THERMAL AND MECHANICAL PROPERTIES OF ORGANICALLY MODIFIED BENTONITE REINFORCED PVC/POLYESTER

BLEND NANOCOMPOSITE FILMS

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Abstract

Polymer nanocomposites (PNCs) have gained more attention for the past decade due to their excellent mechanical, electrical, thermal and permeability property in academic and industrial areas. The present study deals with preparation, characterization of novel PVC/Polyester blend nanocomposite films using FT-IR, XRD and TG-DSC. The tensile strength of synthesized nanocomposite films was also studied.

Keywords: Polymer nanocomposite, PVC, Thermal stability, mechanical property.

Introduction

Polymer nanocomposites have been used in a number of industrial applications, such as building structural panels, gas tanks, bumpers, interior and exterior panels, catalysts, carriers of drugs and penetrants, flame retardant panels and high performance components, food packaging and textiles[1], wound healing[2] and pervaporation[3]. Companies are investing billions of dollars per annum in developing novel polymer/nanoclay composite materials[4]. Polymer/nanoclay composites act as a barrier against the permeation of many gases, such as oxygen, carbon dioxide, water vapors and volatile compounds (flavors and taints); this gas barrier property, along with its basic mechanical, optical and thermal properties, makes these composites excellent candidates for food packing materials[5]. An important task in the preparation of polymer/nanoclay composites is to achieve a uniform dispersion of nanoclay in the polymer matrix. The solution-blending technique often yields favorable dispersion of clay layers in the polymer matrix, in comparison with melt blending, due to its low viscosity and high agitation power. On the other hand, polymer/nanoclay composites are to achieve a uniform dispersion of nanoclay in the polymer matrix. The solution-blending technique often yields favorable dispersion of clay layers in the polymer matrix, in comparison with melt blending, due to its low viscosity and high agitation. Also melt blending leads to mechanical, thermal and oxidative degradation of polymer matrix[6, 7]. Synthesis approaches may lead to different combinations of polymer matrix and nanoclays, such as an immiscible structure, an intercalated structure and an exfoliated structure[8]. In the immiscible structure, the nanoclay dispersion aggregates within the polymer matrix and the polymers are separated from the clay layers[9]. The polymer chains form an intercalated structure between the clay layers, altering the geometry of the clay layers. This alternation includes variation in the stacking mode of the layers, modification in interlayer spacing, and diminishing the electrostatic forces between the clay layers, which lead to greater enhancement of the mechanical and thermal properties of the composites[10-12]. In this present work a novel PVC/polyester blend with bentonite nanocomposite films were synthesized using solution blending technique. The thermal and mechanical properties of nanocomposite films were studied.

Experimental

Materials and Methods:

PVC powder, 3-Hydroxy-4-methoxybenzaldehyde, syringaldehyde, 4-aminophenol, 4, 4'-Diaminophenyl ether, 4, 4'-Diaminodiphenyl sulfoxide, terephthalolyl chloride, sebacoyl chloride and solvents were purchased from TCI Chemicals, Japan. Bentonite clay purchased from SRL chemicals, India. Simultaneous DSC, TG-DSC and DTG was carried out by using NETZSCH STA 449F3 under Nitrogen atmosphere of 20ml/min flow and heating rate of 5˚C/min and sample size was 2-3 mg. The tensile property of Composite films were evaluated by Tinius Olsen Universal Testing Machine H60KT with cross sectional speed 50 mm−60 kN with sample of dimension 10 cm × 1 cm.

General procedure:

Synthesis of Polyesters

Monomers containing 3-Hydroxy-4-methoxybenzaldehyde and 4-Hydroxy-3, 5-dimethoxybenzaldehyde with 4-aminophenol, (4, 4'-Diaminophenyl ether), (4, 4'-Diaminodiphenyl sulfoxide) diol were synthesized followed by polymerization carried out with terephthalolyl chloride (F) and sebacoyl chloride (F2).

