Effect of nanosilica on optical, electric modulus and AC conductivity of polyvinyl alcohol/polyaniline films

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ABSTRACT

Nanosilica (NS) was synthesized by a sol–gel method and mixed with 0.98 polyvinyl alcohol (PVA)/0.02 polyaniline (PANI) in different amounts to produce nanocomposite films. High-resolution transmission electron microscopy (HR-TEM) revealed the average particle size of the NS to be ca. 15 nm. Scanning electron microscopy (SEM) showed that the NS was well-dispersed on the surface of the PVA/PNAI films. The Fourier transform infrared (FTIR) spectra of the samples showed a significant change in the intensity of the characteristic peak of the functional groups in the composite films with the amount of NS added. The absorbance and refractive index (n) of the composites were studied in the UV–vis range, and the optical energy band gap, E_g, and different optical parameters were calculated. The dielectric loss modulus, M'' and ac conductivity, σ_{ac}, of the samples were studied within 300–425 K and 0.1 kHz–5 MHz, respectively. Two relaxation peaks were observed in the frequency dependence of the dielectric loss modulus, M''. The behavior of $\sigma_{ac}(f)$ for the composite films indicated that the conduction mechanism was correlated barrier hopping (CBH). The results of this work are discussed and compared with those of previous studies of similar composites.

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1. Introduction

Polyvinyl alcohol (PVA) has fascinating properties and a wide variety of applications owing to its high dielectric strength and good charge storage capacity. Both its optical and electrical properties depend on the type of filler used. PVA has also gained increasing attention for biomedical applications [1]. PVA has a carbon chain backbone with hydroxyl groups that can act as a source of hydrogen bonding to enhance the formation of polymer complexes [2]. Polyaniline (PANI) has emerged as one of the most promising polymers for its ease of preparation, good environmental stability, and controllable electrical and optical properties. PANI has, therefore, been extensively studied and applied in diverse areas such as secondary batteries, anticorrosive coating, anti-static packaging materials, conductive coatings, capacitors, rotating machines, biosensors, electrostatic dissipation, optoelectronics, and electro-inactive materials [3–5].

PANI is known for its excellent thermal and environmental stability but poor processibility owing to its insolubility and brittleness, which limits its commercial applications. PANI can be made more processable in composites formed with other water soluble polymers such as, poly (vinyl pyrrolidone) (PVA), poly (acrylic acid), and poly (styrene sulfonic acid), which are used as stabilizers [6]. The stability of PANI dispersions in PVA has been reported to increase with PVA content [7], and the physical properties of PVA/PANI show a definite dependence on the ratio of these two polymers [8]. This further indicates the possible optimization of the ratio of the two polymers in the matrix to improve their specific optical and dielectric properties.

Nanosized silica (NS) particles have found large-scale applications in many every-day consumer products, ranging from automobile tires to optical fibers and catalyst supports. It has been reported that NS can increase the hardness and scratch resistance of a coating without affecting its optical clarity [9]. NS particles can also effectively improve the physical properties of polymeric materials [10]. For instance, NS particles have been widely introduced into polymer coatings to improve their heat resistance, wear resistance, hardness, and optical properties [11,12]. Polymer nanocomposites are a group of materials in which nanoparticles are dispersed in a polymer matrix. Compared with those of the pure polymers, polymer nanocomposites have different physical and mechanical characteristics including modulus, strength, hardness, flammability, dimensional stability, electrical conductivity, thermal resistance, and moisture absorption, depending on the type and amount of nanoparticles used [13–18].

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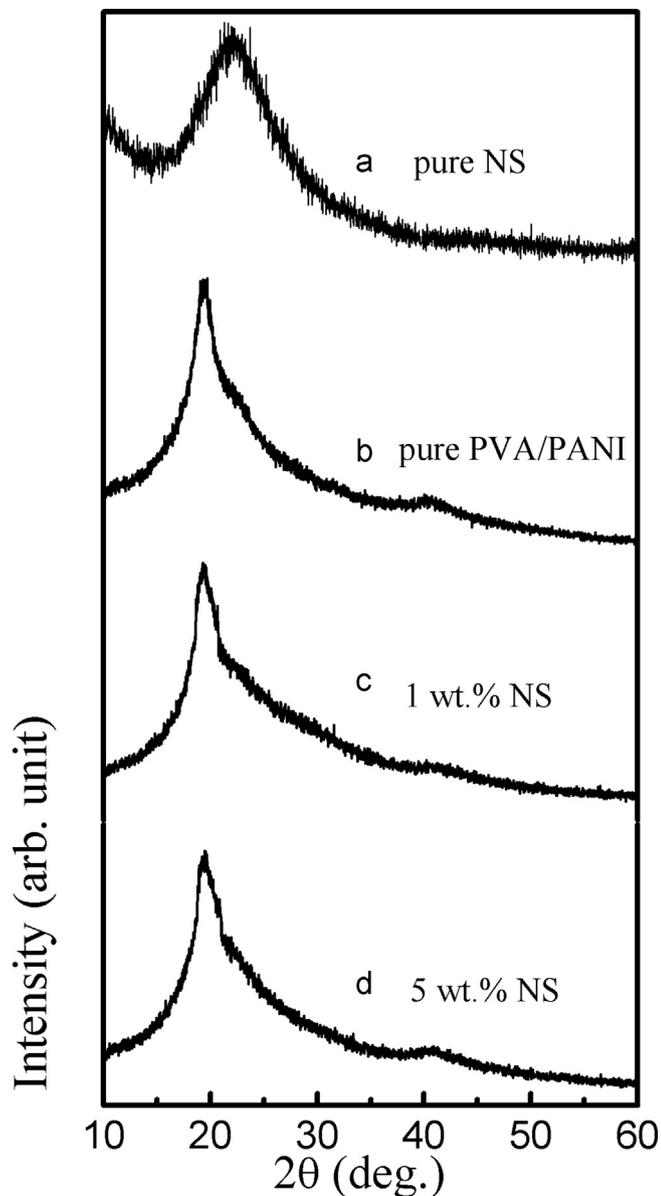E-mail address: somyia.elsayed@yahoo.com (S. El-Sayed).

