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Miscibility Studies of Poly Ethylene oxide / Resol Type Phenolic Resin blends by viscosity, ultrasonic velocity and polarized optical microscope methods

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Abstract

The solutions of blends of poly ethylene oxide / PF – 108 (resol type phenol formaldehyde) were prepared in different proportions in a common solvent. The miscibility of these blends was probed by solution techniques such as viscosity and ultrasonic velocity and a solid state technique such as polarized optical microscopy. Using viscosity data, the interaction parameters of these blends of different compositions were computed with the relevant equations. The immiscible nature of these blends as indicated by viscosity data was confirmed by ultrasonic velocity and polarized optical microscopic methods. The immiscible nature of these blends suggests that these two polymers are favourable for preparing polymer alloys using a suitable compatibiliser.

Keywords: Polymer blends, poly ethylene oxide / Resol type phenolic formaldehyde PF– 108, Miscibility, Ultrasonic velocity, Viscosity & Optical microscopy.

1. INTRODUCTION

In the process of studying the miscibility of different polymer blends, the author has presented the results on the miscibility of Poly ethylene oxide (PEO) / Resol type Phenol Formaldehyde resin blend. The author selected PEO as it acts as a toughening agent. The resol type phenolic resin PF – 108 developed by the Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram is a high temperature polymer which is widely used for making space – craft body. As PF – 108 is brittle in nature, blending it with PEO is expected to induce toughness in it.

In the present work, the author probed the miscibility of PEO/PF-108 by simple physical techniques such as viscosity, ultrasonic velocity, refractive index, density and polarized optical microscopy.

2. MATERIALS AND METHODS

The blends of PEO/PF-108 of different compositions were prepared by mixing solutions of the polymers in water in the presence of small amount (<1%) of NaOH. The presence of NaOH is found to enhance the solubility of PF-108 in water. PEO (M/s Aldrich $\overline{Mn}$ = 100000) and resol type phenolic resin PF-108 (developed by VSSC and manufactured by ABR Organics Ltd., Hyderabad, India) which is a prepolymer were employed in the present study. The total weight of the two components was always maintained at 2g/dl. The ultrasonic velocities of the blend solutions were measured by ultrasonic interferometric technique as described in elsewhere 5-9. The relative viscosities of the blend solutions were measured at 35 ^{o}C using an USLV. The polarizing optical micrograms of the blend films cast for various compositions were recorded using a microprocessor controlled Carl Zeiss polarizing optical microscope.

3. RESULTS AND DISCUSSION

The measured values of reduced viscosity for PEO, PF-108 and PEOP/PF-108 blend (blend of 0.5:0.5 weight fraction composition) in water at 35 ^{o}C are presented in Table 1.

Table 1: Reduced viscosities of PEO, PF-108 and PEO/PF-108 blend (0.5:0:5 composition) in Water at 35 ^{o}C

Concentration (g/dl)	Reduced Viscosity $(\eta_{sp}/C)\,(dl/g)$		
	PEO	PF-108	PEO/ PF-108
1.60	2.3462	0.00137	0.7270
1.66	2.4010	0.00256	0.7548
1.74	2.4379	0.00399	0.8061
1.90	2.5809	0.02616	0.8879
2.00	2.6894	0.07340	0.9844

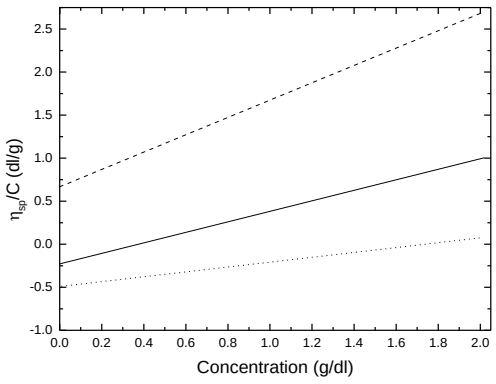

Fig.1: Huggin's plots for the blend of PEO, PF-108 and blend of PEO (0.5)/PF-108 (0.5) composition.
(----PEO; PEO/PF-108 blend; ……PF-108)

The Huggin's plot for this blend is presented in Fig.1. In the same figure, the Huggin's plots for the homo polymers PEO and PF-108 are also presented. In order to probe the miscibility of the PEO/PF-108 blends, the equations suggested by Chee [3] and Sun et al. [4] (Eqns. 1 and 2 respectively) were utilized and the interaction parameters μ and α calculated.

