Solid State Technology
Volume: 63 Issue: 6
Publication Year: 2020

Absorbance, Transmittance and Optical Energy Band Gap Studies of TSP: $NaNO_3$ Based Polymer Electrolyte

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Abstract**—** Solid bio-polymer electrolyte (SBPE) material film was synthesized from (TSP) Tamarind Seed Polysaccharide is doped with salt sodium nitrate ($NaNO_3$) by solution cast method. Energy band gap studies were observed from UV- visible absorption spectroscopy between 220nm-820nm. Optical transmittance, optical conductance is determined from optical absorption. The optical energy band gap is found from these optical parameters. Optical energy band gap changes from 5.01eV to 4.6 eV for various concentrations of TSP: $NaNO_3$. Some of the optical parameters like indirect bandgap and direct band gaps are extremely high and by increasing the dopant salt concertation to host polymer then these parameters are decreased gradually. Finally, the optical band gap of energy had obtained very low value for 70% TSP: 30% $NaNO_3$.

INTRODUCTION

The aim to synthesize a new biopolymer material membrane used in battery application as an electrolyte. By adding different dopant salt concentration to the host biopolymer material then the nature of the material changes gradually and is used in many applications. Biopolymer electrolytes are mostly used in the battery and cell applications[1-2]. Biopolymer electrolytes are used for cell application and utilized in many applications such as supercapacitors and energy storage devices. Biopolymer electrolyte material properties are enhanced due to changing the dopant concentration to the polymer material[3-5].

Tamarind seed polysaccharides (TSP) are obtained from tamarind seeds (tamarind Indica). It is dissolved totally in inorganic liquids such as sulfuric acid, ammonia, water etc. It is naturally obtained biopolymer and nowadays it is used in many eco-friendly applications[6]. By adding the dopant salt to this biopolymer, interaction changes between salt and polymer material and causes to improve the chemical, physical, electrical, and mechanical properties. Tamarind seed polysaccharides are available in gum or powder form and it is extracted from tamarind seeds. It contains monomers of galactose, xylose sugars, glucose present in a molar ratio of 2:1:3. It insoluble in organic liquids and completely soluble in inorganic liquids. TSP is utilized in medical, commercial, food industries[7]. Especially TSP is used in the special packing materials in food package sectors. TSP is a biodegradable polymer, so it is used for paper coating and in textiles industries[8]. By adding some more polymers with this polymer then chemical, physical, mechanical, optical, electrical, and thermal properties changes. Due to the compatible structure, TSP is used in different types of biodegradable related industries[9].

TSP biopolymer is doped with $NaNO_3$ in several concentrations, and their optical properties like optical absorption, optical energy band gap studies are observed. Optical absorption, energy band gap studies are comparatively affected by present processing conditions. The sparse amount of work has been done on this type of the biopolymer, so far and hence it has been chosen to undergo extensive investigation with this material [10]. Molecular structure of TSP is given in figure 1.

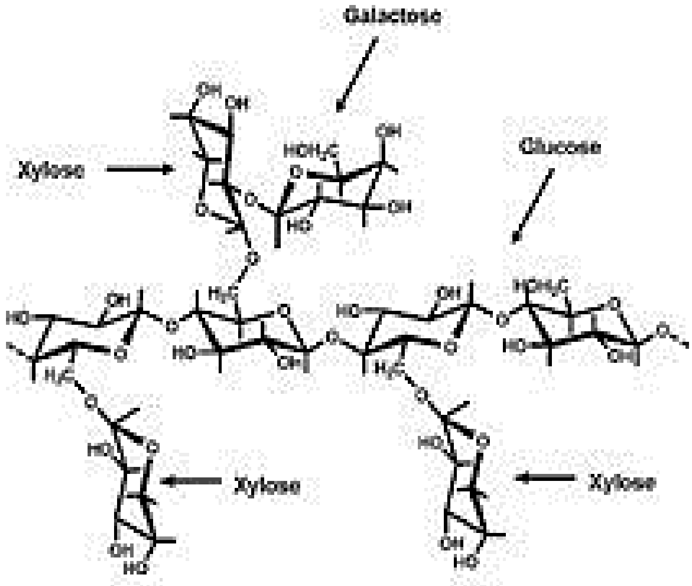

Fig.1. Molecular structure of Tamarind Seed Polysaccharides (TSP)