Fig. 2. (a) HR-TEM image of pure NS. SEM images of some selected NS-doped PVA/PANI films: (b) 1 wt% NS, and (c) 5 wt% NS.

PANI–PVA–NiO (IPN) nanocomposite film containing nickel oxide nanoparticles uniformly dispersed in the polymer matrix has previously been successfully fabricated at room temperature [19]. Magnesium oxide (MnO_2)–loaded PANI/PVA thin films showed better response to ammonia and trimethyl ammine vapor than unloaded film [7]. X-ray diffraction (XRD) analysis revealed an increase in the crystallinity of these films with PVA concentration, with the possible interaction between PANI and PVA also indicated by Fourier transform infrared spectroscopy (FTIR). The non-ohmic I–V characteristics of the films suggest possible application in the field of device (particularly FET, etc.) fabrication [20].

PANI and its charge transfer complexes have been used as engineering materials owing to their unique electrochemical behavior, environmental stability, and high degree of processability. Extensive works on the preparation of electrically conductive PANI blends containing a polymeric matrix having desirable physical and mechanical characteristics represent a promising route to overcome the intractability of PANI. In this work, we aimed to
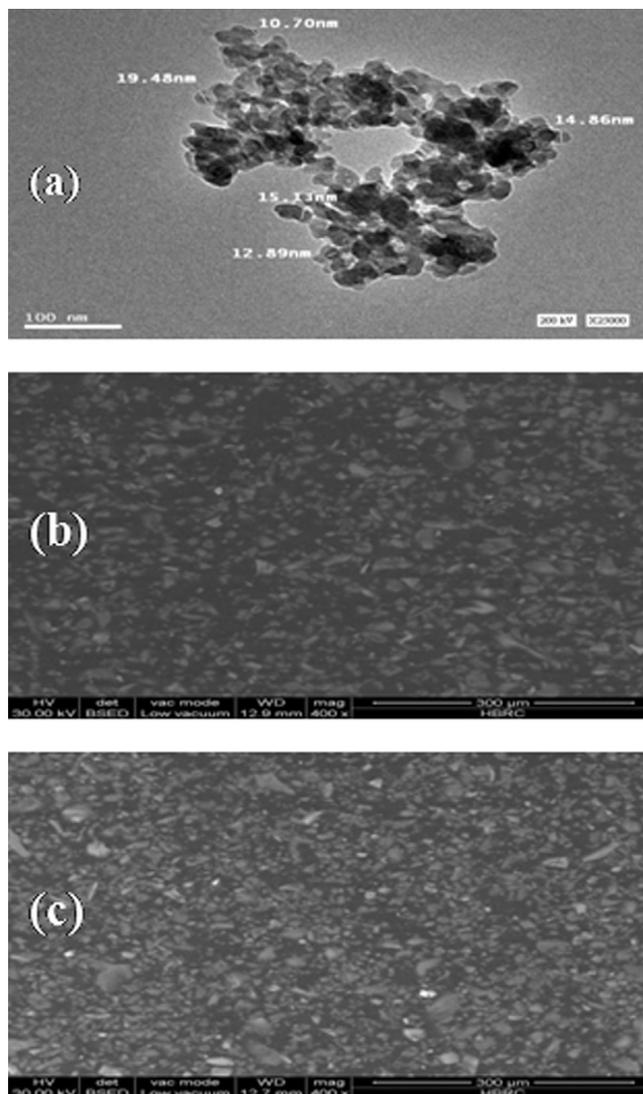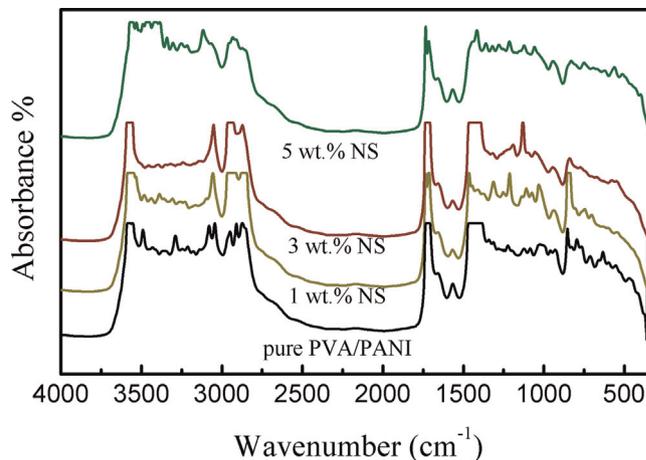

Fig. 3. FTIR spectra of pure PVA/PANI and PVA/PANI loaded with different NS content.

improve the physical properties of PVA by adding 2 wt% PANI and then loading the mixture with different NS contents. The nanocomposite films were characterized by XRD and FTIR in addition to the study of their optical and dielectric properties.