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ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.3, pp 1757-1759, May-June 2014

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

Effect of concentration of nano-Al_2O_3 on mechanical and dielectric properties of plasticized poly(vinyl chloride) nanocomposites

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Abstract: In this paper, effect of concentration of nano-Al_2O_3 on structural, mechanical and dielectric properties were studied. Nanocomposites based on nano-filler (Al_2O_3) with polymer (PVC) are obtained by preparation using melt blending process with plasticizers and heat stabilizer. The nanoparticles were varied in four different concentration, such as (1,2,4 and 6 phr) of nano-Al_2O_3 in the blend system. Structural properties are examined from FTIR-ATR and XRD analysis. Mechanical properties studied using UTM. Tensile strength results indicated that the reinforcement in the nanocomposites was more effective than that in the pristine PVC. The increment of Young's modulus of nanocomposites from 1 to 6 per is about 75%, which is higher than pristine PVC. Dielectric properties of plasticized PVC (p-PVC) nanocomposite sheets were carried out in the frequency range from 20 Hz to 1 MHz at various DC bias potentials using the LCR meter impedance analyzer. In the p-PVC nanocomposites, dielectric constant values are increased upto 4 phr whereas with the addition of higher concentration of nanoparticles, the dielectric constant values are decreased for 6 phr content of nano-Al_2O_3. It can be used as a good electrical insulation for different electronic devices.
Keywords: PVC, nanocomposites, mechanical, structural and dielectric.

Introduction and Experimental:

Poly (vinyl chloride) (PVC) is a well known resin and can be molded in various rigid or plasticized forms. It is an important commercial thermoplastic, which is widely used in industrial fields due to its good properties, low cost and durable applications such as pipes, windows profile, wire and cable insulations. However, one of the least stable thermoplastic due to its low thermal stability, brittleness and poor process ability limit its applications. It will degrade during the melt compounding process without heat stabilizer or plasticizer. During the compounding process heat stabilizer such as Calcium (Ca), Zinc(Zn) and Lead(Pb) or plasticizers such as dioctyl phthalate (DOP), diisoctyl phthalate (DIOP) and dicapryl phthalate (DCP) are used for PVC and its copolymer to stabilize the processing and add flexibility to the finished product[1,2].

We have dispersed unmodified nano-Al_2O_3 particles in PVC through melt compounding process and optimize the particular concentration of nano-Al_2O_3 for improving the performance of the p-PVC matrix. However, preventing nanoparticles from aggregation is the key to achieve a desired performance [3].

Specimen preparation: p- PVC nanocomposites (p-PVCNC) were formulated with 100 parts per hundred resins (phr) of PVC, 2 phr heat stabilizer (Pb), 30 phr dioctyl phthalate (DOP), and various concentrations of nano-Al_2O_3 from 1 to 6 phr. The ingredients were first dry blended in a high speed rotating mixer for 10 min and then plasticized by a laboratory two roll mill at 175^{0}C for 10 min. All of milled sheets were cooled at room temperature and then fragmented into powder through crushers, the compounds were then compression molded to plates at 185^{0}C for 10 min with 5 min preheating period. Specimens of 2 mm thick for mechanical and electrical testing were cut from the compression molded sheets. All the test was performed at room temperature and five measurements were carried out for each data point.

Results and Discussion:

FTIR-ATR spectra of p-PVC and p-PVCNC are shown in Figure 1. The IR spectra can provide a sensitive measure change between p-PVC and p-PVCNC. The strong bands at 692 and 660 cm^{-1} are due to the C-Cl is stretching vibrations of PVC chains, while the band at about 1124.42 cm^{-1} and 1029. 92 cm^{-1} for the oxide bands of metals (Al and Pb) which agree well with reported data. As such no chemical interaction happened between p-PVC and nano-Al_2O_3 particles. No new peak appears in the spectra. This indicates that an ordering takes place in PVC due to the effect of partly disentanglement of polymer chains in DOP after adding the nanoparticle the concentration of DOP reduces due to deformation in p-PVC.

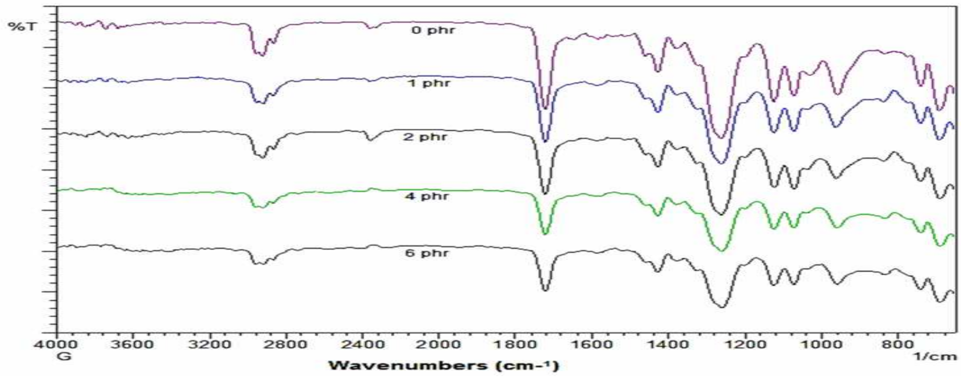

Figure1. FTIR-ATR spectra of p-PVC and p-PVCNC of various concentrations (0-6phr) of nano-Al_2O_3.