EXPERIMENTAL

Several wt.% ratios of TSP and $NaNO_3$ are mixed with double distilled water and a blend of these materials are stirred by magnetic stirrer at 60^0C for 12 hours. After stirring, the homogeneous solution is produced and was poured into polypropylene dishes, these dishes are kept in a vacuum chamber for 24 hours and maintained the temperature 60^0C. Water was evaporated slowly, and the semi-transparent membrane was formed. These biopolymer electrolyte membranes were removed from dishes then stored in a vacuum desiccator until for the further test. Optical energy band gap studies were getting from JASCO V-670 UV-VIS-NIR Spectrophotometer.

RESULTS AND DISCUSSION

Optical Absorbance

UV visible spectrum was produced from UV spectrometer at operating temperature and optical wavelength range 200nm - 900nm. Optical absorption studies are used to identify induced transition[11-12]. In present work, optical absorption is produced between 250 nm to 300 nm. Figure 2 signifies the optical absorption spectra of polymer electrolyte for pure and doped concentrations of TSP: $NaNO_3$. The number of electronic transitions is possible for biopolymer electrolytes. Energy band gap analysis and material structural were identified from optical absorption studies. No absorption (very less absorption) was found for a pure polymer material. Several wt.% salt concentrations are doped with host polymer material then optical absorption is improving gradually[13]. Similarly, in this present research, optical absorption was very less for pure biopolymer and optical absorption was enhancing gradually by increasing the dopant salt $NaNO_3$ to the TSP. Optical absorption value was maximum for 70% TSP: 30% $NaNO_3$ at 290 nm, from here by changing the salt concentration then again absorption also changes are represented here. The coefficient of optical absorption was achieved from the absorption value[14], the relation is given by

$$\alpha = \frac{2.303}{t} \times A$$

Where

A= Optical absorption data from the spectrometer

t= thickness of the film

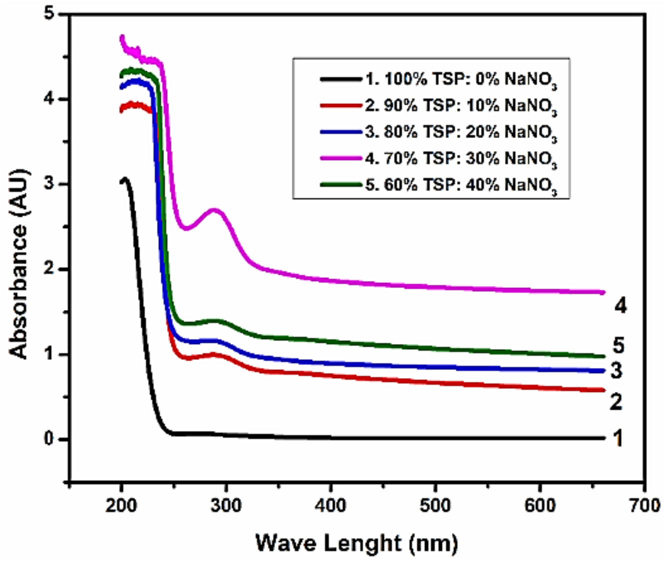

Fig.2. plot for optical absorption for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

Optical Transmittance:

Figure 3 represents the transmittance spectra for pure TSP and various concentrations of the salt $NaNO_3$ is taken from 200 nm to 800nm. A high value of optical transmittance was produced from pure polymer. The transmittance value decreases by increasing the salt concentration, these types of changes are occurring due to inter and intramolecular attraction between polymer and salt chain segments[15]. Initially, very small transmittance obtained at 259 nm then after high transmittance was observed for pure TSP. Transmittance becomes reduces by raising the salt concentration $NaNO_3$ and finally very less transmittance is obtained for 70%TSP: 30% $NaNO_3$. These types of changes are occurring due to the interaction between segments chains in biopolymers[16].

