

## Synthesis and Study of Electrical Conductivity of Cinnamic Acid doped 1:2 (PS+PMMA) Polyblend thin films.

<sup>1</sup>R. V. Joat, <sup>1</sup>A. S. Wadatkar, <sup>1</sup>T. S. Wasnik, <sup>2</sup>P. S. Bodkhe,  
<sup>2</sup>S. Binani, <sup>1</sup>R. M. Agrawal

<sup>1</sup>Department of Physics, Vidya Bharati Mahavidyalaya, Amravati (M.S.)- 444 602, India  
<sup>2</sup>Department of Chemistry, Vidya Bharati Mahavidyalaya, Amravati (M.S.)- 444 602, India

E-mail : rvjoat@rediffmail.com

### Key-words:

PS+PMMA,  
electrical conductivity,  
cinnamic acid.

**Abstract:** In the present investigation, thin films of Cinnamic acid doped 1:2 (PS+PMMA) polyblend were prepared by using isothermal evaporation technique . DC electrical conductivity have been measured at different temperature. In 1:2 PS+PMMA polyblend, conductivity increases with,

- Increase of temperature
- Increase of Electric field
- Increase in the percentage of dopant Cinnamic Acid.

Rise in electrical conductivity ( $\sigma$ ) upto 4% of Cinnamic acid is less marked while electrical conductivity ( $\sigma$ ) increases very remarkably as the dopant percentage is increased from 4% to 8%.

### 1) INTRODUCTION

The d.c. electrical conductivity studies are aimed at understanding the origin of the charge carrying species, their numbers and ways in which they move through the bulk materials. These parameters are related with the morphology, microstructure and chemical compositions of the materials (Seanor, 1982) [1]. For thin films, the mechanisms generally discussed are tunnelling, Schottky, Poole-Frenkel emission (Rao, Reddy *et al.*, 1991)[2] (Bahri and Seth, 1997) [3] and Space Charge Limited Conduction (SCLC) (Sessler, Hahn and Yoon, 1986) [4]. The depolarising current increases with the increase in the percentage of PMMA (Keller, Dubey and Datt 1991)[5].

The electrical conduction in regenerated cellulose film (cellophane) was studied by Bhat and Makwana (1987) [6].

Materials such as polyethylene, polystyrene finds an extensive usage as an electrical insulator. PS is a non-polar, low loss polymer and hence has desirable electric properties for the use in the insulation (Chutia and Baru, 1981) [7]. PMMA is hard, rigid, transparent thermoplastic, which has good weather-ability. PMMA is weakly polar (Blythe, 1979). The blends PS/PMMA doped with iodine (Belsare and Deogaonkar, 1998) [8] and PNA (Waghmare *et al.*, 2007) [9] have been studied earlier. The present study is aimed at finding the effect of proportion of PMMA and percentage of dopant Benzoic Acid (BA) on the dc electrical conductivity of PS/PMMA polyblend thin films by applying electrical field in the range 50V-700V at various thermostatically controlled temperatures in the range 323 K -373 K.

These parameters are related with the morphology, microstructure and chemical compositions of the materials. Both Ps and PMMA being extensively studied polymers having a great range of applications. It was hoped that the doping of Cinnamic Acid in polyblends of 2:1 PS and PMMA would lead to some new results.

## 2) MATERIAL AND METHODS :

### Method of preparation of undoped blend film

1 gm of PS and 2 gm of PMMA were dissolved in 30 ml of benzene (solvent) in glass bottle amber in colour. Before this the bottle was cleaned by using Acetone. The solution was kept steady for 3 to 4 days in order to get fully homogenous mixture solution. The solution was also heated 40°C for 2 to 3 hours. This heating insured the completely homogenous solution. The solution was then poured on a cleaned, transparent, plane glass plate (substrate) placed on the pool of mercury in a plastic tray.

After 2 to 3 days the film of pure PS + PMMA was removed from the glass plate.

Method of preparation of film using dopant

The 4%, and 8% of cinnamic acid (dopant) means 0.12 gm and 0.24 gm, were taken and dissolved in the mixture of 1: 2 PS + PMMA solutions.

After getting homogenous solution the same procedure was repeated to prepare the films.

