Mechanical, Electrical, Thermal and Morphological Properties of PP, PP-g- MAH and Mica Silicate Nanoclay Nanocomposites

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Abstract

Polymer nanocomposites exhibit superior mechanical properties, electrical properties, thermal and morphological properties. Polypropylene/PP-g-MAH/Mica silicate nanoclay Nanocomposites were prepared by melt compounding using Twin Screw Extruder. The tensile strength and modulus strength, Flexural strength and flexural modulus of PP/PP-g-MAH/Nanoclay were highly increased with the loading of clay. The thermal properties were characterized by using differential scanning calorimeter (DSC) and thermo gravimetric analysis (TGA). PP-g-MAH provides better interfacial interactions between the two incompatible constituents, i.e. PP and nanoclay facilitates the exfoliation and dispersion of clay in PP matrix. FTIR analysis shows the effects of functional groups in the nanoclay with respect to potential interactions with the constituents. SEM Shows the microstructure of bulk specimen and phase arrangement of polymer nanocomposites of different constituent also studied.

1. INTRODUCTION

The polymer nanocomposites (PNC) have been reported to exhibit equivalent mechanical properties than conventional composites. Moreover, the nano sized inorganic fillers seem to improve the thermal stability, flame retardance and anticorrosive properties of many composites with small effect on the density and the optical properties (Carraher, 2007). Nano composites can be widely used in the automotive industries. They can also be used in the construction and coating industries (Lee et al., 2008). The effects of clay, wood flour and compatibilizer on the melting and crystallization behavior, mechanical properties and morphology of PP/clay/ wood flour nanocomposites were studied (Yong Lai Lu et al., 2007). The Al_2O_3 nanoparticles were well dispersed in the PP matrix by melt compounding method after particle surface treatment with silane coupling agent. Both Young's modulus and tensile yield strength values are improved, indicating the interaction between the two components is strong enough to restrict the macromolecular shear yielding. By SEDN-4PB technique, some craze like damages and micro cracks can be observed adjacent to the crack tip damage zone where only stable crack propagation takes place. Further work on fracture mechanisms of Al_2O_3/ PP nanocomposites is now under investigation (Liu et al., 2004). This great improvement in modulus is mainly due to the formation of strong clay layers network structures. This field can still be considered to be in its beginnings. In particular, the development of accurate nano mechanical models, and understanding of the properties of the polymer at the interface are required to address the outstanding issues of the polymer-nanoparticles interface and thus optimize the mechanical performance of polymer nanocomposites. It is believed that one of the main issues in preparing good polymer matrix nanocomposites samples is the good dispersion of the nanoparticles in a polymer matrix (William Gacitua et al., 2005; Ling Chen, 2004).

2. EXPERIMENTAL METHODS

REPOL Polypropylene H110MA obtained from Reliance Industries limited India. PP-g-MAH material obtained from EXXON MOBIL INDIA PVT LTD % OF GRAFTING 0.75% of injection grade of exxlor po 1020. Mica silicate nanoclay from Sai Laminates India. Polypropylene, PP-g-MAH, and mica silicate nanoclay were melt compounding in ZE25 BERSTORFF High performance co rotating Twin screw extruder.

