

Structural and Morphological Characterization of Poly (Phenylene Oxide): Poly (Styrene) Polymer Blends

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Abstract— The objective of this work is to study the structural and morphological characteristic of polymer blends of Poly (Phenylene Oxide) (PPO) and Poly (Styrene) (PS). The Polymer blends of Poly (Phenylene Oxide) (PPO) and Poly (Styrene) (PS) has been prepared using solution cast technique. The pure polymeric samples and their blends of various weight proportions of 95:05; 90:10; 85:15; and 80:20 has been prepared. The PPO/PS blends were characterized by using Fourier transform infrared spectroscopy (FTIR), SEM and X-ray diffraction (XRD) techniques. The molecular bond nature of pure polymer samples and their blends has been studied which shows the good compatibility between the polymers. On the basis of XRD studies, interplanar distance, crystallite size and order of crystallinity has been determined. It is found that as the concentration of PPO increases, the interplanar distance and crystallite size and the order of crystallinity increases. The SEM micrograph exhibits a dense and more ordered structure of PPO/PS blends.

Key words: Poly (Phenylene Oxide) (PPO), Poly (Styrene) (PS), FTIR, XRD, SEM

I. INTRODUCTION

In recent years, there has been a huge interest in studying the multiphase polymer blends due to the possibility of simultaneously exploiting the attractive features of component for technological applications along with making an understanding of the phase immiscibility for these polymeric systems [1].

Polystyrene (PS) and Polyphenylene oxide (PPO) constitute one of the important and explored polymer blend system. PPO is known as a good engineering polymer with superior mechanical properties and good miscibility with PS [2, 3]. A combination of polymers is increasingly found to meet the specific property requirements of new end uses. Very few polymers are known to be compatible with each other in nature. Poly (2,6-dimethyl-1,4-phenyleneoxide) (PPO) and Polystyrene (PS) form a pair of such polymers found to be compatible in melts[2, 3]. PPO is one of the aromatic glassy polymers having a high glass transition temperature and a high permeability to gases due to the absence of polar groups in the polymer backbone. Mixtures of PS and PPO have been investigated with regard to their high thermal [4,6] and mechanical [7,8] properties. The phenyl rings make PPO hydrophobic and resistant to a number of chemical reagents including acids, bases, and alcohols. A valuable reference on poly(phenylene oxide) and modified poly(phenylene oxide) membranes is the recent published book by Chowdhury et al. [9]. The studies related to the structural and morphological aspects of PPO:PS blends thus becomes significant to develop them for specific properties.

II. EXPERIMENTAL

The material used in the present investigation Polyphenyleneoxide (PPO) and Polystyrene (PS) were obtained from M/S Fine CHEM Industries, Mumbai. Blend films about 20 to 90 micrometers in thickness were prepared by the solution cast technique on a optically plane glass substrates inside an oven at 50°C using acetone and benzene (LR grade) as the common solvent. Blend film of different compositions were prepared by taking PS, PPO in 95:05; 85:15; and 80:20 weight % ratio. The sample so prepared was dried in air for 24 hrs.

III. CHARACTERIZATIONS

A. FTIR Analysis

FTIR spectroscopy is a qualitative approach that helps in understanding the miscibility of two polymers in the specimen. The prepared blend film was subjected to FTIR spectroscopy using FTIR spectrometer (Shimadzu FT-IR) in the wavelength range of 4000 to 400 cm⁻¹.

B. X-Ray Diffraction

The most frequent technique used for the analysis of polymer system and analysis of materials is the X-Ray diffraction technique [10-18]. XRD bestow the information regarding crystalline and amorphous regions within the blend. In order to comprehend the crystalline nature of the prepared blend, their X ray diffraction were carried out on Bruker AXS D8 Advance X- ray powder diffractometer with operating target voltage as 40KV and tube current as 35 mA. The diffraction data were taken from 10 to 70° and 2θ values with step size of 0.02° using a wavelength of 1.54Å.

