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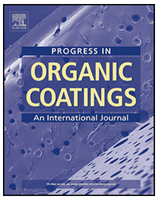

The utilization of poly(amide-imide)/SiO_2 nanocomposite as nanofiller for strengthening of mechanical and thermal properties of poly(vinyl alcohol) nanocomposite films

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ABSTRACT

The present investigation reports the preparation and characterization of the thermally stable poly(vinyl alcohol)/(poly(amide-imide)-SiO_2) nanocomposite (PVA/PAI-SiO_2 NC) films. For this reason, the surface of SiO_2 nanoparticles (NPs) was modified with *N*-trimellitylimido-L-methionine and subsequently, 5 wt.% of modified SiO_2 NPs were dispersed in the PAI matrix via sonochemical reaction. The resulting NC was studied by different techniques. Finally, the PAI-SiO_2 NC was employed as nanofiller and was incorporated into the PVA matrix for the enhancement of its mechanical and thermal properties. The synthesized NCs were studied by Fourier transform infrared and X-ray diffraction spectroscopy analysis. The surface topography and morphology of the NCs were studied by atomic force microscopy techniques, field emission scanning electron microscopy and transmission electron microscopy. The micrographs demonstrated that the nanofillers were homogeneously dispersed in the PVA matrix. The thermo gravimetric analysis curves indicated that the thermal decomposition of the PVA/PAI-SiO_2 NC films shifted toward higher temperature in comparison with the pure PVA. The effect of nanofiller on the mechanical properties of NC films was also explored.

1. Introduction

Nanocomposites (NCs) are a class of high performance materials containing several phases, where at least one of the dimensions of the fillers is in the range of 1–100 nm. NCs owing to the nanometer-size effect, present distinct of functional properties such as, mechanical, thermodynamic, electric, magnetic and optical, which could be optimized for an exacting application. Polymer NCs reinforced with inorganic fillers show excellent mechanical properties and thermal, chemical and physical resistance [1–3].

Poly(vinyl alcohol) (PVA), due to good film-forming nature, hydrophilicity, biodegradability, biocompatibility, water solubility, processability and good chemical resistivity was extensively utilized in protein purification, dialysis membrane separation, artificial skin, artificial cartilage, enzyme immobilization, biomechanical applications, adhesives coatings and paints [4–7]. Due to broad application of PVA, many studies have been performed to enhance the properties of this polymer. In order to improve the thermal stability, modulus and strength of PVA, a novel class of engineering-designed PVA NCs reinforced with nanoparticles (NPs) has been fabricated recently [8]. For example, NPs such as, NiO [6] CuO [9] Ag [10], Fe_2O_3 [11] Al_2O_3 [12], SiO_2 [13], and organoclay [14–16] were added in PVA matrix in order to improve the properties of PVA.

Aromatic poly(amide-imides) (PAIs) are very useful high-performance polymers with high glass transition temperature, high thermal stability, good mechanical strength and chemical resistance. PAIs display superior processing characteristics than those of poly imides of analogous structures. So, these polymers can be a good candidate for the preparation of NCs [17,18].

SiO_2 is one of the most significant amorphous NPs for many applications such as, polishing material, chemical sensors,

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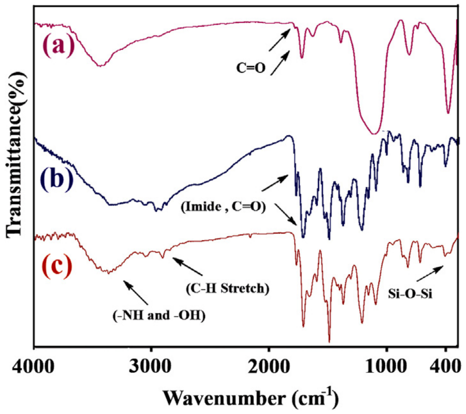

Fig. 1. FT-IR spectra of (a) modified SiO_2 NPs, (b) pure PAI and (c) nanofiller.

varistors, catalysts, solar cells, piezoelectric and luminescent tools and cosmetic materials [19].

The aim of this investigation is the reinforcement of the PVA with PAI-SiO_2 NC as nanofiller and study of the effects of this nanofiller on the morphology, thermal stability and mechanical properties of polymer NCs. For this purpose, for the first time, the PVA NCs reinforced with PAI-SiO_2 NC were produced by ultrasonic technique and further were characterized with different analysis such as, Fourier transform infrared spectra (FT-IR), X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM) atomic force microscopy (AFM) and thermo gravimetric analysis (TGA).