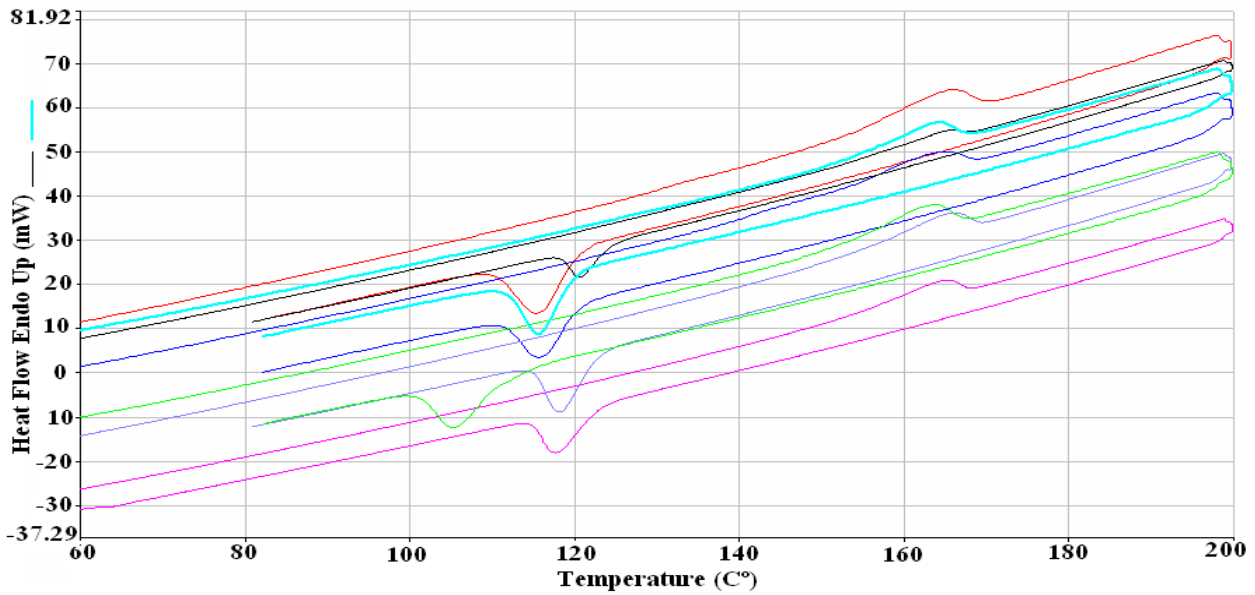[*] Gautam Kumar Sah Tel.: +919872242201
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Fig. 1: DSC Curve for PP / PP – g-MAH / Mica silicate composites with various compositions

PP90%-PP-G-MAH5%-MS5%
PP75%-PP-G-MAH5%-20%MS
PP-85%G-MAH-5%-10MS%
PP-80%-G-MAH5%-15%MS
Virgin PP
PP90%-PP-G-MAH2%-MS8%
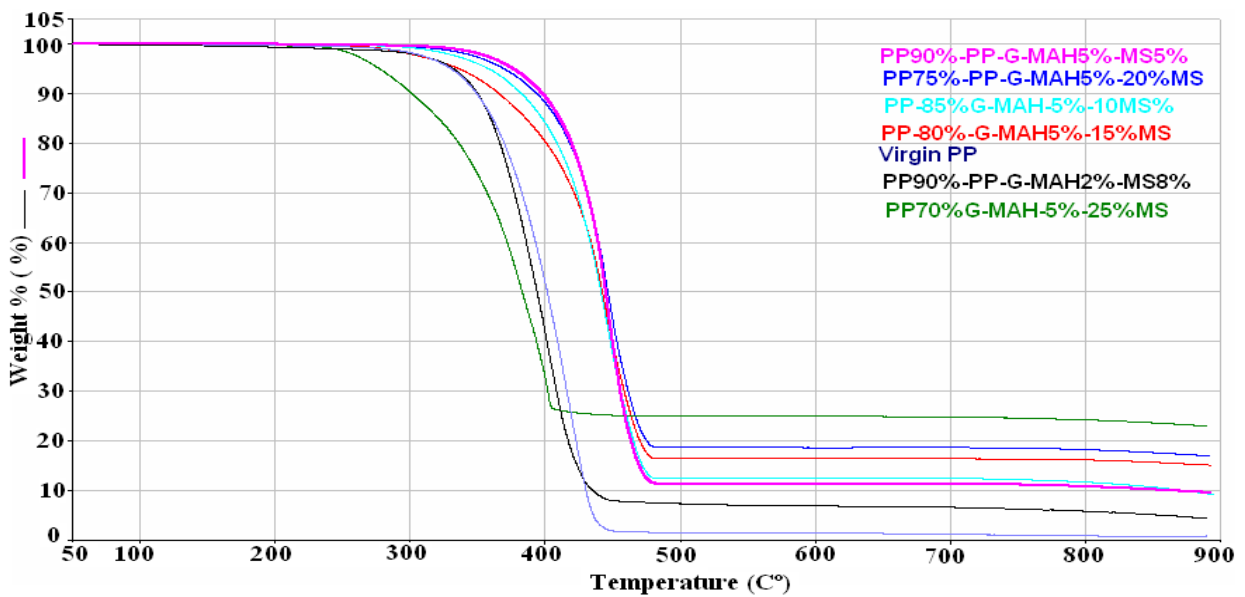PP70%G-MAH-5%-25%MS

Fig. 2: TGA Curve for PP / PP - g-MAH / Mica silicate Nanoclay Nanocomposites with various compositions

The compounding temperature was 170, 190, 200, 210, 220, and 230. Screw speed 140-150 rpm to produce compounded pellet containing 5, 8, 10, 15, 20, 25 % mica silicate. The compounded samples material obtained in pellet form then after compounded pellet dried 90 °C in a vacuum oven for 2 hours compounding and injection molding.