The intensity versus 2θ profile were obtained for all the specimens [19]. The crystallinity has been measured on the basis that increasing amorphousness tends to broaden the line width whereas increasing crystallinity increases the intensity. The height (CrH) of the main peak above its adjacent minimum represents the crystallinity of the sample and the width (AmW) of the peak at this adjacent minimum is considered to represent the amorphousness of the sample. The crystallinity CrI, is calculated from the Eq. 1:

$$CrI = [1-t \times AmW / CrH] \quad (1)$$

where t is the scale factor relating the height of CrH to full scale (total blackness)[15]. The interplanar distance d was computed for different peaks, from the diffraction patterns of the various samples. The distance between two successive planes from which the X-rays were diffracted was calculated using Bragg's equation 2:

$$2d \sin \theta = n \lambda \quad (2)$$

where k is the X-ray wavelength, h is the Bragg's angle and n is the order of diffraction. d was calculated from the first order ($n = 1$) for various peaks obtained in the diffraction patterns (Eq. 3):

$$d = \lambda / \sin\theta \quad (3)$$

The Scherrer's Equation (Eq.4) gives The relationship between the crystallite size and the X-ray line broadening:

$$D = K\lambda / \beta \sin\theta \quad (4)$$

where, D is crystallite size, k is the wavelength, b is the angular line width of half maximum intensity, and h is the Bragg's diffraction angle, k is the constant with a value of 0.89 [10].

C. Scanning Electron Microscopy (SEM)

Morphological studies are one of the best ways to access the information about the specimen. Morphology is a science of form, structure and surface. The Scanning Electron Microscopy (SEM) is one of the versatile and widely used techniques [20, 21]. The combination of higher magnification, larger depth of focus, greater resolution and ease of specimen observations make the SEM one of the most heavily used instrument in research areas today. The surface morphology of the prepared PPO/PS blends was examined by recording their SEM images on a scanning electron microscope JEOL (JSM-6390LV).

IV. RESULTS AND DISCUSSION

A. Ftir Analysis

FTIR spectroscopy is one of the powerful tools for identifying and investigating the presence of various functional groups in polymers [22, 23]. Molecular structure of two different polymers and interaction of their functional groups due to blending was studied using IR absorption spectroscopy. The IR spectrum of PS Fig.1(a) shows absorption bands at 3030 and 2854 cm⁻¹ corresponding to aromatic and aliphatic C-H stretching, respectively. The peaks at 1602 and 1493 cm⁻¹ are assigned to aromatic C=C stretching. The C-H deformation vibration band of benzene ring hydrogens (5 adjacent hydrogens) appear at 771 cm⁻¹. Ring deformation vibration was observed at 700 cm⁻¹. The C-H stretching vibrations of ring hydrogen's are seen from 3000 and 3100cm⁻¹. PS has bands above 3000 cm⁻¹, indicating the presence of aromatic groups.

In the IR spectrum of PPO, Fig1 (b) shows absorption peak at 709.83 and 769.62 cm⁻¹ corresponding to C-H bending of PPO. On inspection of higher wave number end of the spectrum , bands are observed at 2854.74 and 2939.61 cm⁻¹ due to aliphatic symmetric and asymmetric C-H stretching, respectively. A strong band at 1610.61cm⁻¹ is indicative of C=O stretching. Fig 1(c) to Fig 1 (f) represent FTIR spectra of 5 % PPO + PS , 10 % PPO + PS, 15 % PPO + PS, 20 % PPO + PS The minute shift in the parent bands of PS due to small amount of PPO content confirms the molecular interactions between the constituents to form miscible blends.

