitors, Electrochromic devices and photovoltaics. However, the application of PEDOT as an important basic component for DSSCs was greatly affected the water used as a solvent medium the media for counter electrode preparation and its monomer 3,4-ethylenedioxythiophene (EDOT) has a very poor solubility in water (2.1 g/l). Furthermore, polymerization of EDOT is inhibited by water molecules interacting with thienyl cation radical, the polymerization intermediate.
- ❖ To solve these problems, it was recently proposed to add significant amounts of anionic surfactants to aqueous solutions of EDOT. This increases its solubility and lowers during electrochemical oxidation. The use of a surfactant for electropolymerization of heteroaromatic compounds has several important effects.
- ❖ The presence of micelles provides an interesting solvent system for solubilization of these waters-insoluble compounds. Also, the solution affects the electrochemical reactions by irreversible absorption, changing the solution–electrode interfacial properties and producing some template effects at the electrode. Moreover, the addition of surfactants to the electrolyte can stabilize charged species such as anions or cation radicals, and can also improve the properties of CPs.

- ❖ Surfactants also enhance the polymerization process as well as increase electrocatalytic activity of PEDOT/MWCNTs nano composite counter electrode and increase the energy conversion efficiency of dye sensitized solar cell. Then I can optimize the performance of surfactant (anionic, cationic and non-Ionic) used the preparation of PEDOT/MWCNTs nano composite counter electrode for high efficiency and long-term stability of dye sensitized solar cell.

#### 15. Contribution to the society:

We have proposed in the project, the electrochemical polymerization was highly pure, uniform thickness of the polymer-composite formation, controllable and easy to preparation to our research society. The preparation of dye sensitized solar cell assembling the Eosin Y dye , Rose bengal dye and Ruthenium dye of N719 was also used as sensitizer, N719 was best sunlight to electrical energy conversion efficiency. The PEDOT/WMCNTs nano composite counter electrode and the gel electrolyte used in the DSSCs was poor interfacial contact between both the electrolyte/photo-anode, electrolyte/cathode and also gel electrolyte have some viscous nature. These viscous natures of the gel polymer electrolytes were reduced the open circuit voltage and short circuit current density of dye sensitized solar cell. Further developments in this project were viscous gel replaced blend polymer composite gel electrolytes and standard counter electrode of platinum compared with PEDOT/MWCNTs at the same time changed the dye solutions also. The platinum counter electrode was high cost and 40% of cost just spends to preparation of counter electrode for dye sensitized solar cells. Most of the high efficiency dye sensitized solar cell systems based on the low-cost counter electrode materials of carbon and its allotropes of graphene, graphene oxide and reduced graphene oxide. The carbon based counter electrode materials used in the fabrication of the dye sensitized solar cell have the poor electrocatalytic activity lower the iodide-triiodide reduction process, in these types of lower the re-regeneration process of counter electrode materials gave the lower short circuit current density

(Jsc), lower open circuit voltage (Voc). To Minimized the above problem, we are introduced to the low-cost, high electrocatalytic activity and high thermal stability of conducting polymer of Poly (3, 4 ethylene dioxythiophene) combined with higher electrocatalytic activity of carbon of multi walled carbon nanotube used as counter electrodes, improved the open circuit voltage and short circuit current density and also sunlight into electrical energy conversion efficiency (%).

16. Whether any Ph.D. enrolled/produced out of the project:

Ph.D Enrolled : YES

Candidate Name : K.SAKTHI VELU

Reg. No : 570

**17. No. of publications out of the project:**

<b>S. No.</b>	<b>Paper Title</b>	<b>Name of the Journal/ Conference</b>	<b>Status</b>
1	Conductivity, structural and electrochemical behaviour of plasticized polymer electrolytes for dye-sensitized solar cell,	Indian Journal of Chemistry Sec A	Published during April 2015
2	Insitu electrochemical synthesis of poly(o-anisidine) counter electrode for dye sensitized solar cell,	Journal of Applied Polymer Science John Wiley & Sons, Inc	Published during Jan. 2015
3	Preparation and characterization of poly(o-anisidine) with the influence of surfactants on stainless steel by electrochemical polymerization as a counter electrode for dye-sensitized solar cells	Journal of Applied Polymer Science John Wiley & Sons, Inc.]	Published during Jan. 2015



4	Poly(Vinilidene fluoride) - Poly(Ethylene Oxide) Blended Conducting Polymer as Gel Polymer Electrolyte for Dye-Sensitized Solar Cells	<i>International Conference on Recent Advances in Textile and Electrochemical Sciences</i> , held at Dept. of Industrial Chemistry, Alagappa University, Karaikudi, Tamilnadu	March 21-23, 2013.
5	Dye sensitized solar cell using efficiency enhancement Poly acrylonitrile (PAN)-SiO <sub>2</sub> based composite gel electrolytes,	National Seminar on <i>Frontier Areas in Chemical Technologies – 2015, FACTs – 2015</i> , held at Department of Industrial Chemistry, Alagappa University, Alagappa University, Karaikudi, Tamilnadu.	March 6 – 7, 2015.
6	Effect of various concentration of iodide/ tri iodide redox couple for poly (ethylene oxide) based plasticized polymer electrolytes,	<i>Recent Advances in Textile and Electrochemical Sciences-2012</i> , held at Dept. of Industrial Chemistry, Alagappa University, Karaikudi, Tamilnadu,	March 22&23, 2012.

**Signature of Principal Investigator**

**Registrar**