Specimens are prepared by injection molding machine for mechanical, thermal, electrical test under ASTMD STANDARD for specimen preparation. Thermo gravimetric analyzer (PERKIN ELMER, USA, PYRIS 1 TGAC) and Differential scanning calorimeter (PERKIN ELMER, USA, PYRIS DIAMOND DSC) experiments were performed for thermal analysis. The dielectric strength is determined by the test procedure according to ASTM D 149. The electronic structures of samples were examined using FT-IR spectrometer (Thermo scientific, Germany). The surface morphology of samples observed with SEM (HITACHI S3000N).
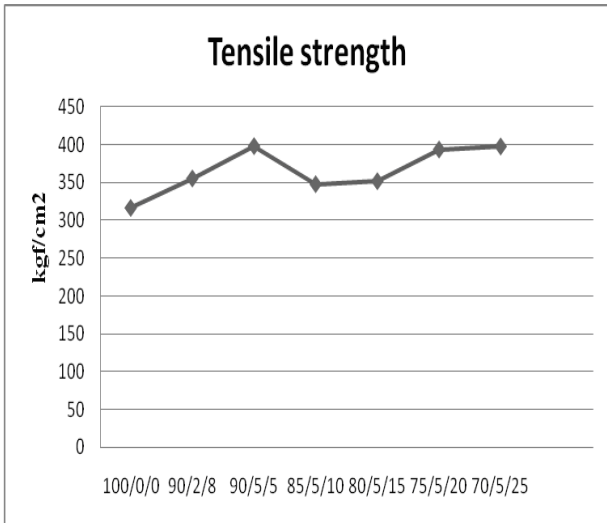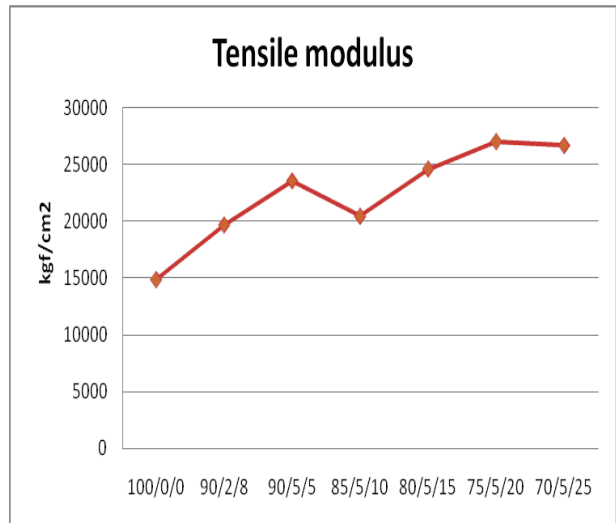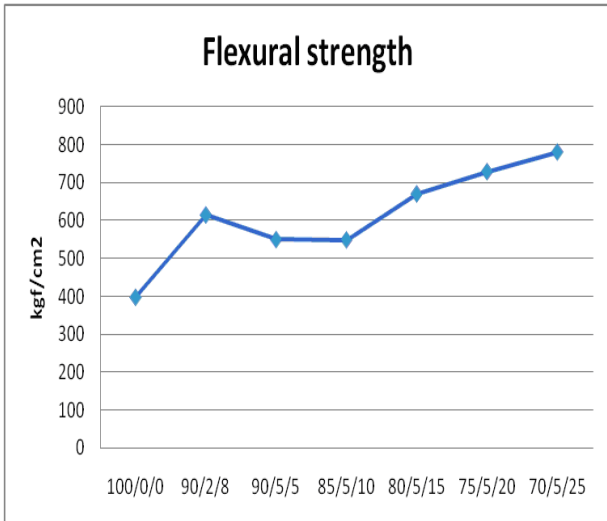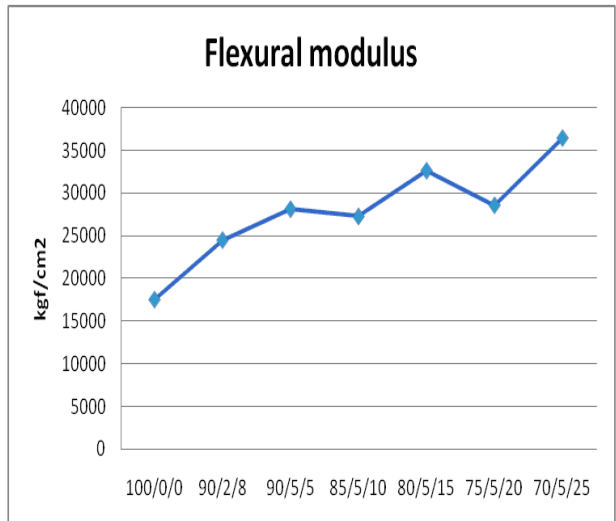
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Fig.3

