

DC Conductivity and Mechanical Properties of Poly(Vinyl Chloride)/ Poly(Ethyl Glycol) Blends

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Abstract—PVC in PEG blends were prepared by using solvent casting method in various weight percentages. The prepared blends were characterized by FTIR and SEM for structural and surface morphology study. Further, the DC conductivity was studied by two probe method and found that the 6 % of PVC – PEG blends shows high conductivity of $4.4 \times 10^{-8} \text{ Scm}^{-1}$. This increase in conductivity may be due to the extended chain length of blends, which is confirmed by the negative thermal coefficient graphs. The PVC with PEG blends enhances the mechanical strength and modulus property as the percentage of elongation increases up to ~720, hence these polymer blends can be used in many applications like solar cells and gas sensor encapsulation device, low k – dielectric materials, food packing and other electronic devices

Keywords: PVC, Blends, Tensile strength, Modulus, Surface morphology

1. INTRODUCTION

Polymer blends, that is, physical mixture of structurally different polymers which interact with secondary forces such as hydrogen bonding with no covalent bonding. Polymer blends have been widely used in the industry because of their ability to combine in a unique material with the properties of their components, at a relatively low cost when compared to the development of a new polymer. It is well-known that the properties of polymer blends are greatly influenced by the morphology that is developed during the mixing process [1]. The physical properties of polymer blends are controlled generally by many factors such as the nature of polymer [2], blend composition [3] and interfacial properties such as interfacial adhesion [4 - 6] and dispersed phase size and shape which are developed during solution blending. Likewise, the morphology of ternary blends is also influenced by thermodynamics and kinetic factors. In comparison with binary blends, ternary polymer system can be viewed technologically as the next generation in multiphase polymers [7]. The fundamental aspect of the ternary polymer blends, have substantial commercial significance as adhesives and coating materials [8]. The addition of plasticizer to the PVC formulation decreases many mechanical properties such as

hardness, tensile strength, modulus, etc. of PVC product [9]. However, low temperature flexibility, elongation and ease of processing are all improved.

In general, plasticizers are solid with relatively low melting point or liquid with relatively high melting point. They are well dispersed among plastic polymer molecules and polar group of plasticizer interact with counterpart of polymer molecules by supramolecular force, which is commonly considered as dipole-dipole interaction. The non polar sections of the plasticizer segregate polymer molecules and reduce the interactions between them. As a result, the mobility of polymer molecules are increased, which is especially helpful to processing. Poly(vinyl chloride) (PVC) is one of the most common commodity plastics, which has been widely used in the automobile, building construction, packaging fields, etc., because of its low cost, easy method of preparation, and the broadening of the properties range [10]. PEGs has many industrial applications like lubricants, binders, carriers, solvent, and coatings in the cosmetics, pharmaceutical, paper, food, textile, and chemical speciality field. The essence of plasticization is to enhance the conductivity of solid polymer electrolytes using low molecular weight and high dielectric constant additives such as polyethylene glycol (PEG) ethylene carbonate (EC), propylene carbonate (PC) etc. [11, 12]. These additives increase the amorphous content of the polymer matrix and tend to dissociate ion-pairs into free cations and anions thereby leading to an overall enhancement in conductivity. However, to the best of our knowledge, only a very few reports are available in the literature which discuss the combined effect of the PVC and the plasticizer PEG as polymer blends [13 - 15]. Therefore, the Authors made an attempt to study the conductivity and mechanical property of PVC – PEG blends.

2. EXPERIMENTAL DETAILS

2.1. Materials and Methods

Poly (vinyl chloride) procured from Sigma Aldrich and poly (ethylene glycol), Himedia, having molecular weight 3500-4000, and tetrahydrofuran (stabilized with 0.1% quinol)

obtained from Si chemical Pvt Ltd were used as received without further purification.

2.2. Characterization

The above synthesized PVC and PVC - PEG blends were characterized by using Fourier transform infrared spectroscopy (FTIR), the surface morphology of the composites were studied using scanning electron microscopy (SEM).

The FTIR spectra of PVC and its blends were recorded on Perkin Elmer (model 783) IR spectrometer in KBr medium at room temperature. For recording FTIR spectra, sample powders were mixed with KBr in the ratio of 1:25 by weight and grounded to ensure the uniform dispersion of samples in KBr pellets. The mixed powders were pressed in a cylindrical dye to obtain clean discs of approximately 1 mm thickness [16].

DC conductivity was measured by using two probe method with Keithly 2100 electrometer to measure the resistance of the blends. The samples were prepared in circular disc of 10 mm diameter and 1 mm thickness by pressing with hydraulic press (De – Luxe Trading Company, India. Ltd). The pellets were coated with silver paste on either surface for better contact between electrodes and sample surface [17]

The tensile properties of PVC and PVC – PEG blends films for different weight percentages (2, 4, 6, 8 and 10 wt %) were measured with a universal testing machine (Instron-5543) under a 1 kN load cell at a constant cross-head speed of 3 mm/min. At least five specimens were tested for each sample, and the tensile properties are measured on an average.