Preparation of Nanocomposite film

Nanocomposite films with bentonite fillers were synthesized by mixing individual solution of PVC, new polyester and bentonite dissolved in THF in the ratio of 3:1:1 wt. % and stirred the mixture vigorously for 5 h and then carefully poured the mixture to avoid air bubbles into glass petri dish. The film was allowed to dry slowly in room temperature for 48 h and then formed film was carefully peeled off from the glass petri dish.

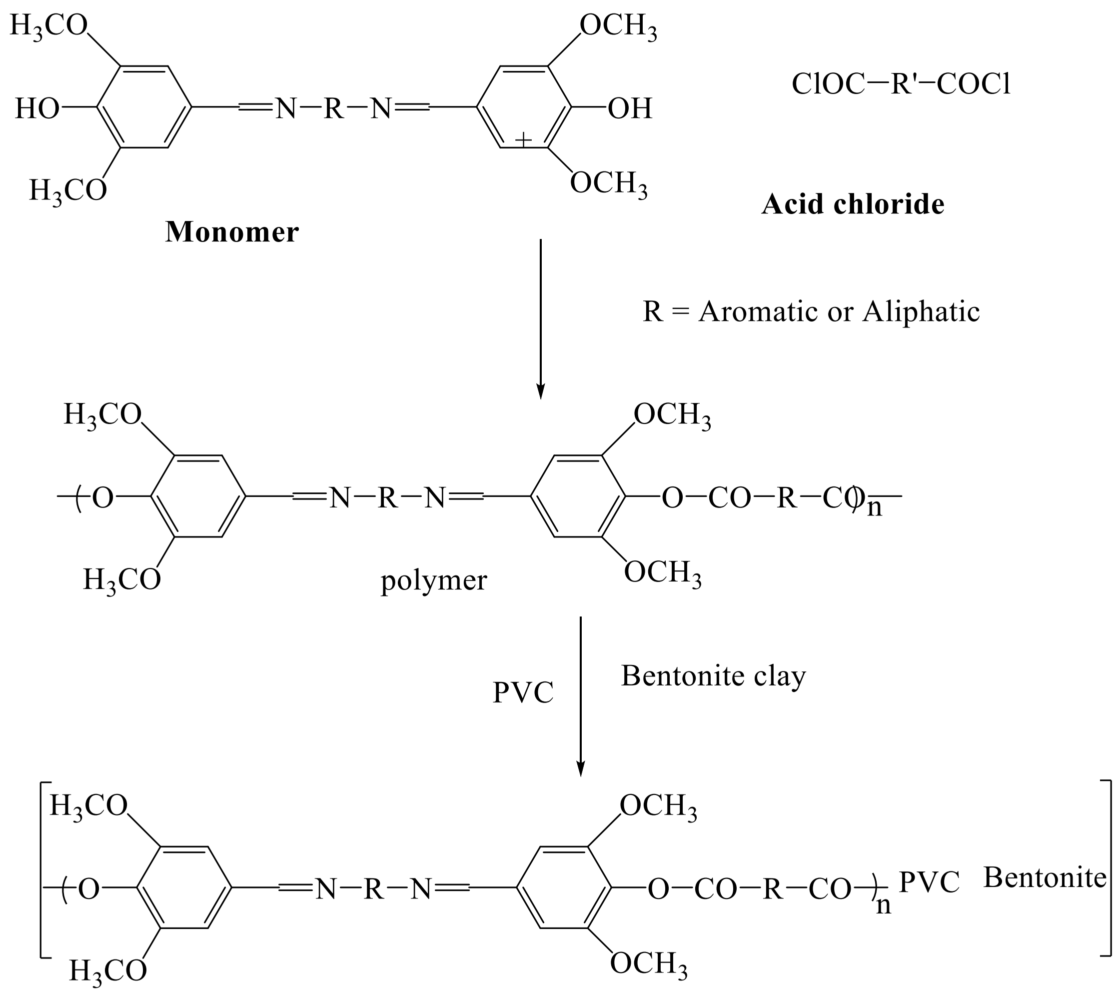
Results and Discussion

FT-IR

The FT-IR spectrum of synthesized polymer blend nanocomposite films was shown in Fig. 1. The broadening of peaks of composite films at 3600-3000 cm-1 and 1500-1200 cm-1 occurred compared to polymer blend, as well as peaks at 1647 cm-1 and 1360 cm-1 shifted to little lower frequency due to Hydrogen bonding between polymer blends and Si-OH functional centers of nan clay.

XRD

Wide Angle X-ray diffraction spectrometer shows strong peak below 5˚ due to organically modified bentonite and another peak around 20-30˚ due to intercalation of polymer blend matrix with high loading of bentonite nan clay filler. The intercalation of PVC/Polyester blend with bentonite clay due to presence of polar groups in the blend and high concentration of clay particles which does not permits the diffusion of polymer blend matrix, Fig. 2.



Scheme-I: PVC/Polyester blend nanocomposite preparation

Thermal Analysis

The Thermal stability of the nanocomposites was analyzed by DSC and TGA. DSC is the technique used to determine the quantity of heat either absorbed or released when substances undergo physical or chemical changes. In the present study, the glass transition temperature and the effect of clay on the glass transition temperature (Tg) values of the polymer blends was shown in Fig. 2 using DSC analysis. The Tg values are summarized in Table 3. The Tg values of the composite films were shifted to higher temperature compared neat PVC film (85.53˚C). The movement of the macromolecular polymer chain is restricted by the nanoclay hence Tg increases. The applied heat was uniformly distributed through clay particles. Thus, the Tg value of the composite was shifted to higher temperature. The incorporation of nanoclay had an effect on the amorphous region of the polymer matrix, and so, the Tg of the nanocomposite is shifted to higher temperature. On minimum filler loading, the nanoclay has no significant effect on the amorphous region and so 15-20 wt. % clay loaded films were synthesized.