$$\mu = \frac{\Delta B}{\left\{ [\,n\,]_2 - [\,n\,]_1 \right\}^2} \quad ..(1)$$

Here $\Delta B = W_1^2\, b_{11} + W_2^2\, b_{22} + 2\, W_1\, W_2\, b_{12}$ in which W_1 *and* W_2 are the weight fractions of the two polymers, b_{11} *and* b_{22} *and* b_{12} are the slopes of the Huggin's plots of the two polymers and b_{12} is that of the blend. $[\,\eta\,]_1$ *and* $[\,\eta\,]_2$ are intrinsic viscosities for pure component solutions.

$$\alpha = K_m - \frac{K_1 [\,n\,]_1^2 W_1^2 + K_2 [\,\eta\,]_2^2 W_2^2 + 2(K_1 K_2)^{1/2} [\,\eta\,]_1^2 [\,\eta\,]_2^2 W_1 W_2}{\left\{ [\,\eta\,]_1 W_1 + [\,\eta\,]_2 W_2 \right\}^2} \quad (2)$$

Where K_1, K_2 *and* K_m are the Huggin's constants for individual components 1,2 and blend respectively. While deriving this equation [Eq. (2)], the long range hydrodynamic interactions are taken into account. Sun et al.[3] suggested that the blend would be miscible if $\alpha \geq 0$ and immiscible when $\alpha < 0$.

The μ *and* α values for blends of different compositions are presented in Table 2. From this table, it is clearly evident that μ and α for PEO/ PF- 108 blends of all compositions under study are negative. This clearly indicates that the blends under investigation are immiscible. In order to further probe the miscibility of polymer blends under study, the ultrasonic velocity, the ultrasonic velocity, of polymer blend solutions was measured. The measured values of ultrasonic velocity of PEO/ PF - 108 polymer blends are presented in table 2. The variation of ultrasonic velocity of PEO/ PF - 108 blends with composition are depicted in Fig. 2. From these figure, it is clearly evident that the variation is non - linear for the system under study showing multiphases in the blend. Singh and Singh (10) have also attributed the non – linear variation of ultrasonic velocity with blend compositions to the immiscible nature of several blends.

Table 2: Interaction parameters μ *and* α for PEO/ PF-108 blends of different compositions in water at 35 ^{0}C

Weight fraction of PEO/ PF-108 Blend	μ	α
0.2/0.8	-107.21	-0.4084
0.4/0.6	-665.01	-0.2970
0.5/0/5	-023.72	-0.0712
0.6/0.4	-001.13	-0.2667
0.8/0.2	-001.79	-0.1214

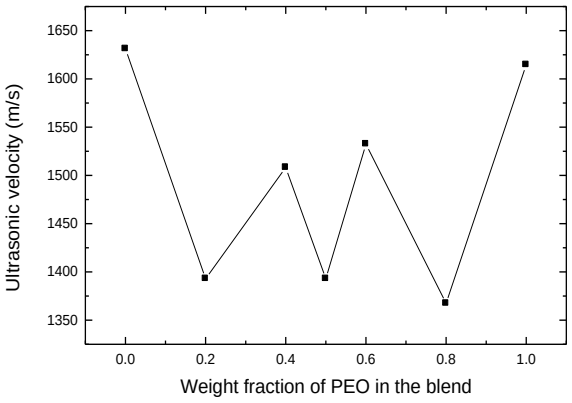

Fig. 2: The variation of ultrasonic velocity with weight fraction of PEO in PEO/ PF-108 Blend in water at 35 ^{0}C

In order to further probe the miscibility or otherwise of PEO/ PF – 108 blend, the author used the solid – state technique, viz., polarized optical microscopy. The optical polarizing micrograms of the PEO/ PF – 108 blends of different compositions are presented in Fig. 3. From these micrograms, it is clearly evident that the components of PEO and PF – 108 exist as two phases. This clearly indicates that the blend is immiscible in nature. Chatopadhay and Banerjee (11) also used polarizing microscopic technique to confirm the miscibility or otherwise of the blends in film form. These studies provide us a clue that the combination of PEO and PF – 108 can be converted into a polymer alloy by suitable compatibilization.