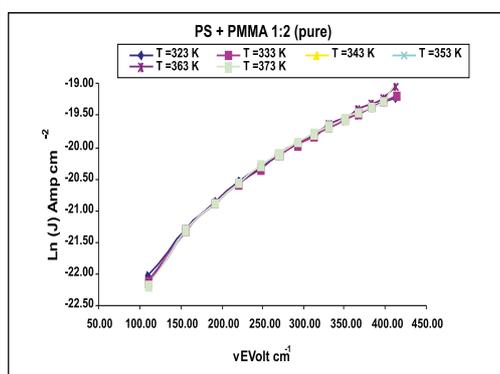
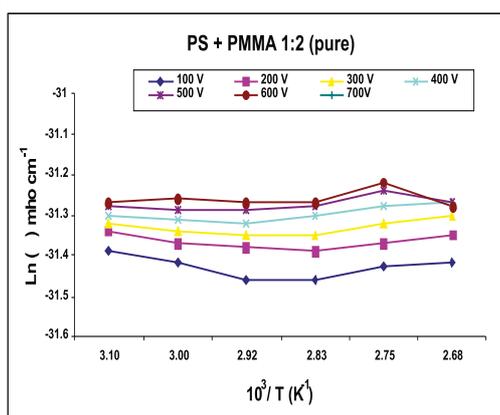
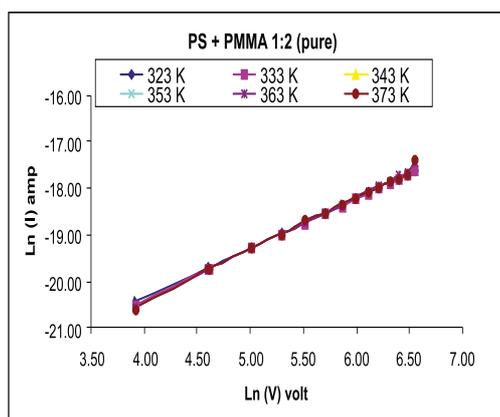
Thus, the present study has been carried out with the following samples:

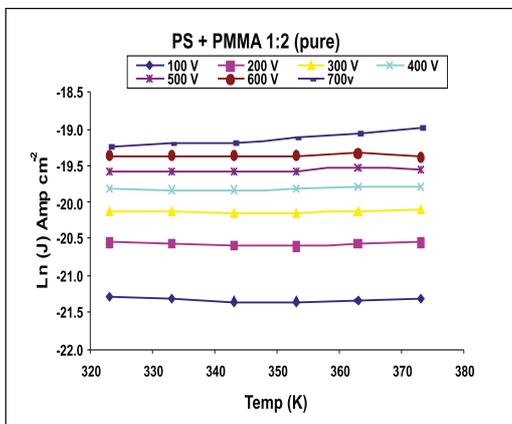
- 1) PS + PMMA + 0% CINNAMIC ACID
- 2) PS + PMMA + 4% CINNAMIC ACID
- 3) PS + PMMA + 8% CINNAMIC ACID

The thickness of the films was measured by digimatic micrometer (Mitutoyo Corporation, Japan). The film was kept in between the electrodes of specially designed sample holder. The I-V measurements were done by using high voltage power supply EHT 11 and Pico-ammeter DPM 111 supplied by Scientific Equipments, Roorkee. Mastech k-type (MS 6500) digital thermometer (with

accuracy 1°C) was used to measure the temperature.

## 3) Results:





#### 4) Discussion:

##### Behaviour of Electrical Conductivity:

Fig show the variation of electrical conductivity ( $\sigma$ ) with respect to the concentration (doping percentage) of dopant Cinnamic Acid at the temperatures 323 K, 343K and 363K respectively.

These graphs reveals, the most important finding of the present work..

The electrical conductivity ( $\sigma$ ) does not increase significantly as the dopant CA is increased from 0 % to 4%. But when dopant percentage is increased beyond 4 % the electrical conductivity ( $\sigma$ ) increases very sharply with the percentage of doping.

Over the entire range of temperature (323 – 373 K) and applied voltage (50-700 V) the electrical conductivity ( $\sigma$ ) for all the samples have been to vary between order of  $10^{-14}$  ( $\text{ohm cm}^{-1}$ ) to  $10^{-13}$  ( $\text{ohm cm}^{-1}$ ).

##### Behaviour of Current Density:

- For the undoped sample PSPMMACA(0), the current density (J) rises very marginally with temperature at the given applied voltage but it considerably in increase with applied voltage at constant temperature.
- For the sample doped with 0% of Cinnamic acid [PSPMMACA(2)], the rise of current density with respect to

temperature is slightly more significant than the previous case and rise with respect to voltage is highly significant.

- For the sample 1:2 PS+PMMACA(4), initially there is a decrease in the value of J with the increase of temperature but then afterwards it maintains almost constancy.
- For the sample 1:1 PS+PMMACA (8), there is more significant rise of J with respect to the increase of temperature as well as applied electric field

In the present study at the highest temperatures 373 K at the highest voltage 700 V the rate of increase of conductivity ( $\sigma$ ) with respect to Cinnamic acid CA percentage is highest. These observations suggest that at higher fields and temperature the rate of rise of current density (J) and conductivity ( $\sigma$ ) is sharper than at lower fields and temperatures. This can be understood by considering the effect of temperature on the dopant.

Ideally, the production of  $\text{H}^+$  ions (or Protons) by heating Cinnamic acid CA should occur at  $133^\circ\text{C}$  (408 K) when no other mode of activation or catalyst is applied.

In the present case, Cinnamic acid CA has been doped in to the 1:2 PS – PMMA blends samples and the sample was heated under the influence of strong electric voltage that varied between 50 V to 700 V. This could be the cause for the occurrence of ionization below the melting point  $133^\circ\text{C}$ . This has been observed in the increase of electrical conductivity at higher temperature and higher voltage.