The TGA experimental results of the PVC/Polyester blend nanocomposites are shown in Fig. 3. Figure 3 shows that the weight loss of the nanocomposite films decreases as the temperature increases. The nanoclay protects the polymer blend against thermal degradation. The DTG results of all samples exhibited three distinct degradation stages (Fig. 4). The first weight loss occurred at around 150 °C because the solvent escaped during heating process. The major weight loss occurs around <250°C for all samples, which corresponds to dehydrochlorination of PVC. The third stage corresponds to the side chain melting temperature of PVC/Polyester blend nanocomposite 430-460˚C. The 50% degradation occurs around 250-290°C, which indicates the addition of nanoclay altered the thermal stability of the polymeric films.

The TGA results are given in Table 1. The thermal stability is higher for 13 wt. % bentonite filled samples and is around 452.3°C. All other samples show better thermal stability than the pure polymer. The increase in the thermal stability was due to the presence of nanoclay layers, which minimize the permeability of volatile degradation product to the material and maximize the heat insulation. On addition of nanofillers to the polymeric matrix, the thermal stability of the polymer enhanced significantly.

Mechanical property

The tensile testing was performed to evaluate the effect of the bentonite clay on the mechanical property of the nanocomposite films. Tensile properties of the composites are given in Table 3. The data shows a lower in the tensile properties of PVC/Polyester blend clay nanocomposite films due plasticizer effect of synthesized polyester. This indicate PVC/Polyester blend become more amorphous. The decrease in tensile strength is due to lack of interfacial interaction between blend components but elongation break increases due to plasticization effect. The plasticizer (new polyester) able to increase the ductility and flexibility of PVC/Polyester blend nanocomposite film which is accompanied by a reduction in tensile strength and modulus of elasticity.

