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RESEARCH ARTICLE

OPTICAL PROPERTIES OF POLYMER/FULLERENE THIN FILM OF POLY (3, 4-ETHYLENEDIOXYTHIOPHENE)-POLY (STYRENESUIFONATE) PEDOT: PSS

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ABSTRACT

In this work the optical properties of the poly (3,4-ethylenedioxythiophene):poly (styrene sulfonate) (PEDOT: PSS) on glass substrate as interlayer and the effect of temperaturevariation on the optical stability was investigated. Measurement of the transmittance, absorption, extinction coefficient, reflectance, and band gap energy are used to study the influence of annealing on the optical properties of PEDOT: PSS thin film. The thin film had 70% transmittance at 550 nm.It is deduced that as the annealing temperature increases there is increase in absorption of photon energy. It also shows that transmission increases as the wavelength increases and decreases with increases in annealing temperature. As the annealing temperature increases the absorption increases and as the wavelength increases the absorption decreases.Observation shows that band gap energy reduces slightly as annealing temperature is increased from 80°C to 240°C. The band gap energy was approximately 3.7eV.

INTRODUCTION

For a variety of applications, poly (3,4 ethylenedioxythiophene) (PEDOT) doped with poly (styrene sulfonate) (PSS) is popular and has been intensively studied. A conducting polymer such as poly (3,4-ethylenedioxythiophene) doped with poly (styrene sulfonate) anions (PEDOT/PSS) is widely used in various organic optoelectronic devices. PEDOT: PSS is a blend of cationic polythiopene derivative, doped with a polyanion. High electrical conductivity and good oxidation resistance of such polymers make it suitable for electromagnetic shielding and noise suppression (Takeya Unuma, 2016). The polymer film was found to possess high transparency throughout the visible light spectrum and even into near IR and near UV regions. The major drawbacks of polymers like PEDOT: PSS are its acidity which negatively impacts device stability, as well as its organic nature (e.g., relatively poor chemical stability). It is important to study the impact of thermal treatment of PEDOT: PSSon the optical propertiesfor application as inter layer and as aHole transporting layer in organic solar cells.

EXPERIMENTAL METHODS AND MATERIALS

Glass slides of dimensions 25.4 mm by76.2mm were rinsed in de-ionized (DI) water. They were then placed in a beaker containing isopropyl (IPA) before cleaning in ultrasonic bath at room temperature for 30 mins.

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The cleaned glass slides were dipped in ethanol and dried in a stream of nitrogen gas (N_2). All glass slides received the same cleaning process.The solution of PEDOT: PSS was purchased from Sigma –AldrichCompany.This solution of PEDOT: PSS was deposited on pre- cleaned glass substrate using spin coatermodel laurel WS-650Hz-23NPP. Which were rotated at 4000 rpm for 30 secs at ambientcondition. Theprocessof coating to drying was repeated to obtain the desired thickness of the film. The films have approximately 35 nm thickness formed on glass substrate for UV/visible/NIR and Morphology characterizations. Filmswere annealed at different temperatures ranging from 80°C to 240°C for 1hr with Carbolite tubular furnance model Srw 21-501042 Type-CT17 and quenched to room temperature in argon gas to study the effect of annealing. One sample was not annealed which served as control sample.

Characterization

The optical transmittance of the samples was measured with Avantes UV-VIS spectrophotometer model-Avalight-DH-5-BAL. The transmittance spectrum is as shown in figure1 and figure 2 The absorption spectra for PEDOT: PSS thin films annealed at different temperatures is as shown in figure 3. It is deduced that as the annealing temperature increases there is increase in absorption of photon energy. It also shows that transmission increases as the wavelength increases and decreases with increases in annealing temperature. As the annealing temperature increases the absorption increases and as the wavelength increases the absorption decreases Optical transmittance measurement. Percent transmittance is the percentage of light that passes through (or is transmitted through) the sample. The optical transmittance of the samples was measured with Avantes UV-VIS spectrophotometer model Avalight-DH-5-BAL. Transmission increases with increases in wavelength and decreases with increase in annealing temperature. The transmission of the film is above 70% in this visible region. Mathematically A+R+T=1, A is the absorbance, R is the reflectance and T is the transmittance. To convert between the absorbance and transmittance, use the equation (1). Absorbance is the portion of light that gets absorbed by the sample

$$\text{Absorbance (A)} = 2.0 - \log_{(\%T)} \quad (1)$$

The absorption coefficient of thin film is calculated from the formula below (2) (Kumar, 2011).

