

Compatibility Study of Polystyrene and Poly Methyl-methacrylate Blends using FTIR and Viscometry Methods

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Abstract: *Polystyrene and poly(methyl - methacrylate) are widely applied polymers but suffer from some property's failures such as brittleness, especially when used in crude form. In view of this, and other materials requirements that is expected to be met by most polymers. This study seeks to investigate compatibility of various blends of polystyrene and poly (methyl methacrylate) (in chloroform solvent) using Fourier transformed infra-red spectroscopy and viscometry methods. Results obtained from Fourier transformed infra-red spectroscopy indicated that blending did not change the functional groups of the polymers significantly, which pointed towards the existent of little or no interaction. Viscometry measurements revealed that plots of relative viscosity versus concentration, specific viscosity versus concentration and reduced viscosity versus concentration were respectively parallel to each other and assumed S-shaped which also indicated the absence of interaction, hence incompatibility. It is concluded in this work that at the operation temperature of 303 K, there is no compatibility between polystyrene and poly (methylmethacrylate) blends.*

Key Words: *Compatibility, blends, polystyrene, polymethylmethacrylate, FTIR, viscometry*

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1.0 Introduction:

A polymer blend is a material which is formed by the mixing of at least two or more polymers together resulting in the creation of a new material with different properties. Blends offer a major alternative in meeting materials requirements of polymers for some engineering and other applications. Production of polymer blends can provide alternative to materials that are expensive, scarce and even improve the quality of existing polymers.

Most of the earlier work in this field of blending are based on observation and experience and were more of academic rather than commercial interest. Blending is an effective method for designing polymer materials with various

properties. The advantage of blending is that properties of the existing polymer may be adjusted without the development of the new macromolecules. One of the important controlling parameters in polymer blending process is the degree of compatibility of the polymers. However, the degree of compatibility is very much dependent on the interaction between the phases of the polymer blend. Studies on compatibility of polymer blends is necessary in order to obtain polymers with better and desirable properties. Compatibility can be influenced by various factors such as intermolecular interaction, morphology, crystalline phase, and reduction of surface tension.

There are several techniques for studying the compatibility of the polymer blends. The most useful techniques are viscometric measurements according to (Sun et al., 2009., Mamza and Folaranmi 1996), thermal analysis (Song. and Long, 1991), ultrasonic velocity (Singh and Paladhi, 2014), refractive index (Rajulu, *et al.*, 2015), NMR method (Crispim, *et al.*, 2000) and optical spectroscopy (Wu, et al., 1999). However, FTIR and viscometry methods of studying compatibility have been found to be one of simple, inexpensive, rapid technique and can provide information about both polymer interactions and polymer solvent interaction in solution (Chee, *et al.*, Wang and Feng, 2002).

Viscometry is a simple and effective technique for monitoring the interactions in polymer blend's solutions through determination of viscosity while FTIR analysis reveals the functional groups in a polymer. Consequently, changes in viscosity and associated functional groups can be used to investigate the degree of compatibility of a polymer blends.

Some studies have been reported on FTIR and viscometry studies of polymer blends. For example, Gupta and Sah (2013) studied the miscibility of PC and OMMA blends and found a general structural change in the polymer due to blending. FTIR, viscometry and SEM studies were able to provide sufficient information on the level of interaction between the polymer. In their study, Roumana and Akilandeswari (2015) adopted viscometric, ultrasonic, refractometry

and FTIR techniques to study the miscibility properties of methyl methacrylate and nitrocellulose blends and reported that FTIR analysis was informative for identification of vibrational characteristics of the samples. Ramprasad and Rao (2017) used FTIR, SEM and viscometry methods to study morphology and miscibility of chitin-polyaniline blend and reported that the adopted techniques were comparable to those obtained from DSC, TGA and XRD methods. Lewandowska (2015) investigated miscibility properties of chitosan and polyacrylamide blends and concluded through FTIR analysis, that the miscibility of the blend is a function of the level of interaction between the functional groups of the polymeric components.