Table 1 Thermogravimetric Analysis (TGA) of the PVC/ Polyester Nanocomposite films

Sample	T_{10} (°C)	T_{50} (°C)	Tmax (°C)	Residue mass (%) at 998.6 °C
F2SP	166.4	264.8	452.3	13.00
F2SDE	137.8	246.2	452.0	15.48
FIP	145.4	274.0	447.0	16.86
FIDE	135.0	242.6	439.7	21.13
FIDS	165.8	285.9	448.6	16.87

Table 2 Effect of Bentonite Clay on the Glass Transition Temperature (T_g) of the PVC/Polyester blend Nanocomposite films

Sample	T_g (°C)
F2SP	232
F2SDE	223
FIP	218
FIDE	231
FIDS	258

Table 3 Tensile strength, Elongation break and Young's modulus of the PVC/Polyester blend Nanocomposite films

Sample	Tensile strength (MPa)	Elongation break (%)	Young's modulus (MPa)
PVC	37.36	6.7	676.07
F2SP	15.88	58.8	265.15
F2SDE	15.01	51.6	385.62
FIP	15.55	52.3	347.45
FIDE	15.67	56.2	289.36
FIDS	16.72	59.6	241.46

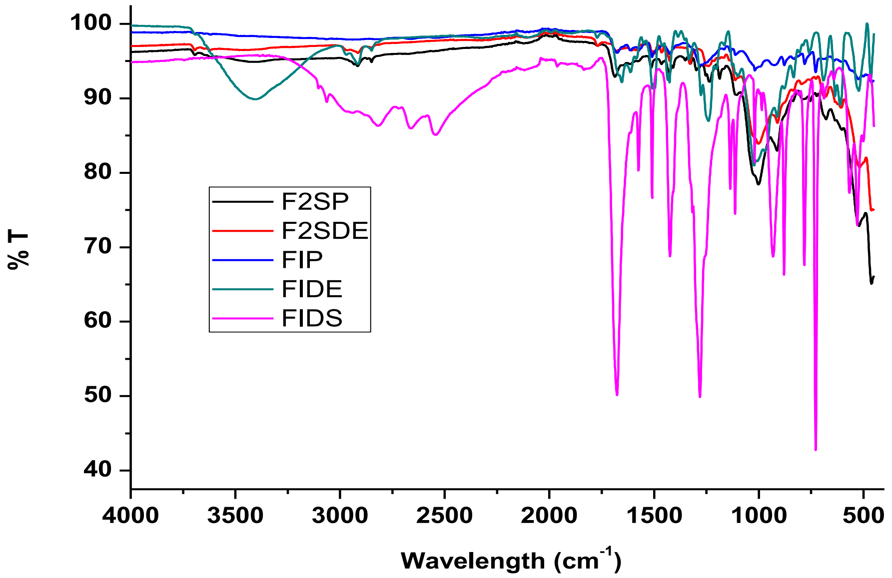


Fig. 1 FT-IR spectrum of Polymer blend nanocomposite films

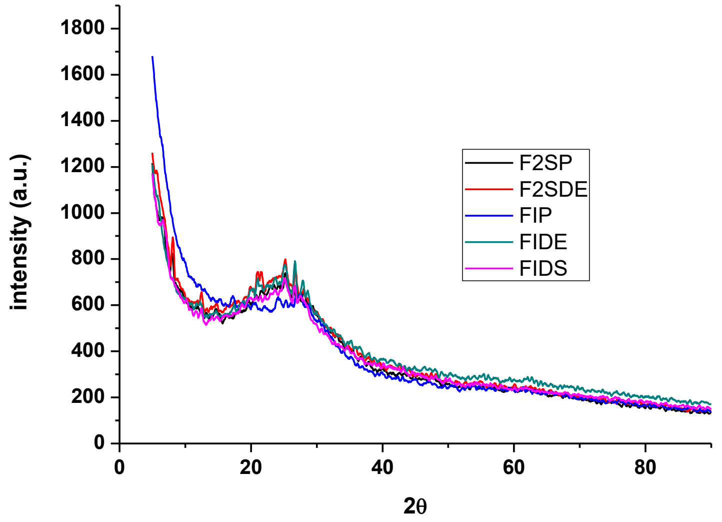


Fig. 2 XRD spectrum of Polymer blend nanocomposite films

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Fig. 2 DSC thermogram of Polymer nanocomposite films