Fig.4

Fig.5

Fig.6

Fig. 3, 4, 5 and 6:   Tensile Strength, Tensile Module, Flexural Strength, Flexural Modules

3. RESULTS AND DISCUSSIONS

All polymer nanocomposites systems had a higher melting temperature(Tm), compared to neat pp. Neat pp had the lowest Tm 162.7 ^{o}C . The increasing loads of mica silicate affect the Tm of polymer nanocomposites up to 2.1^{o}C. The enthalpy (ΔHm) of caloric processes was determined at the heating rate of 10 ^{o}C/min.   The ΔHm of neat pp at transition temperature was 56.58 j/g, but the ΔHm value with different mica silicate clay loading level ranged from 33.5919 j/g to 46.4054 j/g, indicating the increasing thermal stability. The crystalline peak temperature of PP was 105.61 ^{o}C and addition of clay and PP-g-MAH act as a nucleating agents, which increase the crystallization temperature of nanocomposites 120.80 ^{o}C.   The crystalline enthalpy (-ΔHm), of neat pp was 84.5059j/g. As clay, PP-g-MAH were added, the crystalline enthalpy increased. Since, the addition of clay interested with crystallization. DSC curves for endothermic and exothermic are shown in Fig. 1.

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3.1 Mechanical Properties

Table 1. shows the tensile strength and modulus of neat PP 316.5 and 14905.7 kgf/cm^2 respectively. The addition of mica silicate (5, 8, 10, 15, 20, 25%) and PP-g-MAH (2% & 5%) to PP increased the tensile strength and modulus up to 397.861 and 26681.8 kgf/cm^2 compared with those of neat PP. Thus addition of mica silicate and PP-g-MAH for systems increased the tensile modules and strength compared with the neat PP. From these results, the high tensile strength is seen to be an intercalation phenomenon of clay layers by PP-g-MAH, which are shown in Fig. 3, 4, 5 and 6.

3.2 Dielectric strength

Polymer nanocomposites containing 0 wt%, 5 wt%, 8 wt%, 10 wt%, 15 wt%, 20 wt% and 25 wt% respectively. The dielectric strength is increasing as per clay loading. Mica has greater dielectric strength than any other insulating material (Fig. 7).

3.3 Scanning electron microscopy

Fig. 8 shows the phase morphology polymer nanocomposites containing 5 wt%, 8 wt%, and 10 wt%, 15 wt%, 20 wt% and 25 wt% addition of mica silicate respectively. The SEM photomicrographs shows that phases morphology are clearly visible for all systems and the Clay dispersed randomly and uniformly within the nanocomposites.
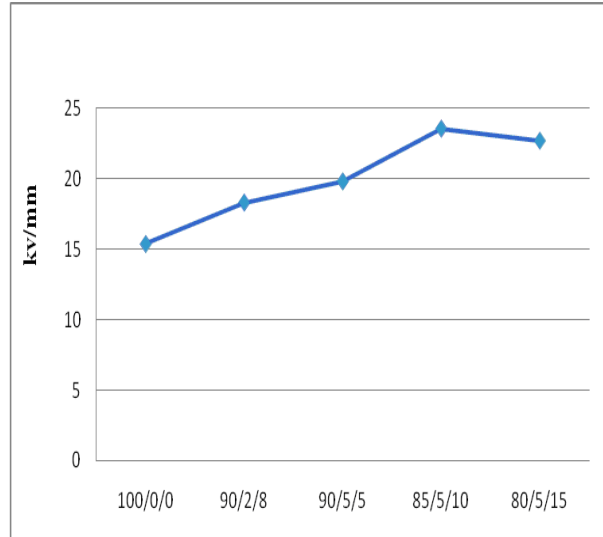

