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Poly(Vinyl Alcohol)/Zincoxide-Ceriumoxide Nanocomposites: Electrical, Optical, Structural and Morphological Characteristics

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ABSTRACT

With the objective to investigate the influence of zinc oxide–cerium oxide (ZnO-Ce₂O₃) nanoparticles on the optical and electrical properties of polyvinyl alcohol (PVA), PVA/ZnO-Ce₂O₃ nanocomposite films were prepared by solution intercalation method with different weight percentage viz., 0.5, 1.0 and 2.0 wt% of ZnO–Ce₂O₃ nanoparticles. The fabricated nanocomposites were characterized by Fourier transform-infrared spectroscopy (FT-IR), UV/visible and X-ray diffraction (XRD). The effect of ZnO-Ce₂O₃ nanoparticles on the dielectric constant (ε), dielectric loss (ε "), electric modulus (M' and M''), ac conductivity (σ ac), and dielectric loss tangent (tan δ) over a range of frequencies at room temperature of PVA nanocomposites interaction with the PVA matrix. The morphological behavior of the nanocomposites has been performed using scanning electron microscopy (SEM). The dielectric behaviors such as dielectric constant (ε ') and dielectric loss (ε '') increases with increase in frequency. Dielectric loss tangent (tan δ) decreases with increase in frequency. Dielectric behaviors such as dielectric constant (ε ') and dielectric loss (ε '') increases with increase in frequency. Dielectric loss tangent (tan δ) decreases with increase in frequency. Dielectric loss tangent (tan δ) decreases with increase in frequency. Dielectric behaviors such as dielectric constant (ε ') and dielectric loss (ε '') increases with increase in frequency. Dielectric loss tangent (tan δ) decreases with increase in filler concentration, but decreases with increase in frequency between the increase in frequency. Dielectric loss tangent (tan δ) decreases with increase in frequency between the probability of the anaccomposites here the performed using scanning electron microscopy (SEM). The dielectric behaviors such as dielectric constant (ε ') and dielectric loss (ε '') increases with increase in frequency. Dielectric loss tangent (tan δ) decreases with increase in filler concentration, but decreases

Keywords: poly vinyl alcohol, Zink oxide, Cerium oxide, Nanocomposites.

1. INTRODUCTION

There is increasing research interest in polymeric nanocomposites owing to improvements in electrical, thermal, optical, and mechanical properties [1] and their great potential for highly particular. functional materials [2-3]. In nanoparticles embedded in a transparent matrix have attracted attention as advanced technological materials because of their high transparency, high and refractive index attractive [4], electrical/electronic properties [5]. Metal oxide nanocomposites play a very important role in electrical and optical devices. Polymeric nanocomposites also demonstrate high thermal

*Corresponding Author: *E-mail: chandrakalakit@gmail.com* stability compared to virgin polymers [6]. In the present study, we selected poly(vinyl alcohol) (PVA) as a transparent host and zincoxide ceriumoxide (PVA/ZnO-Ce₂O₃) nanoparticles as a nanofiller. PVA is a water-soluble polymer that allows preparation of nanocomposites film via environmentally friendly aqueous solution casting. PVA films are flexible and show excellent transparency in the visible range, with good dimensional stability. PVA films have very high dielectric strength (41000 kV/mm) and good charge storage capacity and dopant-dependent electrical and optical properties. Hence, PVA films are of importance for the microelectronic industry. The



Figure 1. FTIR spectra of PVA loaded with (a) 0, (b) 0.5, (c) 1.0 and (d) 2.0 wt% of ZnO-Ce₂O₃ nanoparticles.



Figure 2. UV (a) transmittance and (b) absorbance spectra of PVA/ZnO-Ce₂O₃ nanocomposite films.

electrical properties of PVA nanocomposite films have been extensively investigated [7]. Their electrical conductivity depends on thermally generated carriers and dopants [8]. In the present investigation ZnO-Ce₂O₃ metaloxide nanoparticles on the optoelectrical properties of PVA matrices were studied. Our primary focus was to explore the potential of ZnO-Ce₂O₃ metaloxide nanoparticles on the structural, optical and electrical properties of the transparent PVA host.

2. Experimental

Electrical properties were measured using an LCR meter (Wayne KERR model: 6500P) in a frequency range of 20Hz-10MHz, at voltage of 1V. UVvisible transmittance spectra were recorded using UV-ANALYTIK JENA (model Specord S600) in the wavelength range 220-300 nm. FTIR spectra of the samples were measured in the spectral range 4000-400 cm⁻¹ using Perkin Elmer FT-IR. X-ray diffraction (XRD) patterns were recorded using Miniflex II, Desktop diffractometer (RIGAKU) (radiation, λ =1.54 Å, scanning speed of 3°/min and of 0-60°. Surface images of 2θ range PVA/Na₂ZrO₃ film samples were recorded by scanning electron microscopy (SEM, Model ESEM Quanta 200) at 10

KV voltage.