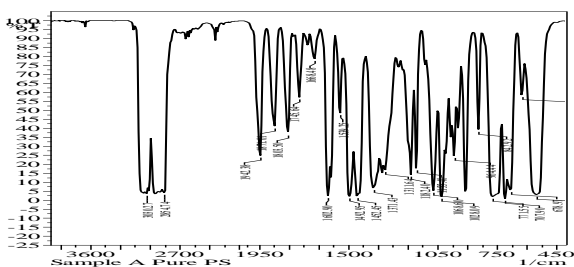


Fig. 1: FTIR spectra of (a) pure PS

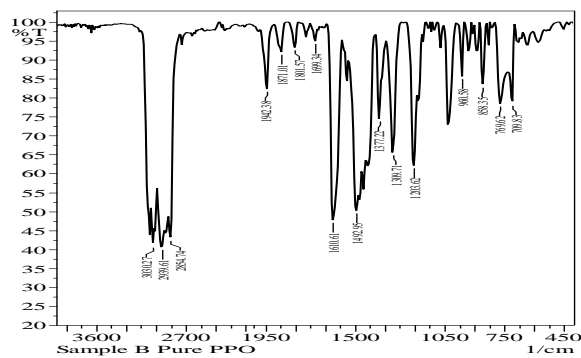


Fig. 2: FTIR spectra of Pure PPO

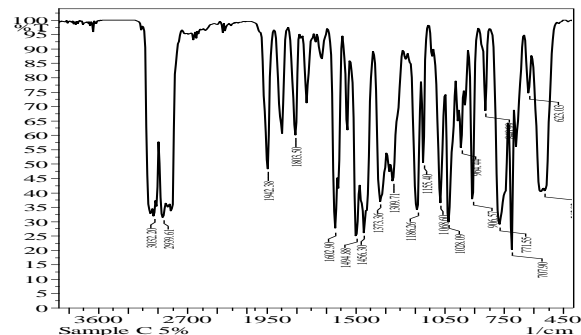


Fig. 3: FTIR spectra of 5% PPO + PS

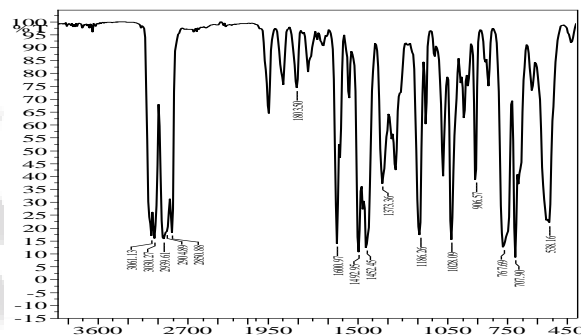


Fig. 4: FTIR spectra of 10 % PPO + PS

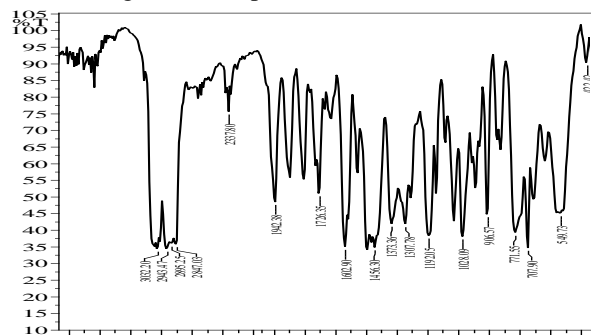


Fig. 5: FTIR spectra of 15 % PPO + PS

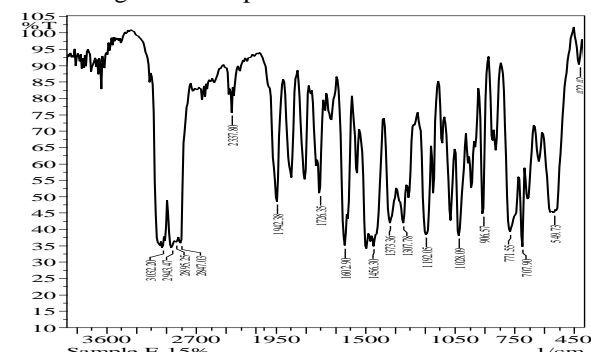


Fig. 6: FTIR spectra of 20 % PPO + PS

V. XRD ANALYSIS

The X ray diffraction spectra of various samples are shown in the Fig.2 The presence of sharp peaks are observed in the XRD spectra of PPO/PS blend. These peaks suggest the development of more polycrystalline structure. A broad maxima is observed in the 2θ range of 14.287o to 24.0o for pure polystyrene which suggest the amorphous structure of pure polystyrene. The sharp peak observed in the XRD spectra of pure PPO suggests crystalline structure of pure PPO. The broad peak observed in the pure polystyrene is found to be broadening with increasing PPO percent in the blends up to 20 wt%. This shows that as we go on increasing PPO content in the blend, PPO/PS blend become more amorphous [24]. The sharp crystalline peak for pure PPO at 2θ value of 27.075o can be seen in the entire PPO/PS blend but with low intensities. Interplanar distance (d), crystallite size (D) and order of crystallinity (CrI) for PPO/PS blends are tabulated in table 1.

