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Effect of Viscous Solution of PEDOT: PSS on Thin Films

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Abstract: Highly conductive poly (3, 4-ethylenedioxythiphene): poly (styrenesulfonate) (PEDOT:PSS) films were obtained on polyethylene naphthalate (PEN) substrates by pretreating the solution of PEDOT:PSS by keeping in vacuum desicator. Before deposition of the films, oxygen plasma treatment was done on the substrates to increase the adhesion of the films and dimethyl sulfoxide (DMSO) was added in the solution to increase the conductivity of the films. The films were deposited by a spin coating technique and then annealed in air at 140 ^{o}C for 1h. Resistivity of the films was measured by four probe and surface morphology and surface roughness was measured by atomic force microscope (AFM). The films obtained from 5% DMSO added PEDOT:PSS solution show highest conductivity of 1171 S/cm and transparency more than 80% in the visible region. The results show that PEDOT:PSS can be a promising electrode material for flexible and transparent electronics.

Keywords: PEDOT:PSS, DMSO, Spin coating, Conductivity, Transparency PACS: 81

1. Introduction

During the last years, much attention has been given to the field of organic electronics due to its low cost, high flexibility, light-weight, and simple process. But the problem arises due to very low conductivity of solution- processable organic compounds compared with inorganic counterparts. The high resistance of the organic electrodes lowers the device performance and lifetime. Until now indium-tin oxide (ITO) has been widely used as the transparent electrode in flexible devices but its mechanical flexibility is limited and also it is becoming expensive due to rare material and high demand in a variety of applications. Thus, research is being focused to develop highly conductive and transparent organic-based electrodes to replace ITO.

Poly (3,4-ethylenedioxythiophene): polystyrenesulfonate (PEDOT : PSS) has been emerged as a promising electrode material in optoelectronic devices. It has many advantages such as high transparency in the visible range, excellent thermal stability, and aqueous solution processability over other conducting polymers. Although, commercially available PEDOT:PSS (Baytron P, Bayer Corporation) has a conductivity of less than 1 S/cm, recently, it is observed that the conductivity of PEDOT : PSS (PH-1000) films can be enhanced by three orders of magnitude by adding polyalcohols (alcohols with more than two OH groups on the molecule) or high dielectric solvents, such as dimethyl sulfoxide (DMSO) into the PEDOT : PSS solution[1-5].

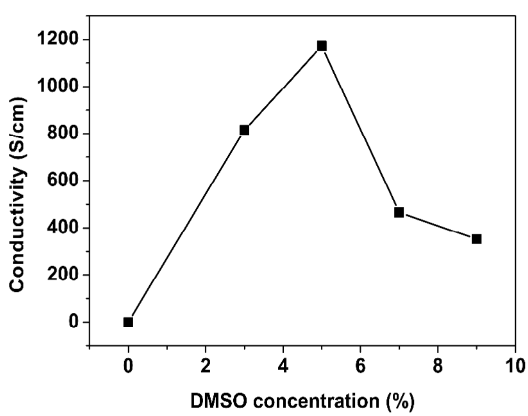

Figure 1. Conductivity versus DMSO concentration

There are several reports on the mechanism of enhanced conductivity of PEDOT:PSS due to additives but the subject is still under debate. To date, conductivities higher than 1100S/cm have been reported[6-9] by undergoing different processing steps. While PEDOT:PSS doped with additives shows somewhat lower conductivities[10] compared to the alternative processing steps. In this study, we obtain conductivities as high as 933 S/cm for PEDOT:PSS (Clevios PH1000) with the addition of 5% DMSO while conductivity of 1171 S/cm is obtained using a viscous

PEDOT:PSS solution with 5% DMSO. At the same time, there is markedly any change in transparency in the range from 500 to 800 nm in both cases (more than 80%).