$$\alpha = 2.303(A/t) \quad (2)$$

Where, A is absorbance and t is the thickness (Shakti, 2010). The absorption coefficient α and the extinction coefficient k are related by the formula (3)

$$K = \alpha\lambda/4\pi \quad (3)$$

Where, λ is the wavelength. The variation of extinction coefficient k with wavelength is shown in Figure 4

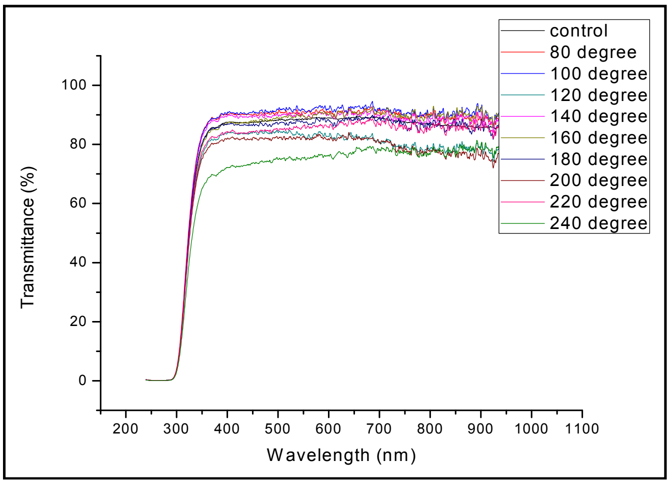

Figure 1. Plot of Transmittance vs Wavelength graph

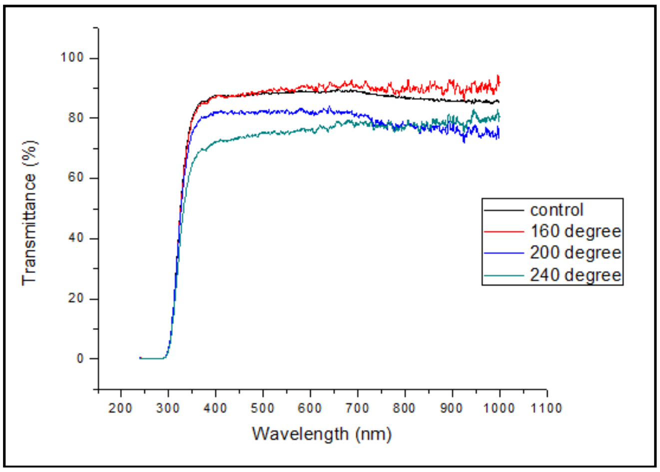

Figure 2. Plot of selected Temperatures of Transmittance vs Wavelength graph

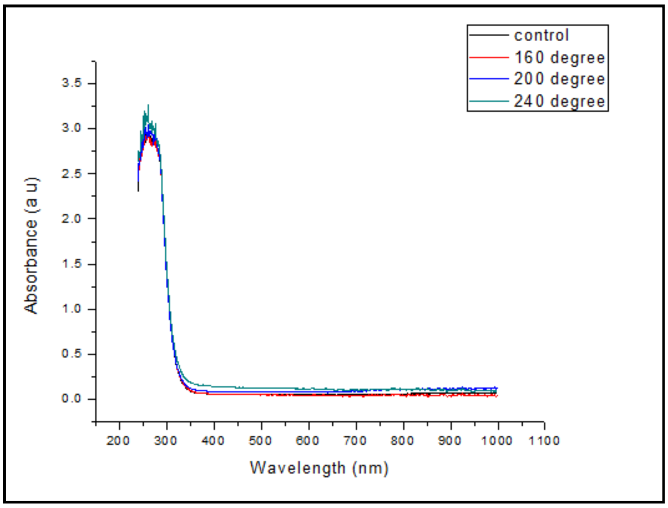