Sample	Peak	2θ (°)	d-spacing (Å)	D (Å)	CrI
Pure PS	Peak 1	19.57	4.518	19.1163	0.7743
Pure PPO	Peak1	27.076	3.2907	117.561	0.9738
	Peak 2	35.71	2.5122	5.691	0.9784
	Peak 3	43.682	2.0702	145.91	0.7836
5% PPO	Peak 1	19.63	4.5185	15.18	0.7695
15 % PPO	Peak 1	19.480	4.553	16.2	0.7757
20 % PPO	Peak 1	19.37	4.577	16.53	0.7788

Table 1. The interplanar d-spacing, crystallite size (D), Order of crystallinity for pure PS, pure PPO and for PPO/PS blends

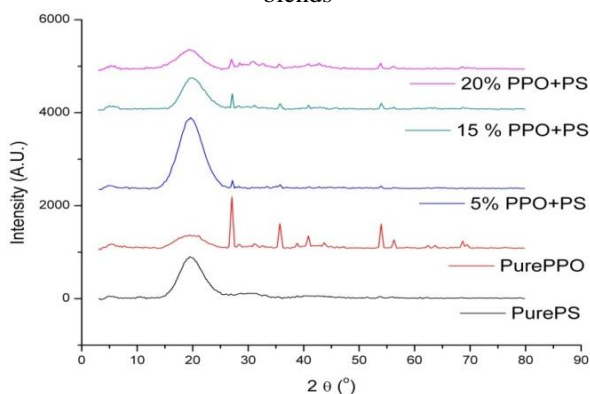


Fig. 2: X-ray Diffraction spectra of Pure PS , Pure PPO ,5 Wt. % PPO ,15 Wt.% PPO ,20 Wt. % PPO

A. Scanning Electron Microscopy (SEM)

The SEM micrograph visualizes the phase morphology of the prepared specimen shown in Fig. 3. These images reveal interesting morphological information about pure PPO, pure PS, and PPO/PS blends. Fig 3(a) shows micrograph of pure PS which shows that the surface of PS is clear and having regular structure. Whereas the typical PPO (Fig. 3(b)) structure is micro globule. It could be seen that the

morphologies of PPO/PS blends are strongly affected by PPO content in the blends (Fig. 3(c)-3(f)). It shows the modification of clear structure of PS by PPO. The SEM morphology of the PPO/PS blends also exhibit that the particles appear to be more densely packed. It also shows that the PPO/PS component exists as a continuous phase which is in good agreement with the observations of Meijje et al [25].