According to Sundararajan and Flory (1974), polymethylmethacrylate (PMMA) is an example of disubstituted vinyl chain in which the substituents COCH₃ and CH₃ differ in size and shape. The COCH₃ is non cylindrical and the CH₃ resembles the CH₂ skeletal group in its steric interaction. PMMA is a thermoplastic and is widely used because of its excellent properties. However, non modified PMMA are known to be brittle, thereby limiting their usage. The monomer in PMMA is shown in Fig. 1. On the other hand, polystyrene (PS) is the most widely used plastics. It is an aromatic hydrocarbon polymer that is synthesized from styrene monomer (See Fig. 1). The polymer is hard, brittle and has a poor barrier to oxygen and water vapour. Some of these properties sometimes limit its applications. Consequently, blending, if feasible can enhance the useful properties of these materials. In spite of their excellent properties and applications and a large numbers of polymer blends that have been studied, literature is scanty on PS/PMMA blends. Perhaps those to the best of our knowledge, are the two reported by Khan *et al.*, (2008) and Baraka *et al.* (2003) using a different solvent from the one we are using. Therefore, the aim of this study is to study the compatibility of various proportion of PS/PMMA blend.

2.0 Materials and Methods

2.1 Materials and equipment



Equipment and apparatus used in the study were weighing balance, 25 ml volumetric flasks, 250 ml conical flask, 5 ml graduated pipette, 25 ml specific gravity bottle, Oswald capillary viscometer (model 1-7), stirrer, Cotton wool, Fourier transform infrared spectrophotometer (Scimadzu FTIR-8400S), Oswald viscometer (type D), polystyrene (BDH England), poly (vinyl chloride) (BDH England), poly (methylmethacrylate) (BDH England) and chloroform (Analar BDH England), purchased from Romptech Scientific Supplies Company, Zaria.

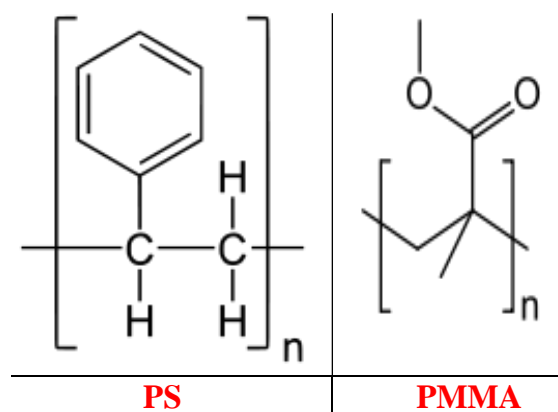


Fig. 1: Structures of PS and PMMA monomers

Table 1: Composition (%) of PS/PMMA blends.

Blend	PS:PMMA
A1	0:100
A2	10:90
A3	20:80
A4	30:70
A5	40:60
A6	50:50
A7	60:40
A8	70:30
A9	80:20
A10	90:10
A11	100:0

2.2 Preparation of PS/PMMA blends



Composition of PS/PMMA blends prepared for this study were as recorded in Table 1. The required proportion of the blend was prepared using chloroform as a solvent. The volume prepared in each case was 100 ml. they were preserved and used for viscometry studies.

2.3 Fourier transforms infrared spectroscopic analysis

Fourier transforms infrared spectroscopy analysis of PS, PMMA and their blends (PS/PMMA) was carried out using Scimadzu FTIR-8400S Fourier transform infra-red spectrophotometer. The sample was prepared in KBR and the analysis was carried out by scanning the sample through a wave number range of 400 to 4000 cm^{-1}

2.4 Viscometry analysis

10 ml of the prepared stock solution was transferred into Oswald capillary viscometer (model 1-17) maintained at 30 $^{\circ}\text{C}$ in a thermostated water bath. The content in the viscometer was forced to rise above the marked bulb levels and the timer taken for the fluid to drop between the two marks was recorded and used to calculate relative viscosity. Triplicate measurements were made for each set of measurement and the experiment was repeated for other test blends.

3.0 Results and Discussion

3.1 FT-IR Analysis

FTIR spectrum of 00:100 (00: 2.0 g/dl) blend of PS: PMMA indicated absorption bands at 3437.26 and at 3053.42 cm^{-1} which were assigned to O-H in carboxylic acid. Aromatic C-H stretch was found at 3053.42 cm^{-1} . FTIR spectrum of PS/PMMA blend of composition, 10:90 (0.2:1.8) revealed that the amide N-H and aromatic CH stretches were shifted to 3431.48 and 3049 cm^{-1} respectively. Also observed was a broad O-H stretches at 2613.63 cm^{-1} due to carboxylic acids (Vinod and Sashidhar, 2010). The FTIR spectrum of PS/PMMA blend with composition, 20:80 (0.4:1.6) indicated the presence of amides N-H and aromatic =C-H stretches which was shifted to 3429.55 cm^{-1} respectively.