Figure 3. Plot of selected Temperatures of Absorbance vs Wavelength graph

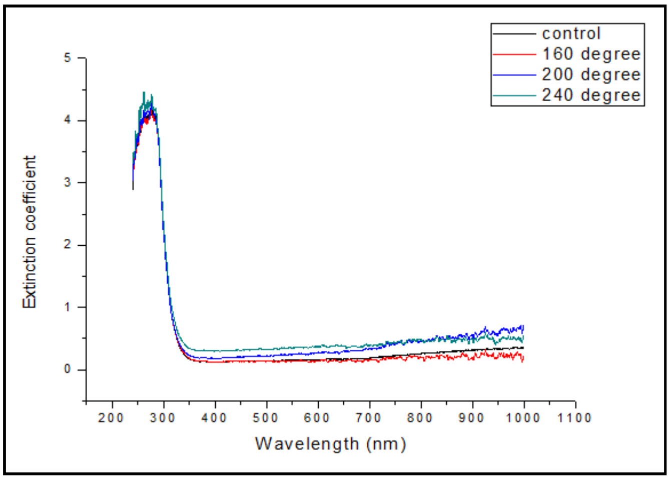

Figure 4. Plot of Extinction coefficient vs Wavelength graph

Optical Reflectance Measurement

Figure 5 to 6 showsthe reflectance.

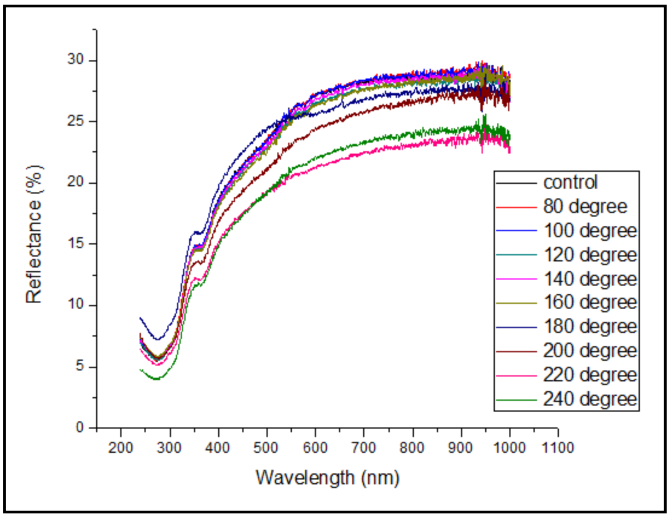

Figure 5. Plot of Reflectance vs Wavelength graph

Band gap Energy

$$Energy = h\nu = \frac{hc}{\lambda}$$

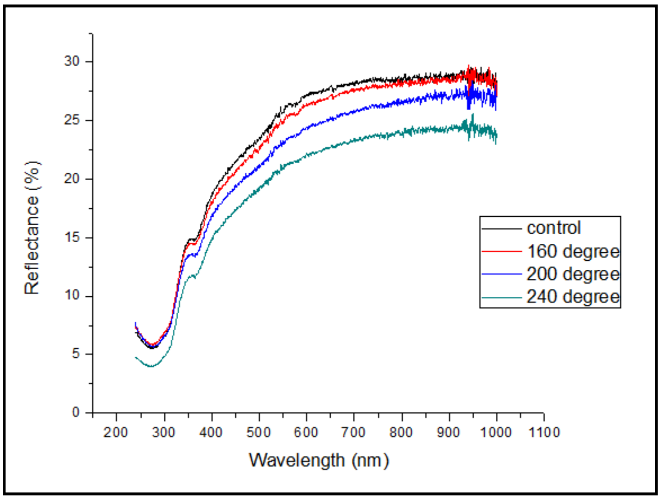

Figure 6.Plot of selected Temperatures of Reflectance vs Wavelength graph

The optical band gap energy Eg and absorption coefficient α is related by the equation (4) (Tauc, 1970).