Table 1. Intensity of transmittance values of PVA and $PVA/ZnO-Ce_2O_3$ nanocomposites.

ZnO-Ce ₂ O ₃	Peak intensity at different wave		
111 PVA (wt. %)	253	257	278
0.0	78	38	65
0.5	100	78	42
1.0	89	89	88
2.0	100	57	30

3. RESULTS AND DISCUSSION

The FTIR spectra of PVA and ZnO-Ce₂O₃ filled PVA are shown in Figure 1. A strong broad band in the wave number range 3000-3600 cm⁻¹ is assigned to the O-H stretching vibration of PVA. A peak at 1715-1729 cm⁻¹ corresponds to C=O stretching vibration (of vinyl acetate group of PVA) and peak at 1432 cm⁻¹ corresponds to a C=C group in PVA backbone. A shift in the peak position has been noticed corresponding to C=O stretch and C-O-C stretch vibrations of PVA and is indicative of a positive interaction between hydroxyl groups of PVA have a very strong



Figures 3. (a)-(d). Dielectric constant, loss, conductivity and loss factor of $PVA/ZnO-Ce_2O_3$ nanocomposite films as a function of frequency at different ZnO-Ce₂O₃ nanoparticles.



Figure 4. X-Ray profiles of (a) ZnO-Ce₂O₃ nanoparticles and (b) PVA/ZnO-Ce₂O₃ nanocomposites.

tendency to form charge-transfer complex with nO-Ce $_2O_3$ nanoparticles through chelation.

3.1 Effect of ZnO-Ce₂O₃ content on optical transmittance characteristics of PVA

In the transmittance spectra, three prominent peaks are observed at 253, 257 and 278 nm in UV

(220-300 nm) region for nanocomposites. As illustrated in Figure 2, the transmittance intensity of the peaks varied with nanoparticles concentration and it shows that the peak observed at 253 nm shows 100% transmittance in some of the compositions. This has led to the presumption that the peak intensity variation corresponds to the

formation of charge transfer complexes between $ZnO-Ce_2O_3$ nanoparticles and hydroxyl groups of PVA.

Figures 3(a)-(d) show the dielectric constant, loss, conductivity and loss factor of PVA/ZnO-Ce2O3 nanocomposite films as a function of frequency at different ZnO-Ce₂O₃ nanoparticles concentration. The dielectric constant (ε') values of composite films decrease with increase in frequency. This may be attributed to the tendency of dipoles in polymeric samples to orient themselves in the direction of the applied field. Dielectric loss (ε ") drops suddenly with an increase in frequency. This behavior may be due to the fact that at lower frequencies, the dipoles have sufficient time to align with the applied field before it changes its direction. Consequently, the dielectric loss is high. The conductivity increases with increase in frequency following the universal dielectric response law, $\sigma = A \omega^n$, where, n is found to be very close to 1.

2.2. WAXS studies

The crystalline nature of synthesized nano ZnO-Ce₂O₃ was observed by sharp crystalline peaks in the XRD pattern of pristine ZnO-Ce₂O₃ (Figure 4(a)). Six distinct diffraction peaks at 2θ of 28, 31, 34, 35, 47 and 57° are noticed for the nanosized $ZnO-Ce_2O_3$. Figure 4(b) shows the X-ray diffraction patterns of pure PVA and PVA/ZnO-Ce₂O₃ nanocomposites. All the X-ray profiles of nanocomposites exhibit a main peak at $2\theta = 19.7^{\circ}$ corresponding to (101) crystal plane for PVA, which indicates the semi crystalline nature of PVA. But new peaks at 2θ values of 28, 31, 34, 47 and 57° are observed in the X-ray profile of PVA/ZnO-Ce₂O₃ nanocomposites. It clearly indicates the presence of ZnO-Ce₂O₃ nanoparticles inside the PVA matrix.

4. CONCLUSION

The FTIR data of PVA/ZnO-Ce₂O₃ nanocomposite films reveal the interaction between nanoparticles and PVA. UV-visible analysis shows that the formation of charge transfer complexes between ZnO-Ce₂O₃ nanoparticles and hydroxyl groups of PVA. The electrical properties of PVA nanocomposite films strongly depend on frequency and ZnO-Ce₂O₃ content. As ZnO-Ce₂O₃ content increase, the dielectric permittivity, dielectric loss and conductivity of PVA host increase. Dielectric loss tangent decreases with increase in filler content at lower frequency, but at higher frequencies the tan δ increases with increase in nanoparticles content. AC conductivity (σ_{ac}) of PVA/ZnO–Ce₂O₃ nanocomposites increases with increasing frequency following the universal dielectric response law.

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