FTIR spectrum of 30:70 (0.6:1.4) PS/PMMA blends. indicated OH stretch due to carboxylic acid at 3435.34 cm^{-1} . Aromatic C-H stretch at 3051.49 cm^{-1} confirmed that the blend is aromatic The FTIR spectrum of 40:60 (0.8:1.2) PS/PMMA

composition showed absorption bands at 3437.36 and 2621.35 cm^{-1} assigned to OH stretching. (Cunha *et al.*, 2007). Aromatic C-H was also found at 3055.35 cm^{-1} . FTIR spectrum of 50: 50 (1.0:1.0) PS/PMMA blend. The spectrum indicated a broad absorption band at Alkane/alkyl CH stretch was observed at 2935.76 cm^{-1} . At PS/PMMA blend composition of 60:40 (1.8:0.2), the FTIR spectrum indicated an absorption band in the spectrum due to OH stretch at 3406.40 cm^{-1} (associated with carboxylic acid), -CH stretch due to alkene at 3041.84 cm^{-1} and alkyl C-H stretch at 2926.11 cm^{-1} . Recorded FTIR spectrum for PS/PMMA blend composition of 70:30 (1.6:0.4) revealed the appearance of OH stretches at 3423.78 and 2621.35 cm^{-1} which signify the presence of carboxylic acid group. Aromatic C-H stretch was found at 2055.35 cm^{-1} . Other peaks were observed at 2621.35, 2914.54 and 2922.23 cm^{-1} and are attributed to CH stretches due to alky and alkanes respectively. At PS/PMMA blend composition of 80: 20 (1.4:0.6), the spectrum revealed alkanes and alkyl peaks at 2347.45 cm^{-1} . This absorption band of PS/PMMA blends reveal no significant interactions and the aromatic rings was not affected by blending/ The FTIR spectrum for PS/PMMA blend composition of 90:10 (1.2:0.8) indicated C-H stretches at 2922.2 cm^{-1} signify the presence of strong aromatic group of the blend. At PS/PMMA blend composition of 100.00 (2.0:0.0). The spectrum also shows the appearance of =C-H stretching at 3078.8 cm^{-1} , confirm that the blend is alkane group which also reveal no significant interactions. Consequently, PS/PMMA does not have significant compatibility at any composition which is in agreement with the work reported by Mohammad and Raina (2008).

3.2 Viscometric study

In viscometric measurements, several viscosity terms can be deduced from relative viscosity measurements including specific and reduced viscosities. The relative viscosity was calculated using equation 1

$$\eta_{rel} = \frac{t}{t_0} \quad (1)$$

where t is the flow rate of solution blend while t_0 is the flow rate for the solvent. The specific

viscosity is expressed in equation 2 while equation 3 gives the expression for the reduced viscosity,

$$\eta_{sp} = \frac{t - t_0}{t_0} \quad (2)$$

$$\eta_{rel} = \frac{\eta_{rel} - 1}{C} \quad (3)$$

C is the concentration in g/dl. And other parameters are as defined earlier. Fig. 13 below shows the variation of relative viscosity of the polymer blends with concentration while Figs. 14 and 15 show the variation of specific and reduced viscosity with concentration of the blend respectively. From the plots the pattern of variation is seems to be parallel to each other (and they all assume S-shape plots) indicating that they all follow the same mechanism and that blending has not created significant interaction in rheological behaviour of the polymers.