Fig. 7: Dielectric Strength

Table 1. Mechanical Properties of PP / PP -g-MAH / Mica silicate Nanocomposites with various compositions

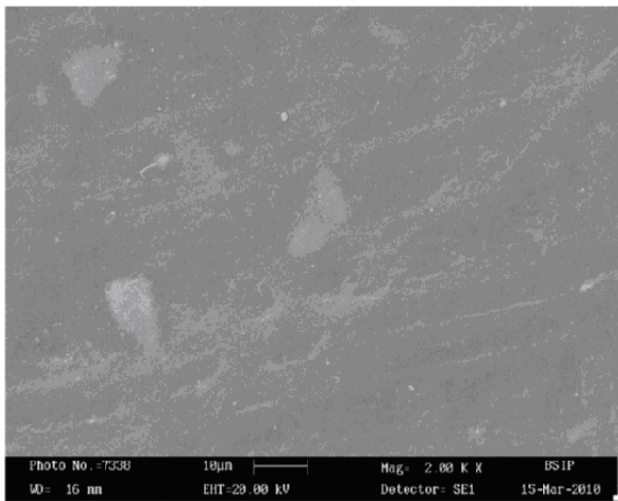| pp/pp-g-MAH/mica silicate	Tensile Strength yield (kgf/cm^2)	Tensile modulus (kgf/cm^2)	Flexural strength (kgf/cm^2)	Flexural modulus (kgf/cm^2)
100/0/0	316.5	14905.7	398.2	17550
90/2/8	355.279	19704.6	614.6	24520
90/5/5	397.861	23564.5	549.9	28133
85/5/10	347.805	20461.0	549.16	27283.4
80/5/15	351.680	24608	670	32640
75/5/20	393.393	27019	728.4	28600
70/5/25	397.499	26681.8	780.2	36460
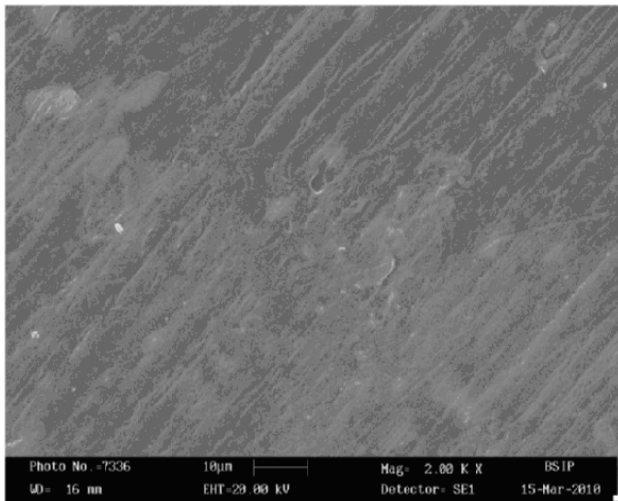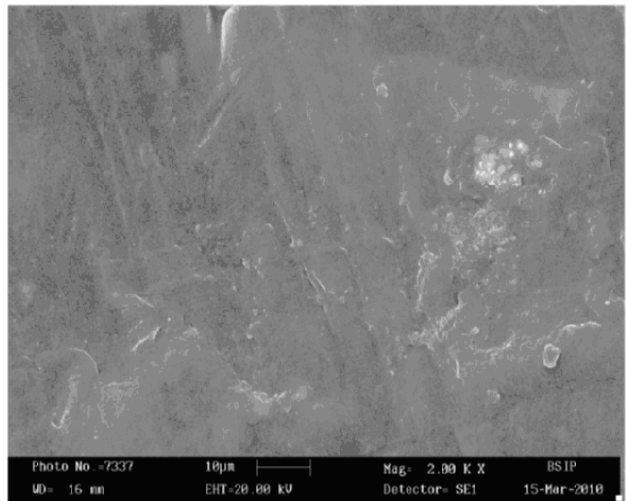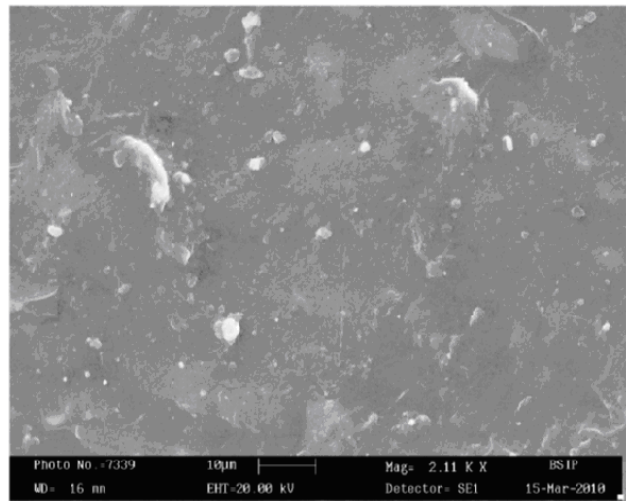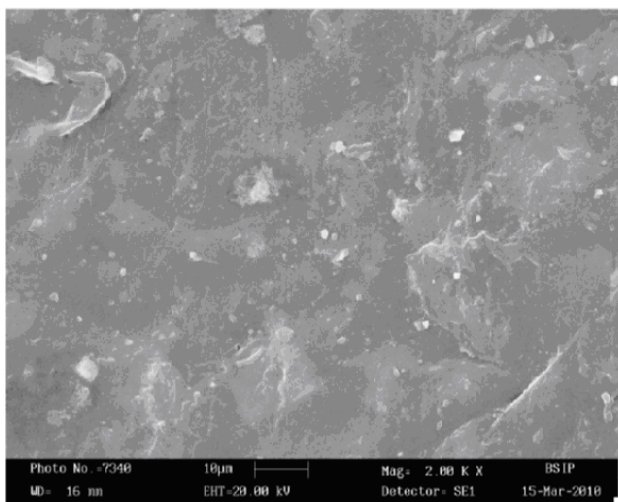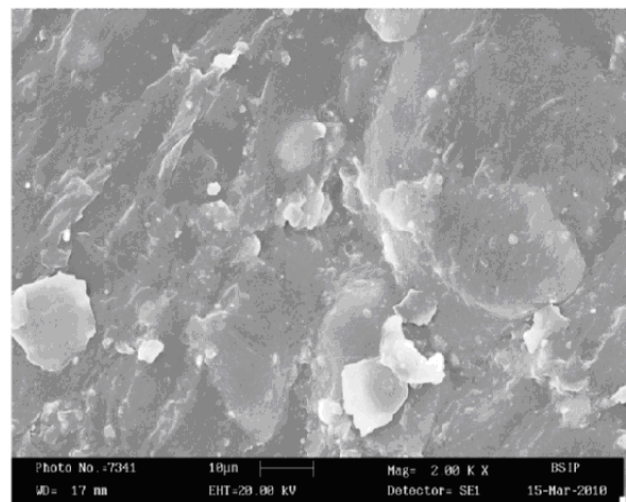