The heating of Cinnamic acid CA releases proton ( $\text{H}^+$ ) ions. Therefore, the availability of ions increases at higher electric fields and temperatures. The increase of electric field also enhances the mobility of thermal generated carriers. As a result, there is an increase in the current (I), current density J and conductivity ( $\sigma$ ). The reason for the increase of conductivity ( $\sigma$ ) with the increase of the percentage of the dopant Cinnamic acid CA can also be explained. The Cinnamic acid CA has a

carboxylic group (-COOH) which is electron attracting. It attracts the electrons from the Phenyl group of polystyrene (PS) which is an electron donor, this enhances the possibility of the formation of the charge transfer (CT) complexes when Cinnamic acid (CA) is doped in 1:2 PS/PMMA polyblends. Release of excited charge carriers in these dominates the conduction process. As a result of these, we noticed a relatively less rise in the value of electrical conductivity when the doping percentage is low up to 4% but there is a remarkable rise of conductivity 4% onwards to up to 8%. When a dopant is present in low concentration, the dopant's molecules give rise to additional molecular sites for the trapping of charged carriers. Such localized sites formed by dopant molecules can be defined in molecular terms using the difference in ionization potential as an indication of trap depth. As the dopant concentration is increased, the dopant molecules start bringing the gap between the two localized states and lowers the potential barrier between them. This lowers the potential barrier and enhances the transfer of charge between the two localized states.

Besides the thermal generation of charged carriers within material itself there is also an injection of charged carrier from the electrode. These charge carriers considerably increase the conductivity. The introduction of localized states due to doping facilitates the injection of charge carriers from the electrode because the injection takes place via localized states. Among the two polymers PS is non-polar and PMMA is weakly polar. We have noticed that activation energy ( $E_a$ ) is higher in LTR than that in the HTR. Further the activation energy  $E_a$  almost decreases with the increase of applied voltage at the given temperature. This can be understood as follows.

The glass transition temperature  $T_g$  of PS is  $95^\circ\text{C}$  and that of PMMA is  $105^\circ\text{C}$ . In LTR (below  $T_g$ ) the samples are known to be in glassy state and in HTR above  $T_g$ , they are in rubbery state. The glassy state, the chain back-bones are highly immobilized and the motion of long chain is not possible. As

a result of this high energy of activation is needed in the LTR. At higher temperature (around  $T_g$ ) it goes into rubbery state and the conductivity is found to increase very sharply. As the rise in temperature rises some of the hydrogen bonds in the polyblend matrix may be broken and protons may be transferred between neighbouring chains. When the rubbery state is fully reached the chain back-bones become highly mobilized. This leads to the motion of long chain and transfer of ions (Protons between neighbouring chain). As a result of this low energy activation is needed by the charge carrier in HTR.

At the higher electric field the transportation of charge carrier is facilitated due to availability of energy  $eV$ . As a result of this, the  $E_a$  decreases with the increase of electric field.

#### 5) Conclusions:

In 1:2 PS/PMMA polyblend, conductivity increases with,

- Increase of temperature
- Increase of Electric field
- Increase in the percentage of dopant Cinnamic Acid.

Rise in electrical conductivity ( $\sigma$ ) up to 4% of Cinnamic acid is less marked while electrical conductivity ( $\sigma$ ) increases very remarkably as the dopant percentage is increased from 4% to 8%.

Range of variation of electrical conductivity ( $\sigma$ ) suggests that the doped polyblends are predominantly insulators.

They demonstrate semiconducting properties in a sense that the electrical conductivity ( $\sigma$ ) increases, though very poorly with temperature.

#### REFERENCES:

- [1]. Seanor D. A. (1982); "*Electrical properties of polymers*", Chapter 1, (Academic Press, New York).
- [2]. Rao Vijayalakshmi, Ashokan P.V. and Shridhar M. H. (2000).; *Material Science and Engg.*, (Elsevier),

- A281, 213-220.
- [3]. Bahri R. and Seth R. K. (1997); Indian Journal Pure and Applied Physics, Vol. 35, 104-108.
- [4]. Sessler G. M, West J. E., Berkley D .A. and Morgenstern G. (1980); Phys. Rev. Lett., 38 , 368.
- [5]. Keller S. S. Dubey J. M. and Dutt S. C. (1991); Indian Journal of Pure and Applied Physics, Vol. 29, 150-52.
- [6]. Bhat N. V. and Makwana D. N. (1987); Indian Journal Pure and Applied Physics, Vol. 25, 402-406
- [7]. Chutia Jand Barua K(1981); Indian Journal Pure and Applied P h y s i c s , Vol. 19, 1210-12.
- [8]. Belsare N. G. and Deogaonkar V. S. (1998); Indian Journal Pure and Applied Physics, Vol. 36, 280-89.
- [9]. Waghmare R. V., Belsare N. G., Raghuwanshi F. C. and Shilaskar S.N. (2007); Bulletin of Material Science, 30(2), 167-172.