Journal of Industrial and Engineering Chemistry 30 (2015) 295–301

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

journal homepage: www.elsevier.com/locate/jiec

Fabrication of polyvinylchloride based nanocomposite thin film filled with zinc oxide nanoparticles: Morphological, thermal and optical characteristics

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ARTICLE INFO

Article history:
Received 27 January 2014
Received in revised form 20 January 2015
Accepted 27 May 2015
Available online 10 June 2015

Keywords:
Nanocomposite
PVC based film
Zinc oxide nanoparticles
Fabrication
Morphological/Thermal/Optical characteristic

ABSTRACT

PVC-co-ZnO nanocomposite film was prepared by solution casting technique with different concentration of zinc oxide nanoparticle. Optical measurements showed that utilizing zinc oxide nanoparticle in polymeric matrix caused to increase of UV absorption obviously. X-ray diffraction showed polycrystalline structure with no preferred orientation for prepared nanocomposite films. Atomic force microscopy images also showed smooth surfaces for the nanocomposite films. The thermal properties investigation of prepared films revealed that utilizing ZnO nanoparticles in polymeric matrix accelerated the polymer decomposition which was assigned to catalytic behavior of zinc oxide nanoparticles. Moreover, utilizing zinc oxide nanoparticles enhanced the char yield of prepared films.

Introduction

Nowadays nanocomposites play an important role in diverse industries and also daily human life. Utilizing metal nanoparticles into polymeric matrices has been examined widely to improve features and capacities such as mechanical, electrical, thermal and optical properties [1–4].

ZnO is a wide direct band gap semiconductor (3.2–3.4 eV) and have a large exaction binding energy (60 meV) at room temperature which makes it a promising material for electronic and optoelectronic applications such as solar cells, gas sensors, heat mirrors, surface acoustic wave devices and etc. [5–7].

Zinc oxide is also one of the most important inorganic material which has been served as catalyst for chemical reactions, photo catalysts and photoelectric conversion, UV-shielding materials and especially antibacterial agent [8–11]. Moreover ZnO is considerable because of low prices, lightness, semi-conducting properties and ease of accessibility compared to metal oxides. It is known that UV radiation can cause foods' spoiling. So, using zinc oxide nanoparticles in plastic food covers could prevent the foods' spoiling due to UV-shielding and antibacterial properties. Also due to the transparency of ZnO, plastic food covers will be nearly transparent [12–14].

For the purpose, polyvinylchloride based nanocomposite films were prepared by solution casting technique using different concentration of zinc oxide nanoparticle. The effect of ZnO nanoparticles concentration in the casting solution on physico-chemical properties of prepared film was studied.

Polyvinylchloride (PVC) is a flexible and durable polymer with suitable mechanical, biological and chemical resistance [15] which has been extensively used in various applications like pipes, house siding, toys, medical supplies, wire cable insulation and windows profiles [16].

In order to improve the PVC physico-chemical properties such as fire resistance and etc., various filler additives such as zinc borate, zinc oxide, antimony is used necessarily during the production process [17].

Also utilizing zinc oxide nanoparticles into polymeric materials results in a composite with special properties such as good flexibility and antibacterial behavior which make it useful in medical applications [18]. In addition due to luminescence attributes of ZnO nanoparticles, it can be utilized as flexible display in LEDs [19]. Also due to ultraviolet absorption aspect of ZnO, makes it a good candidate for anti UV applications [13].

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http://dx.doi.org/10.1016/j.jiec.2015.05.036
1226-086X/

Although some works on PVC and ZnO have been carried out, but few reports considered adding zinc oxide to PVC for special purposes such as UV absorption, antibacterial properties [20,21] and separation process [22–24].

In this study PVC-co-ZnO composite films were prepared by solution casting technique and the effect of nanoparticles concentration on physico-chemical properties of polymeric film such as optical, structural/morphological and thermal characteristics was studied.

Experimental details

Polyvinylchloride (PVC, grade S-7054, high porosity, bulk density: 490 g/lit) was used as binder. Tetrahydrofuran (THF) was applied as solvent and zinc oxide nanoparticles (ZnO nano-white powder, Merck Inc.) was used as inorganic filler additive.

One gram of PVC was dissolved in 20 ml of THF. The solution was mixed for 1 h with a mechanical stirrer (Model: VelpSientifica Multi 6 stirrer). This was followed by dispersing of ZnO nanoparticle as filler additive (0.0%wt, 5.0%wt, 10.0%wt, 15.0%wt and 20.0%wt) in polymeric solution. The mixture was mixed vigorously at room temperature to obtain uniform particle distribution. In addition, for better dispersion of particles and breaking up their aggregates, the solution was sonicated for 1 h using an ultrasonic instrument. Then, the mixing process was repeated for another 30 min using the mechanical stirrer. The mixture was then cast onto a clean and dry glass plate at 25 °C. The samples were dried at ambient temperature. The nanocomposites films' thickness was measured around 50 μm.

Optical study was carried out by using a double beam spectrophotometer (Camspec model 350), with wavelength of 200–1100 nm. The transmittance (T) and absorption coefficient (α) of samples were studied.

To study the surface morphology and roughness of prepared films atomic force microscopy was carried out (AFM, Park Scientific Instrument).

Moreover, structure of prepared composite samples was examined by X-ray diffraction (XRD, Philips PW 3373, 1.54 Å).