2. Experimental Details

In this work, we adopted a different approach of keeping the as received PEDOT:PSS (Clevios PH1000, Heraeus Clevios GmbH, Germany) solution in vacuum desiccator for 30 minute. In order to increase the conductivity, DMSO was added from 0-9% (volume %) in PEDOT:PSS solution and mixed well before deposition. Films were deposited on PEN substrates by using spin coating method (4000 rpm, 40 sec) and after deposition, films were annealed at 140 ^{o}C for 1h in air. Before deposition of the films, the substrates were UV-Ozone treated for 1h in order to increase the adhesion of the films. After deposition, the resistivity of the films at room temperature was measured using four probe method and the transmittance study was done from UV-Visible spectra. The topographic image and roughness study was done by atomic force microscope (SEIKO (Japan), SPA400)

3. Results and Discussion

The viscosity of the as received PH1000 solution was 0.0148+/-0.0002 while the viscosity of the solution kept for 30 min in vacuum desiccator was 0.0497+/-0.0031. Contact angle measurement shows appreciable decrease in contact angle (from 82^0 to 13^0) due to UV-Ozone treatment. But the conductivity of both the films obtained from solution without any additive was below 1 S/cm. Films grown from more viscous PH1000 solution with 5% DMSO shows highest conductivity (from four probe measurement) of 1171 S/cm (shown in Figure
1) and the transmittance spectra (Figure 2) shows transmittance of more than 80% in the visible region in both cases.

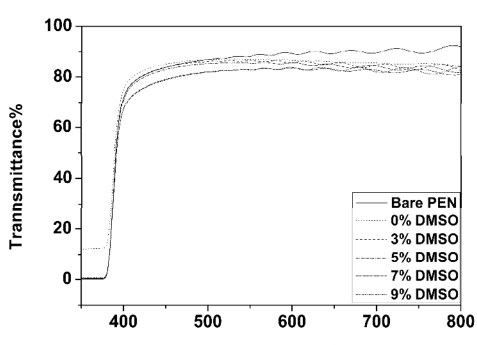

Figure 2. Transmittance Spectra of DMSO Doped PEDOT: PSS Films

Figure 3 shows the topographic image taken on 5 µm x 5 µm surface by atomic force microscopy which indicates granular connected network of the surface while the films with 5% DMSO have smoothest surface (rms roughness of 3nm).

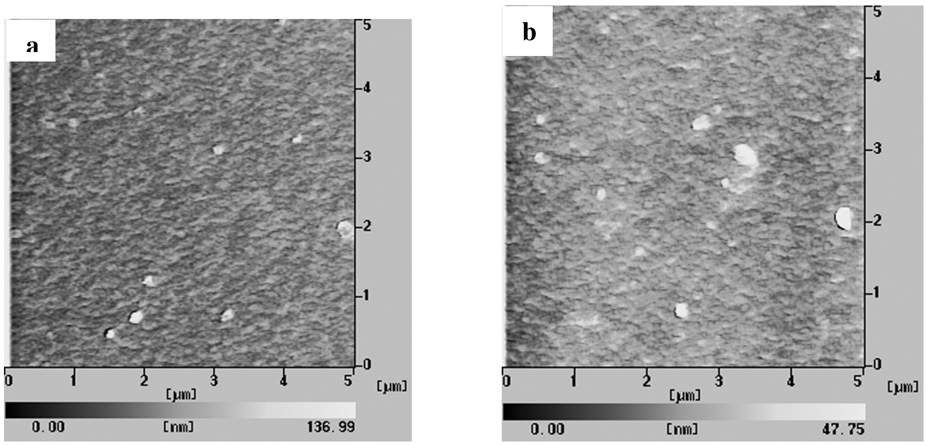

Figure 3. AFM Topographic Image of (A) 0% (B) 5% DMSO Doped PEDOT: PSS Films

It is known that due to addition of high boiling point solvent, there is re-ordering and conformational changes of the PEDOT:PSS polymer chains[11]. Along with this conformational changes, the removal of PSS may be the reason for enhanced conductivity in our case. In order to clarify this, more experiments have been conducted.

4. Conclusions

In conclusion, we reported high conductivity of 1171S/cm and transparency more than 80% in the films grown from viscous solution of PEDOT:PSS (PH1000) with addition of 5% DMSO on PEN substrates by using a spin coating technique. Along with reordering and conformational changes due to addition of high boiling point solvent, the removal of PSS may be the reason for enhanced conductivity. Hence, they look promising electrodes for optoelectronic devices.

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