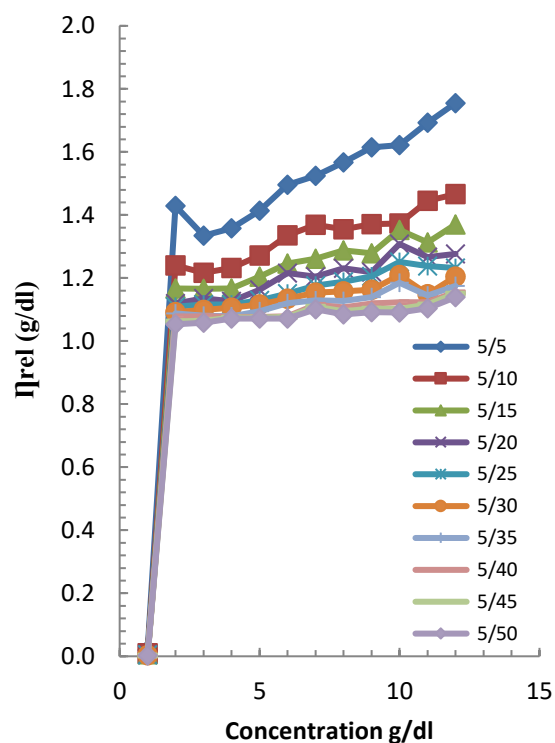


Fig. 13: Variation of relative viscosity with concentration of PS, PMMA and their blends

Compatibility of polymer blends basically depends in principles on the method used and the temperature of blending. A study on compatibility of polymer blends solution using



viscometric and FTIR methods reveal no degree of compatibility of PS/PMMA blend.

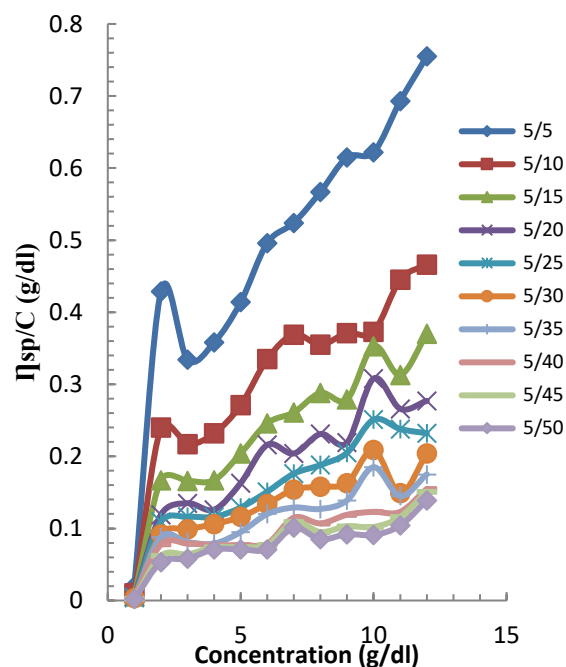


Fig. 14: Variation of specific viscosity with concentration of PS, PMMA and their blends

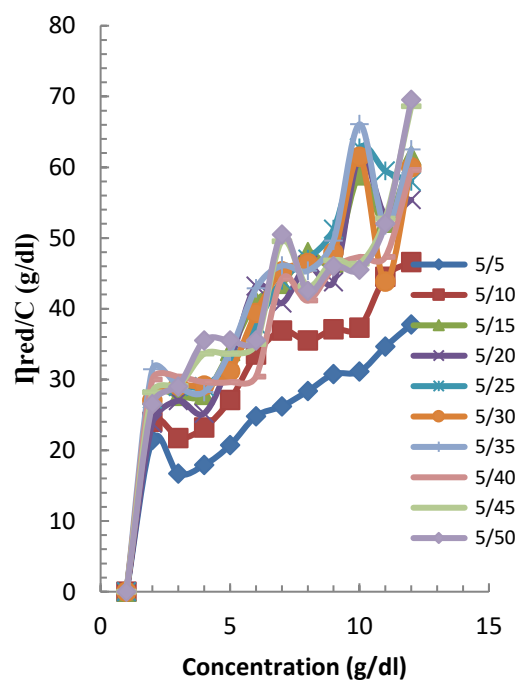


Fig. 15: Variation of reduced viscosity with concentration of PS, PMMA and their blends

4.0 Conclusion

The viscometric study revealed that plots of relative viscosity are almost an S-shape. This is an indication that the polymers are incompatible in the studied solvent (chloroform) at temperature of 30 °C. This may be attributed to the mutual repulsion of molecules in solutions which lead to decrease of dynamic volume of the polymer. The FTIR spectrum recorded for PS/PMMA blend did not indicate the existence of any interaction between the components. There is no change in the position of either peak of aromatic ring of PS or the lone pair.

Although there are conflicting data in some literatures on polymer blends, there is need for more research on improving more polymer blends, justification of some these conflicting data in the literatures, study some of the functional properties of traditional and versatile polymers by use of different solvents and temperature when blended.

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