Fourier-transformed infrared (FTIR) spectra measurements were carried out using Galaxy series FTIR 5000 spectrometer in spectral rang of 400–4000 cm^{-1}. The photoluminescence (PL) spectra at room temperature was recorded using luminescence spectrometer (Model LS-5, Perkin-Elmer, USA, Xenon lamp) by excitation wavelength of 325 nm.

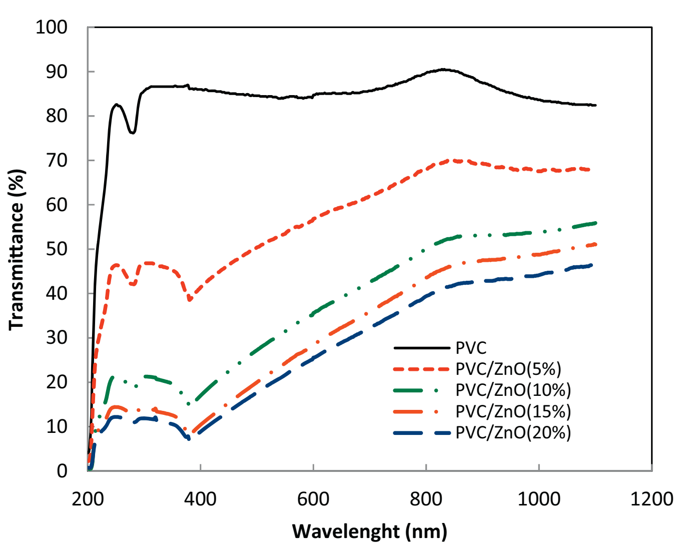

Fig. 1. Transmittance spectra of pure PVC and PVC/ZnO nanocomposite films.

Scanning optical microscopy was also carried out using a microscope (Olympus–BX51, camera: DP71).

The thermal behavior analysis of prepared nanocomposite films with various ratios of additive loading was investigated by thermo

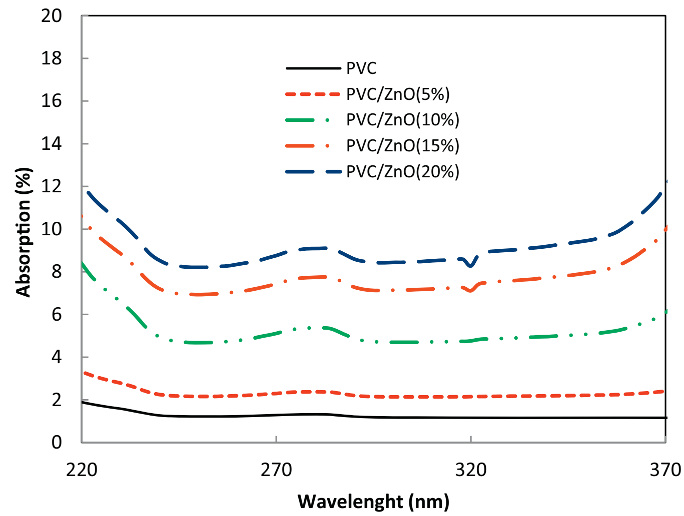

Fig. 2. Absorption of PVC and PVC-ZnO nanoparticles nanocomposite films.

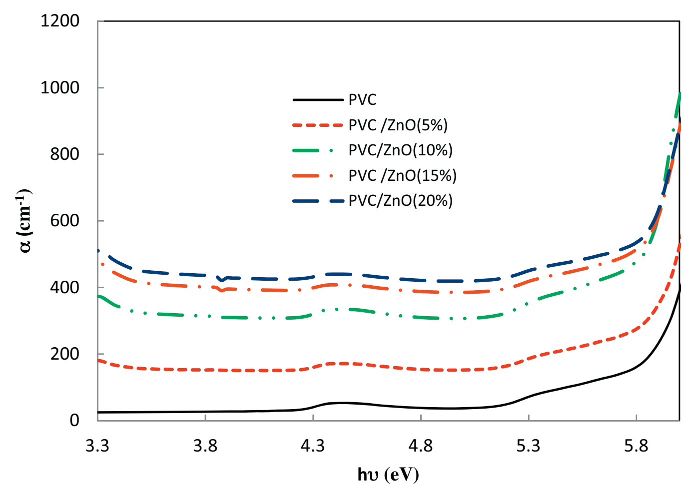

Fig. 3. Absorption coefficient of pure PVC and PVC filled with different content of ZnO nanoparticles.

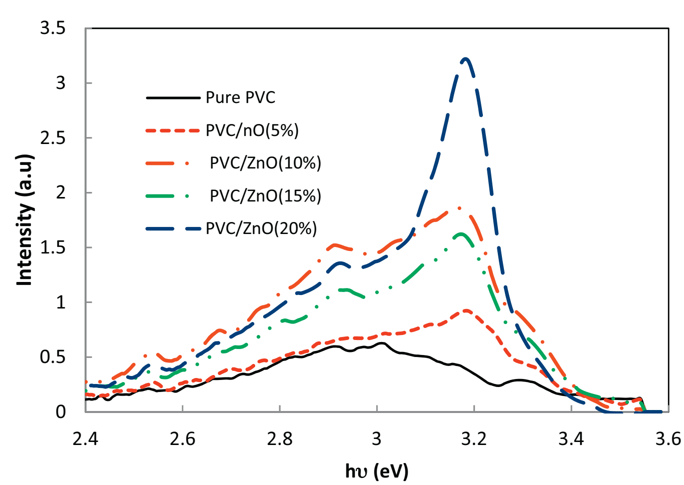

Fig. 4. The photoluminescence intensity of pure PVC and PVC-ZnO nanoparticle films.