2.3. DC conductivity

The DC conductivity of the poly (vinyl chloride)/ poly (ethyl glycol) blends was studied at various temperatures from 35 to 250 °C as shown in Fig. 1. It is observed that the conductivity increases with increase in temperature as well as the increase in PEG concentration in the polymer matrix. The observed conductivity increases with three steps similar to Nevl Mott semiconductor theory [18]. It is observed that initially conductivity is constant up to 140 °C, after that, it gradually increases with increase in temperature till 160 °C and then exponentially increases up to 250 °C. The conductivity increase with increase in PEG concentration which may be due to the increase in the charge carriers from the PEG and elongation of polymer blends. Among all the blends, it is found that 6 wt % shows the high conductivity of $4.32 \times 10^{-8} \text{ Scm}^{-1}$ which may be due to the higher activation that significantly affecting the charge transport properties in polymer blends. The degree of elongation of polymer blends can be estimated from negative thermal coefficient (α) of the PVC/PEG blends is shown in Fig. -2 as a function of various weight percentages of PEG. Generally the negative thermal coefficient (α) refers to blends that display decrease in the electrical resistance with increase in dopant concentration. It is

observed that the negative thermal coefficient (NTC) increases with increase in PEG weight percentage in PVC indicates that there was decrease in electrical resistance due to the extended chain length of the polymer on increase in temperature [19, 20]. It is also observed that there is a small change in the thermal coefficient values among blends, on increasing temperature as well as PEG concentration. The α value linearly increases with increase in dopant concentration up to 6 wt % after that its value decrease.

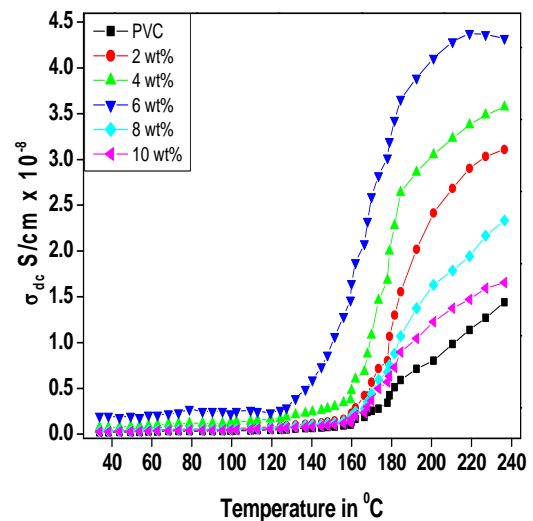


Fig. 1: DC conductivity of PVC and its blends as a function of temperature

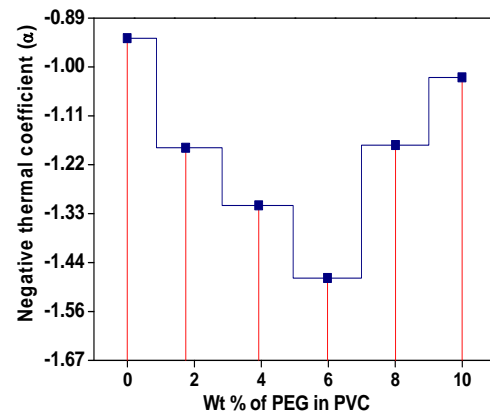


Fig. 2: NTC plot of various wt % of PEG in PVC

2.4. Mechanical property

The stress–strain curves of PEG loaded in PVC with different concentrations are illustrated in Fig. 3. These curves are

typical of elastomeric materials, with no well-defined yielding point and a long plastic flow region. At low strains, the kinetic theory holds. At large deformations, there is limited extensibility of the cross linked chains. Meanwhile, there is a stress softening effect at moderate strains [21]. Authors showed strain-independent regions at very low strain values. Loadings of PVC up to approximately, less than 6 wt % do not affect the values of E. In this region, no any reactions are present between PEG and PVC. Slight increase in E is observed at concentrations between 2 to 6 wt % which may indicates the formation of weak Vander Waal bonds. A sharp increase is observed at concentrations of PEG up to 6 wt % after that its value decreases. Such a trend indicates that incorporation of PEG into PVC increases the stiffness of the blend.

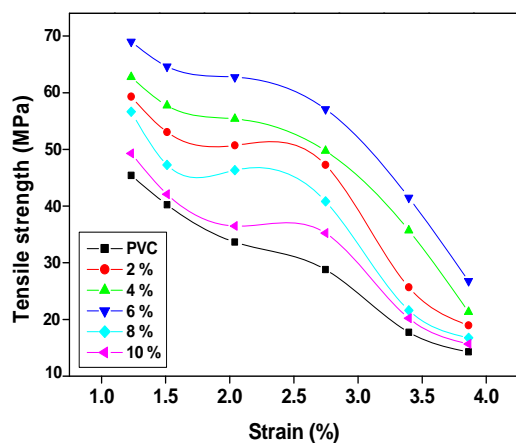


Fig. 3. Tensile strength of PVC – PEG blends at constant loading

3. CONCLUSION

The films of PVC – PEG blends were prepared by solvent casting method. The conductivity of the PVC – PEG blend increases with increase in temperature as well as PEG wt % up to 6%. This increase in conductivity is due to the extending chain length of polymer found in NTC plot. Among all composites 6 wt % is having high conductivity of 4.4×10^{-8} S/cm. Tensile strength decreases with increase in PEG content in the PVC matrix, but the flexibility of these blends significantly enhance. Therefore, these blends can be used in many technological applications such as low- κ dielectric materials, packing materials, encapsulation of solar cell and sensor devices etc.

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