Transmittance value is produced from the absorbance and absorbance coefficient. The transmittance and absorbance coefficient relative formula is given below.

$$T = e^{\alpha t}$$

Where
α=Optical absorption coefficient
t=Thickness of the sample.

I.

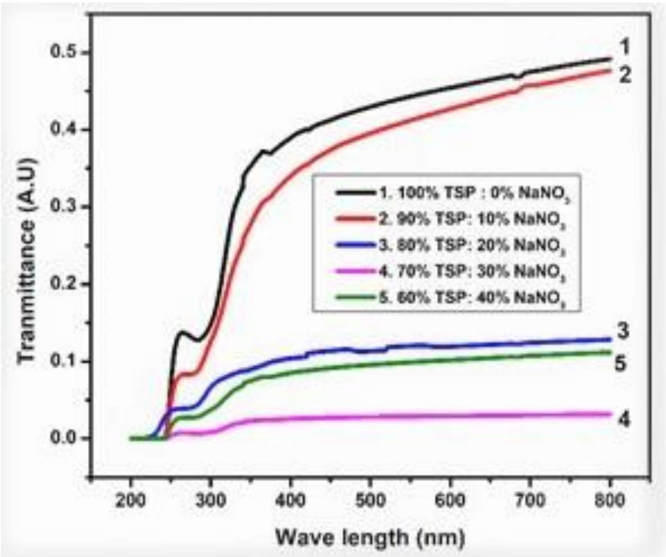

Fig. 3. Optical transmittance versus wavelength for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

Conductance

Optical conductance versus photon energy plot is represented in figure 4. The conductivity is always directly proportional to absorbance & refractive index of the material[17]. Dispersion occurred due to particles rotation and change of moment. Due to this dispersion, Conductivity is increasing gradually.

Initially, very low conductivity was observed for pure TSP. By increasing $NaNO_3$ concentration to pure polymer, conductivity had improved gradually and finally 70% TSP: 30% $NaNO_3$ has shown the highest conductivity value. Optical conductance has obtained from the refractive index & absorption coefficient of the material. Optical conductance is obtained from the relation[18].

$$\sigma = \frac{\alpha n c}{4\pi}$$

where
α= Optical absorption coefficient
n= Refractive index of the sample
c= Velocity of the light.

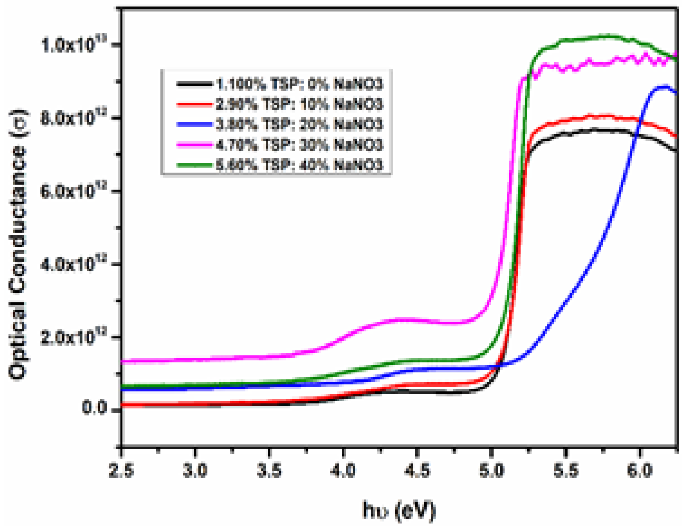

Fig.4. Optical conductance versus photon energy for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

Optical Energy Band Gap:

An optical energy band gap is one of the important parameters among all the optical parameter. The optical energy band gap of biopolymer electrolyte is found from absorption studies. On the base of direct & Indirect band gaps, materials are separated into semiconductors and insulators. Zero crystal momentum is observed in a direct band and it is not noticed in the indirect bandgap, but phonon momentum arises in the indirect bandgap. According to Shalliday and Davis, indirect & direct band values are recognized from plots drawn $(\alpha h\nu)^2$ vs. hν & $(\alpha h\nu)^{1/2}$ vs. hν respectiviely[19].