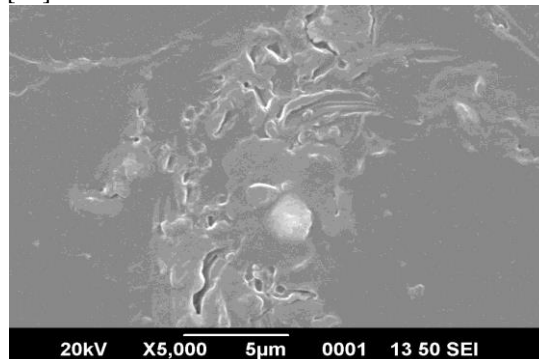


Fig. 7: SEM images showing the effect of PPO into PS matrix (a) pure PS

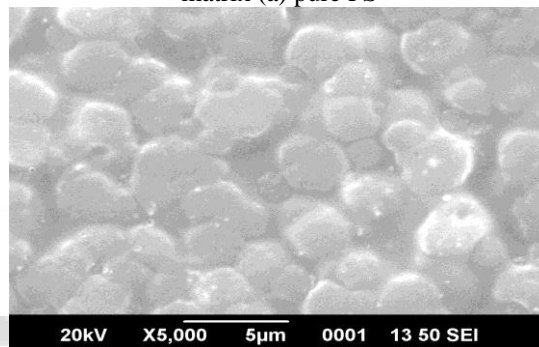


Fig. 8: SEM images showing the effect of PPO into PS matrix pure PPO

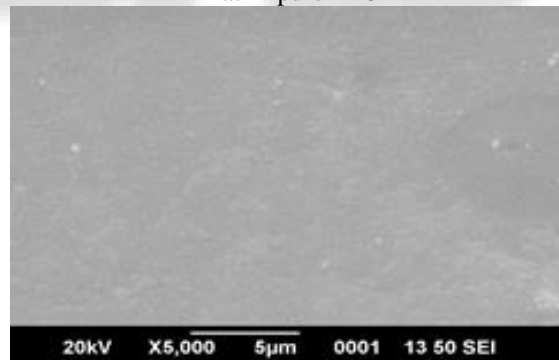


Fig. 9: SEM images showing the effect of PPO into PS matrix 5% PPO + PS

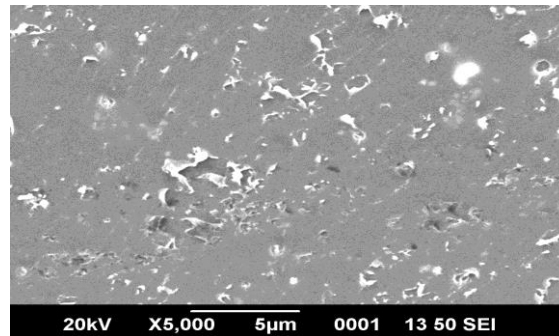


Fig. 10: SEM images showing the effect of PPO into PS matrix 10 % PPO + PS

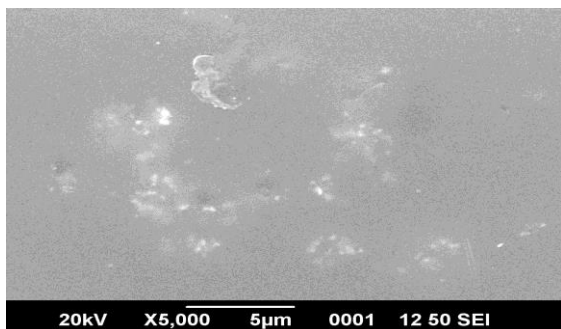


Fig. 11: SEM images showing the effect of PPO into PS matrix 15 % PPO +PS

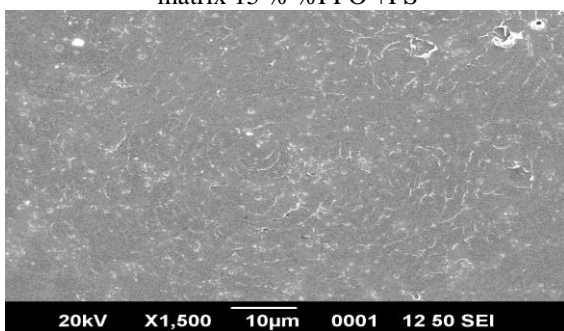


Fig. 11: SEM images showing the effect of PPO into PS matrix 20 % PPO + PS

VI. CONCLUSION

The present study reveals that compatibility polymer blends of PPO: PS can be developed. The SEM and FTIR studies support the formation of miscible polymer blends while the XRD measurements reveal the crystalline nature of the blends. Further, the XRD exhibits development of crystalline blends as the degree of crystallinity increases with increase in the content of PPO in the blends

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