Fig. 8: SEM images of PP / PP - g-MAH / Mica silicate Nanoclay Nanocomposites containing 5 wt%, 8 wt%, 10 wt%, 20 wt% and 25 wt% of Mica silicate respectively.
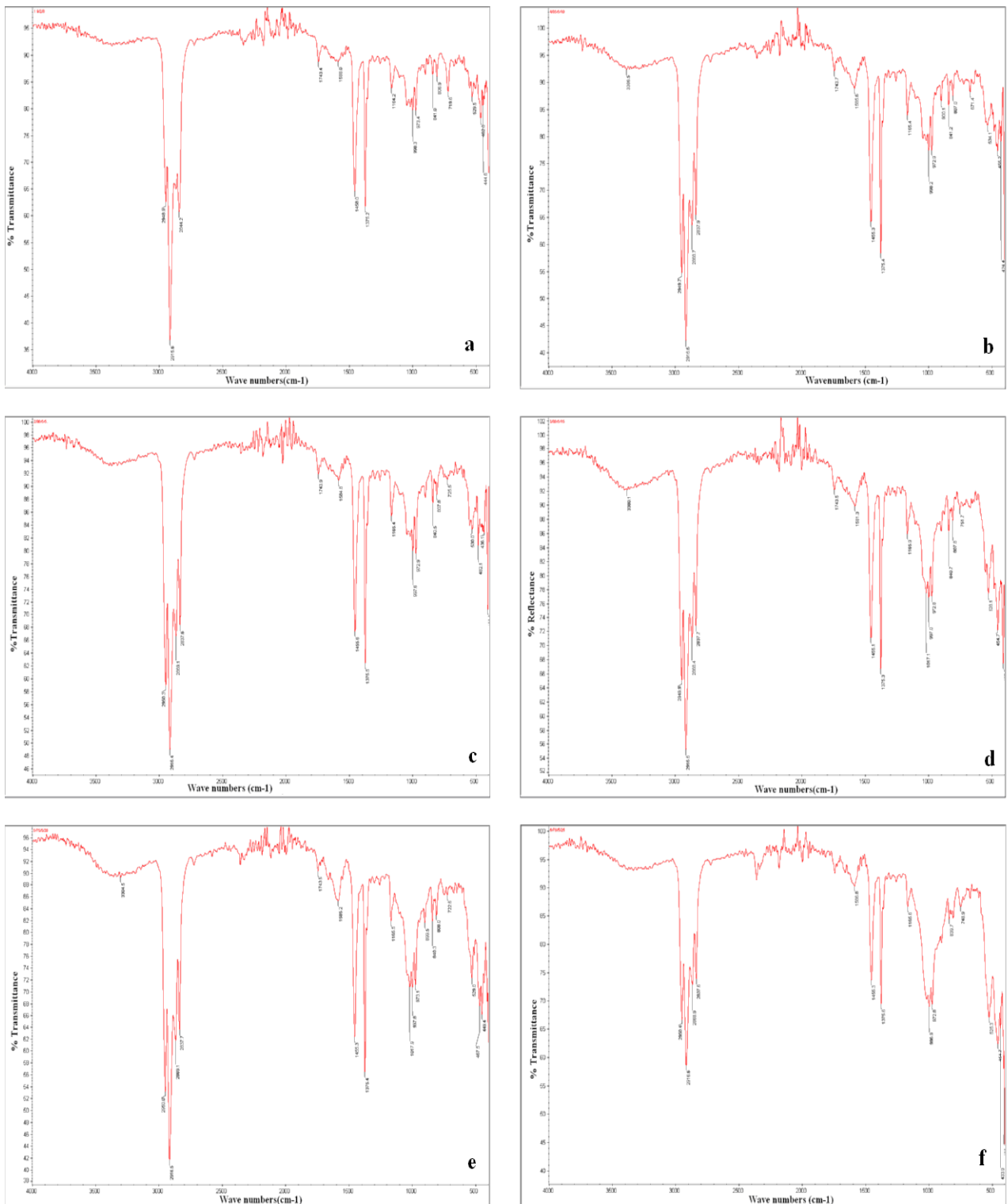
Fig. 9: **FTIR Spectral data of Nanocomposites containing 5 wt%, 8 wt%, 10 wt%, 20 wt% and 25 wt% addition of Mica silicate respectively.**

3.4 FTIR Studies

It is important to gain information on interfacial interactions but it is necessary to differentiate between interaction at interfaces and in the bulk due to partial miscibility. Radiation energy in the infrared region is absorbed by the organic compound and converted in to energy of molecular vibration.

The energy absorption pattern thus obtained is commonly referred to as an infrared spectrum which has the plot of intensity of radiation absorption versus wavelength of absorption (Fig. 9).

4. CONCLUSIONS

The dielectric strength is increasing as per clay loading. Nanocomposites have greater dielectric strength than any other insulating material. It is almost insensitive to atmospheric weathering and offers greater resistance to chemical. Electrical Apparatus, Electric Heating, Appliances, Electrical, Control, Electrical Lighting Equipment, Industrial Electric Heating Appliances, Mechanical Uses, Miscellaneous Electrical Uses, Radio, Radar, Television, Motors and Generators Transformers. Nanocomposites material gives better surface appearance than those attributed by glass fiber reinforcements. Automotive industry will use as a substitute of glass fiber.

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