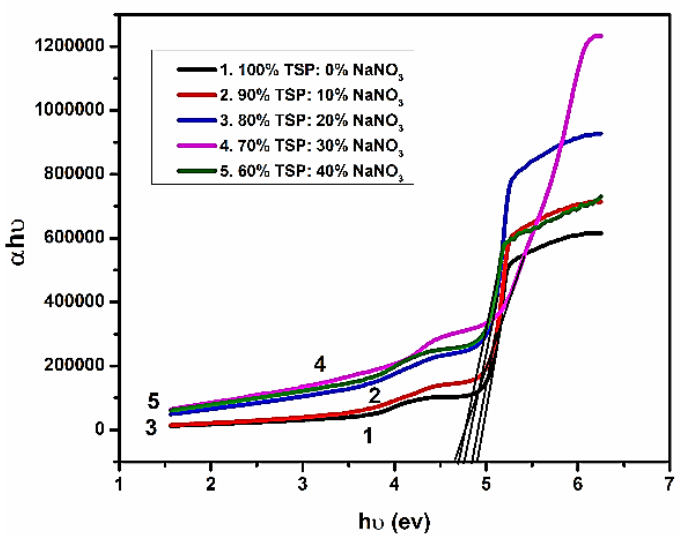

Fig.5. Plots of (αhν) versus (hν) for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

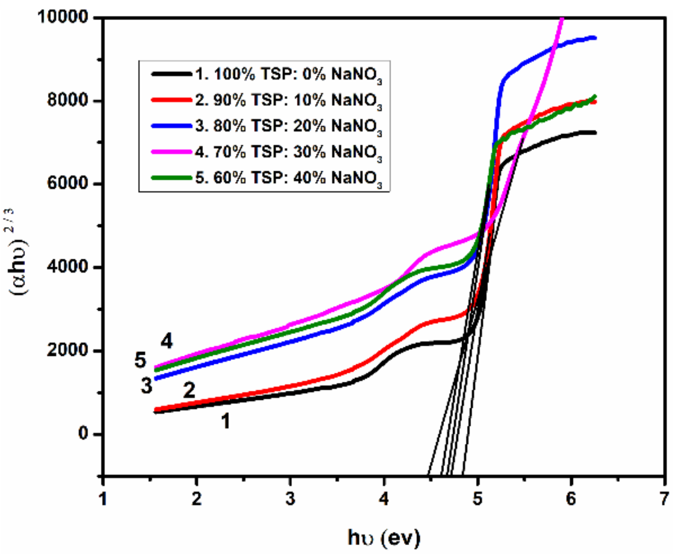

Fig.6. Plots of $(\alpha h\nu)^{2/3}$ versus (hν) for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

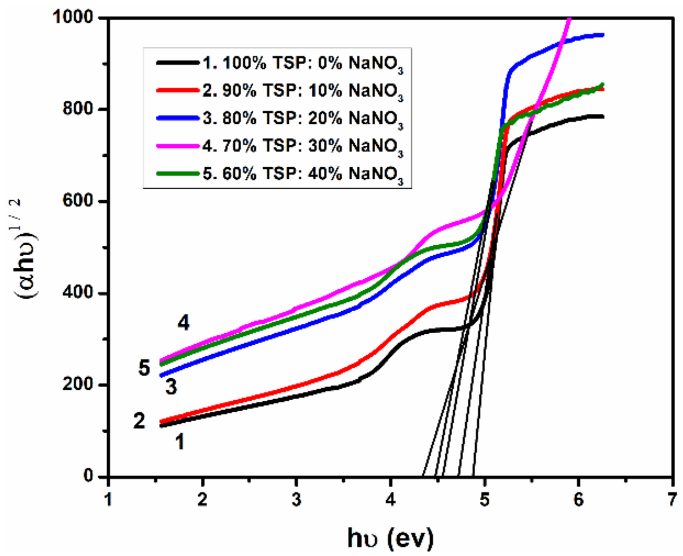

Fig.7. Plots of $(\alpha h\nu)^{1/2}$ versus (hν) for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