2. Experimental

2.1. Materials

All chemicals and solvents were achieved from Merck (Darmstadt, Germany), Fluka Chemical Co. (Buchs, Switzerland), and Aldrich Chemical Co. (Milwaukee, WI). Trimellitic anhydride, tetrabutylammonium bromide (TBAB), L-methionine amino acid, triphenyl phosphite (TPP) and PVA 99% hydrolysis (Mw = 145,000 g mol^{-1}) were purchased from Merck Co. and were used without further purification. Nanopowder SiO_2 was purchased from Neutrino Co. (Tehran, Iran) with average particle

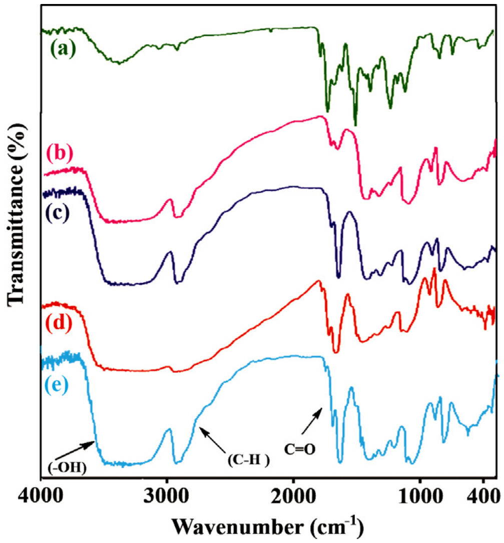

Fig. 2. FT-IR spectra of (a) nanofiller, (b) pure PVA, (c) PVA/PAI-SiO_2 NC 1 wt.%, (d) PVA/PAI-SiO_2 NC 3 wt.%, and (e) PVA/PAI-SiO_2 NC 5 wt.%.

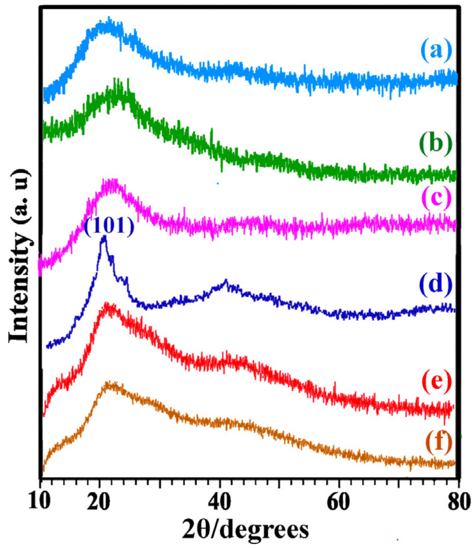

Fig. 3. XRD patterns of (a) pure PAI, (b) pure SiO_2, (c) nanofiller, (d) pure PVA, (e) PVA/PAI-SiO_2 film 3 wt.% and (f) PVA/PAI-SiO_2 film 5 wt.%.

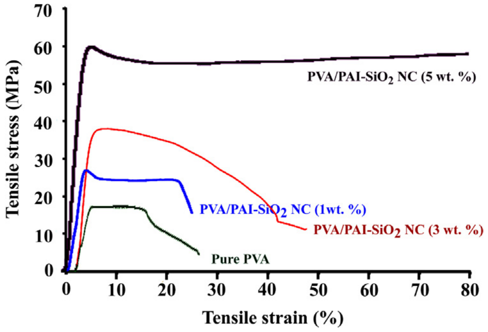

Fig. 4. Stress–strain curves of PVA and PVA/PAI-SiO_2 NC films.

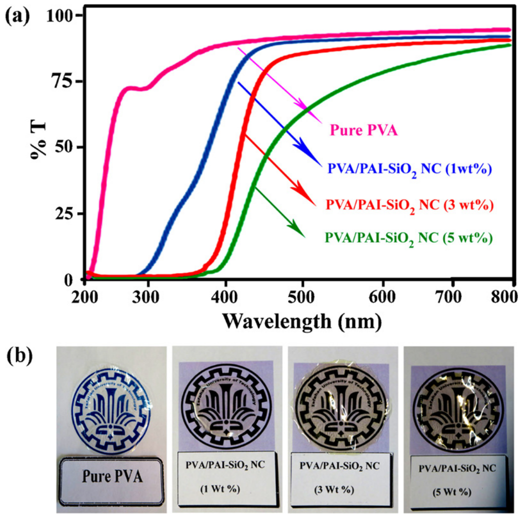

Fig. 5. (a) UV–vis transmittance spectra and (b) visual transparencies of the pure PVA and PVA/PAI-SiO_2 NCs.