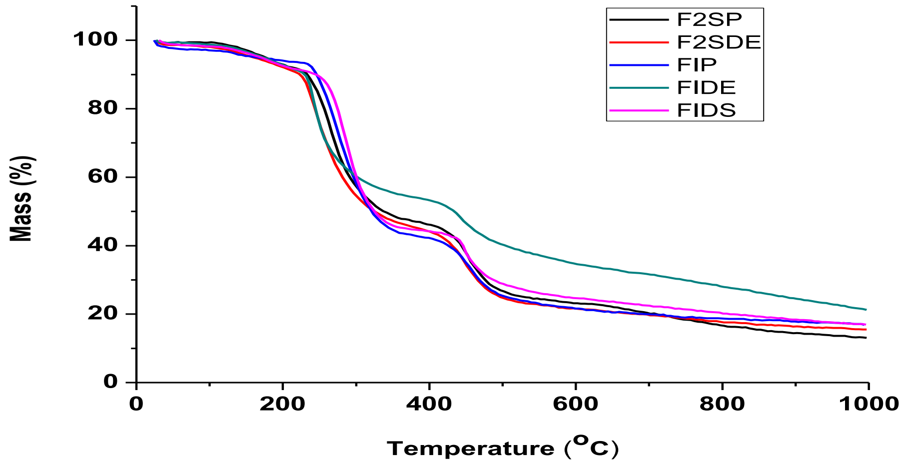

Fig. 3 TGA thermogram of Polymer nanocomposite films

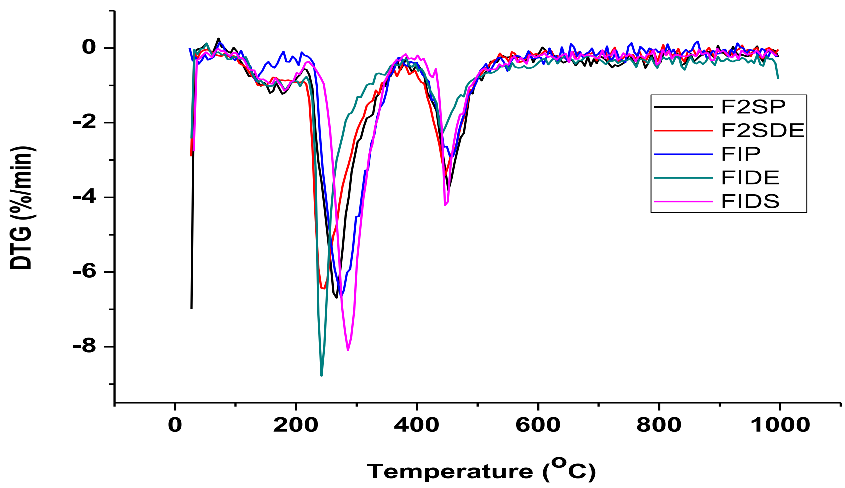

Fig. 4 DTG thermogram of Polymer nanocomposite films

Conclusions

A series of Novel PVC/Polyester bentonite nanoclay composite films were prepared using simple solution casting method. From the TGA, DSC and DTG data, it is clear that thermal stability of nanocomposite increases due to presence of nanoclay. The Xrd data reveals that polymer blend matrix intercalated between nanoclay layers. The mechanical properties of nanocomposite films were studied. These composite films may have wide application in areas such as waste water treatment, flame retardant etc.

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