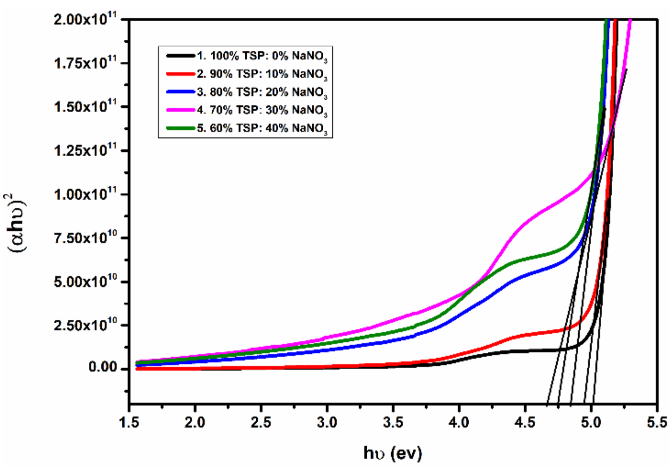

Fig. 8. Plots of $(\alpha h\nu)^2$ versus (hν) for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

The absorption band gap was found from the plot between (αhν) and (hν) is shown in figure 5. Different kinds of energy band gaps are obtained from plots between $(\alpha h\nu)^x$ and (hν). The linear segment of the curve 'hν' meet on the horizontal axis and it identifies the bandgap of the curve[20-21]. The optical energy bandgap for several concentrations is represented in table 1. Here it represents two types of energy band gaps, these are one is indirect energy bandgap & the second one is direct energy bandgap. In these plots, figure 6 represents an indirect band allowed transaction ($x={}^2/_3$), figure 7 represents indirect forbidden transition ($x={}^1/_2$) and figure 8 indicates the direct energy bandgap (x=2). Electron transition is possible in direct & indirect energy band gaps known as optical bandgap[23].

Here in this work, energy band gap 5.01 eV is detected for pure TSP, by raising the dopant of salt to a polymer. Energy bandgap for absorption band, indirect & direct bandgap are decreasing gradually[23-24]. A very low energy band gap is obtained for 70%TSP: 30% $NaNO_3$, from here again by changing the salt concentration to host polymer material then energy band gap is increasing gradually for the above-mentioned optical parameters. The data for all types of optical energy band gaps represented in table 1.

Table 1 Optical energy bandgap values for pure TSP & several wt.% ratios of TSP with $NaNO_3$ doped concentration

S. No	Composition	Absorption bandgap	Forbidden indirect bandgap	Allowed indirect bandgap	Direct bandgap
1	100% TSP: 0% $NaNO_3$	4.91	4.87	4.83	5.01
2	90% TSP: 10% $NaNO_3$	4.84	4.71	4.71	4.95
3	80% TSP: 20% $NaNO_3$	4.75	4.56	4.64	4.84
4	70% TSP: 30% $NaNO_3$	4.64	4.33	4.47	4.65
5	60% TSP: 40% $NaNO_3$	4.71	4.47	5.59	4.74

Conclusion

In present research work, solid biopolymer electrolyte (SBPE) films are synthesized from TSP: $NaNO_3$ (100:0, 90:10, 80:20, 70:30, 60:40 wt.% ratios) by solution cast method. Optical parameters are obtained from optical absorption data which is produced from UV-spectrometer. For pure polymer, optical absorbance is very high & optical transmittance is very low. By raising the salt concentration to the pure polymer in several ratios, then the low value of absorbance and the highest value of transmittance had occurred for 70% TSP: 30% $NaNO_3$. An optical energy band gap is depending upon the transition activity of photon energy. The energy band gap is high for pure polymer and by adding salt to this host then energy bandgap reduces progressively. Finally, it is recognized that by rising the dopant salt $NaNO_3$ content to biopolymer TSP then the indirect & direct bandgap is decreasing gradually. The least value of energy bandgap has observed for 70% TSP: 30% $NaNO_3$.

Acknowledgement

I would like to thank the department of science and Technology (DST, Delhi), Govt of India for the award of DST-FIST Level-1(SR/FST/PS-1/2018/35) Scheme to the Department of Physics, KLEF. Thanks to the KLEF offering infrastructure resources (Perform basic instruments) and encouragement to carry out the research.

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