From the XRD analysis, nano-Al_2O_3 dispersed in PVC matrix very well and has broken nanoparticles agglomeration upto certain level of concentration. It may be due to shearing and temperature effect which leads to better results

Mechanical properties of p-PVC and p-PVCNC: Effect of nano-Al_2O_3 concentrations on tensile properties of p-PVCcomposites are shown in Fig.2. It reveals that Young's modulus of the p-PVCNC at lower concentrations of nano-Al_2O_3 has a higher modulus than the p-PVC matrix. It leads to an obvious increase in the modulli of nanocomposites compare with the higher concentration (6 phr) of nano-Al_2O_3 content which has a slightly lower modulus or leveled off but it is greater than p-PVC matrix. This phenomenon may be caused by the better dispersion of nano-Al_2O_3 particles in the matrix at lower concentrations and poor dispersion or agglomeration of nano-Al_2O_3 particles in the matrix at higher concentration of content [4]. Tensile strength was increased with increasing the nano-Al_2O_3 content in the p-PVC matrix. Elongation at break decreases with increasing concentration of nano-Al_2O_3 content in the p-PVC matrix due to the restriction of polymer chain movements [5].

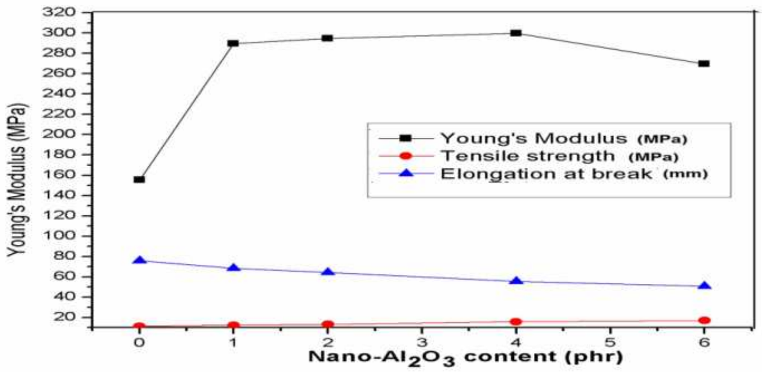

Figure 2. Young's Modulus, Tensile strength and elongation at break of p-PVC and p-PVCNC

Dielectric properties: The variation of dielectric constant and dielectric loss as a function of frequency at various bias voltages shown in Fig. 3. The value of dielectric constant increases with increasing DC bias voltage and decreases with increasing frequency. Similar behavior was noticed in the literature. The increase in dielectric constant as the bias voltage raised can be explained by the resulting increase in mobility of polar groups and decrease in density which allows the molecule's orientation of such groups. The decrease of dielectric constant with the frequency may be caused by dielectric dispersion and insufficient time for orientation of molecules [6].

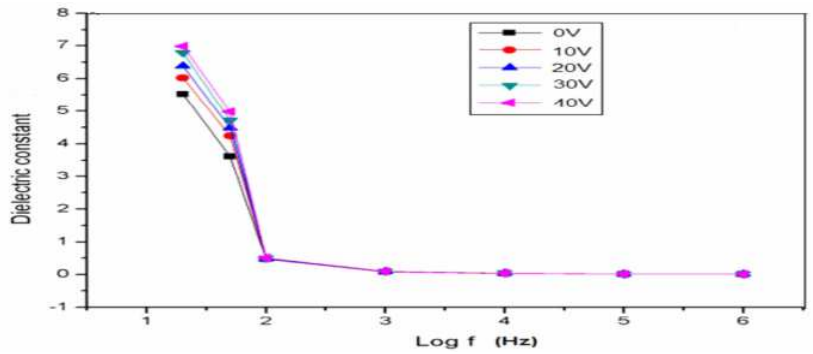

Figure 3. Dielectric constant as a function of frequency of p-PVC.

Conclusion: Nanocomposites of p-PVC were prepared via melt compounding process. Structural analysis shows that an ordering takes place in p-PVC due to the partly disentanglement of polymer chains in the DOP. The XRD analysis shows that nano-Al_2O_3 was dispersed in p-PVC matrix may be due to shearing and temperature effect which might have broken nanoparticles agglomeration. It is clear that the effect of nano-Al_2O_3 concentration influences p-PVC matrix, which is responsible for the mechanical improvement with nano-Al_2O_3 content. Further investigation is under progress for the establishment.

Acknowledgement : Authors gratefully acknowledge University Grants Commission (UGC-SAP) India for the research fellowship and consumable grant.

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