$(\alpha hv)^2 = hv — Eg$ (4)

Where,α is the absorption coefficient and hv is the incident photon energy. Band Gap Energy (E) = hc/ λ where h = planks constant =6.626 x 10^{-34} joules sec. C= speed of light =3.0 x 10^8 meter/sec. where1ev =1.6 x 10^{-19} joules (conversion factor).]. For calculation of the optical band gap of films, the curve of $(\alpha h\upsilon)^2$ vs. hυ was plotted. The energy band gap was obtained from straight line plot of $(\alpha h\upsilon)^{2/}$ vs. hυ by extrapolating of the line to base line in Figure 7 to Figure 11.

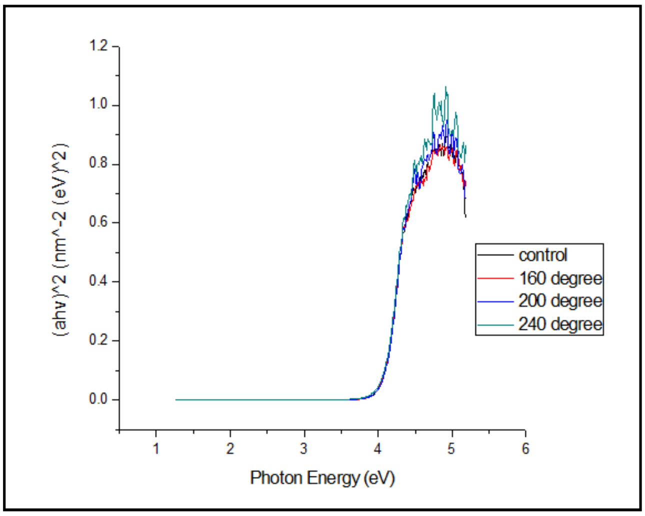

Figure 7. Plot of $(\alpha hv)^2$ versus hv for PEDOT:PSS thin films annealed at different temperature

RESULTS AND DISCUSSION

PEDOT:PSS thin films prepared on glass substrate by spin coating process and annealed at different temperatures from 80ºC to 240ºC step of 20^0C. It was observed that as the annealing temperature increases there is increase in absorption of photon energy. It also shows that transmission increases as the wavelength increases and decreases with increases in annealing temperature. As the annealing temperature increases the absorption increases and as the wavelength increases the absorption decreases. It was deduced that annealing temperature affects the optical properties of the PEDOT: PSS thin film.