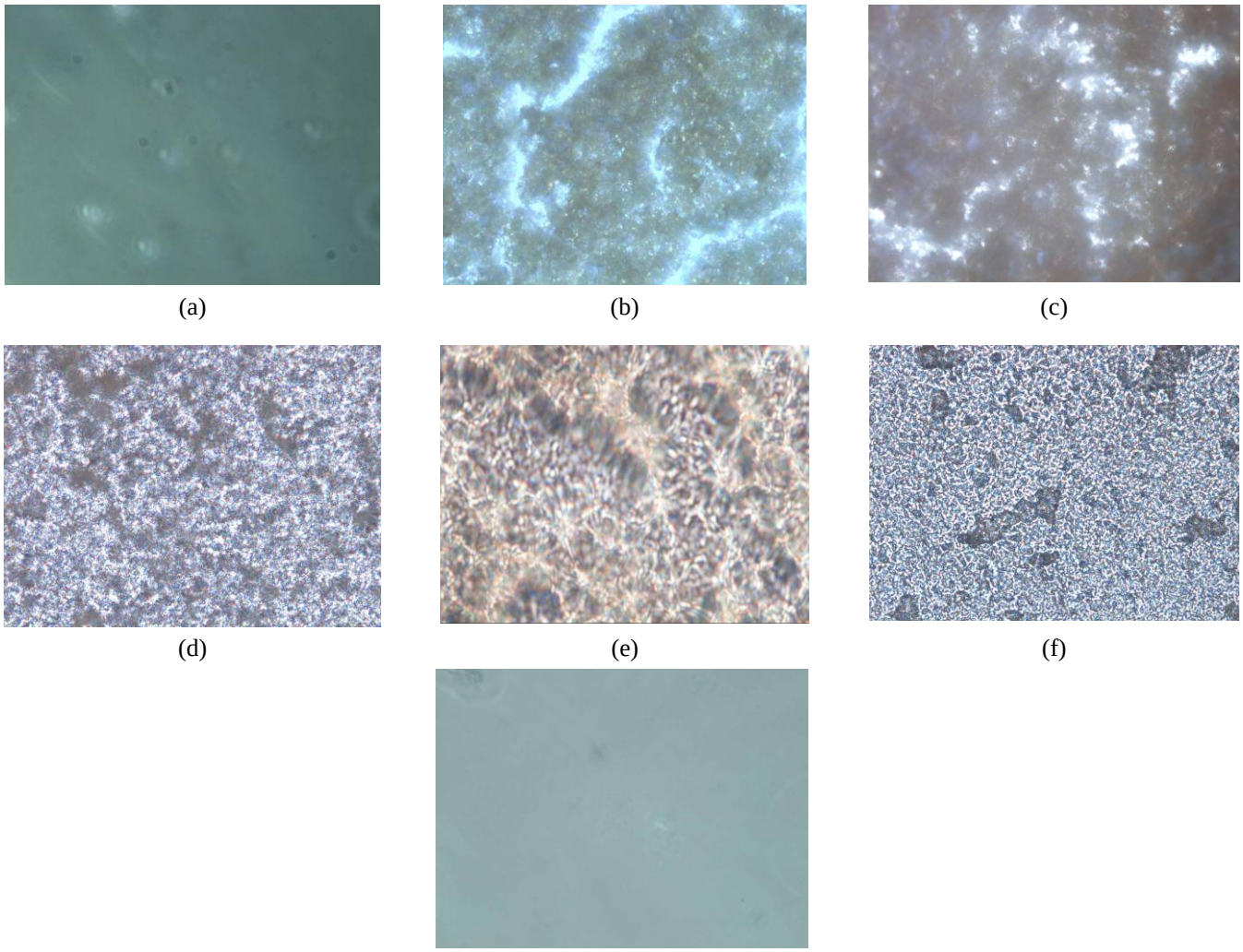

Fig. 3: Polarized Optical Micrographs of PEO/ PF-108 blends with the weight fraction of PEO – (a) 1.0; (b) 0.8; (c) 0.6; (d) 0.5; (e) 0.4; (f) 0.2 ; (g) 0.0.

In order to explain the immiscible nature of PEO/ PF – 108 blend basing on thermodynamics, the solubility parameters were calculated using Van Krevelen group additive method (12).

The computed values of solubility parameters of PEO and PF – 108 are found to be 20.41 $J^{1/2}\ cm^{3/2}$ and 23.13 $J^{1/2}\ cm^{3/2}$ respectively. The difference between these two values is 2.72H. As per thermodynamic criterion, the components in a mixture are miscible only when the difference in their solubility parameters is less than 2H. As in the present case, the value exceeded 2H, the blend of PEO/ PF – 108 is immiscible.

CONCLUSIONS

Basing on viscosity, ultrasonic velocity, and polarized optical microscopic investigations, the blends of PEO/ PF – 108 were found to be immiscible. The computed solubility parameters by Van Krevelen group additive method also confirmed the same.

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