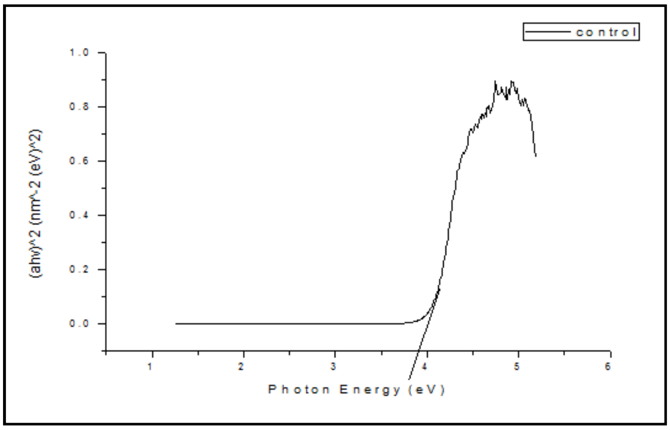

Figure 8. Plot of $(\alpha hv)^2$ versus hv for PEDOT:PSS thin film un-annealed

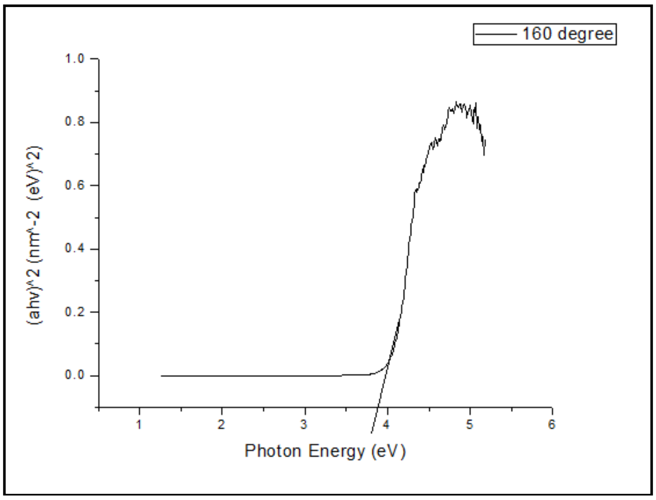

Figure 9. Plot of $(\alpha hv)^2$ versus hv for PEDOT:PSS thin filmannealed at 160 degree

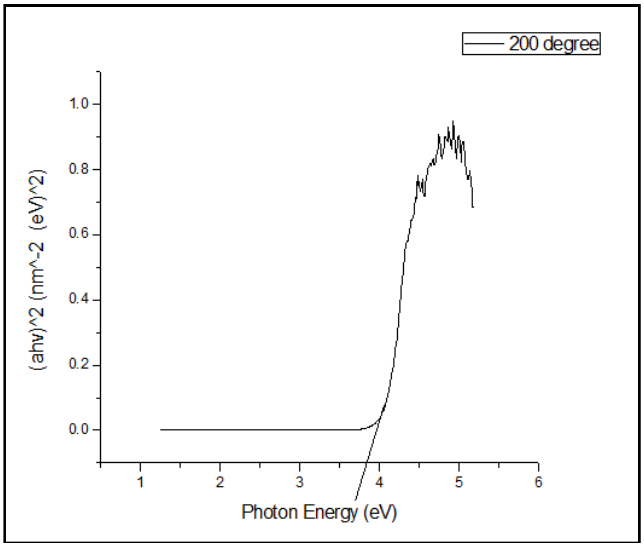

Figure 10. Plot of $(\alpha hv)^2$ versus hv forPEDOT:PSS thin filmannealed at 200 degree

The transmission spectrums of the films were recorded by UV-VIS Spectrophotometer.

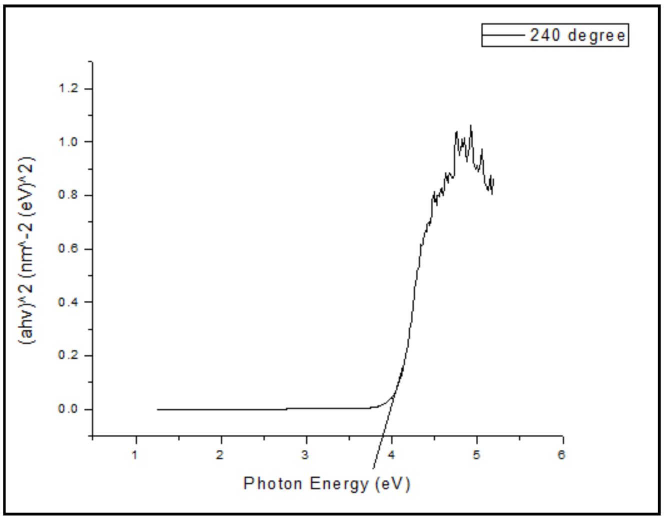

Figure 11. Plot of $(\alpha h\nu)^2$ versus hν for PEDOT:PSS thin filmannealed at 240 degree

The films showed high transparency in the visible region. Extinction coefficients were calculated. The extinction coefficient showed some variation with rise in annealing temperature of PEDOT: PSS films.

The Optical energy band gap values were obtained by plot of $(\alpha h\nu)^2$ versus hν. The value of band gap agrees approximately with the theoretical value.

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