Research Article

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Improving the characteristics, optical and electrical features of a biopolymer blend *via* silver–multiwalled carbon nanotube nanocomposites for practical applications

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Abstract

Environmental perspectives have forced researchers to develop novel electrolytes/nanocomposites based on biopolymers for recent and future technological applications. In this study, multiwalled carbon nanotubes (MWCNTs) and $AgNO_3$ were incorporated into bio-blend films through the solution casting process. Fourier transform IR and XRD indicated that the fillers interacted and formed complexes with the blend's functional groups and increased the amorphous areas. Field emission SEM/energy dispersive spectroscopy techniques showed the compatibility between the blend and fillers and an even filler distribution at the atomic level. The UV–visible–near IR revealed that loading MWCNTs and $AgNO_3$ resulted in almost zero transmittance in the UV and blue light regions. The *k*-index spectra exhibited a symmetrically shaped surface plasmon resonance at $\lambda = 423$ nm, which means that nano-sized Ag was formed. The direct (indirect) bandgap of the blend is 4.3 (4.2) eV, reduced to 4.0 (3.9) eV upon loading MWCNTs and to 3.6 (2.3) eV when $AgNO_3$ is introduced. Moreover, after the additives, the blend exhibited a dual bandgap nature. The materials have DC and AC conductivities in the range (3.27–43.32) $\times 10^{-8}$ S cm^{-1} and (6.98–63.10) $\times 10^{-5}$ S cm^{-1} (at 1.0 MHz), respectively. Both the dielectric permittivity and loss were enhanced by MWCNTs and $AgNO_3$ incorporation. The dielectric moduli formalism revealed the existence of multiple relaxation mechanisms. The impedance exhibited a reverse behaviour to that of conductivity and confirmed that the conduction mechanism follows the Cole–Cole model. The findings of this study reveal that the $AgNO_3$/MWCNTs/blend has a promising usage in flexible dielectrics and bandgap-adjustable materials for micro-optoelectronics, photonics, shielding and food packaging applications.

Supporting information may be found in the online version of this article.

Keywords: $AgNO_3$/MWCNTs; Cole-Cole mechanism; DC/AC conductivity; optical constants; PEG/chitosan/PVA blend

INTRODUCTION

The complete decomposition of plastic waste takes 10 years or more, leading to serious environmental issues.[1] Hybrid biopolymeric (biodegradable) materials modified with inorganic fillers are promising for recent and futuristic applications in flexible optics, electronics, environmental engineering and remediation (food processing, wastewater purification etc.), electrochemical devices in the energy sector (batteries, electrochemical sensors, fuel and dye-sensitized solar cells), and pharmaceutical and biomedical applications.[2,3] Blending the biopolymers using a common polar solvent is a direct and facile route to obtain new compositions with modified physical and chemical features. The polymers can dissolve the salts and interact with the fillers through their hydrophilic groups (NH_2, OH, CONH, $CONH_2$ etc.).[4–8]

Polyvinyl alcohol (PVA) is synthetic, non-toxic and exhibits good chemical resistance, an insulating nature, sealing ability, thermal stability ($T_g \sim 80$ °C, melts at 230 °C) and high dielectric strength. In addition, PVA exhibits good compatibility with various biopolymers and can improve their elongation at break and biological qualities for textile coating, paper, pharmaceutical and medical devices, and gas barriers for oxygen/aroma/water vapour permeability for packaging applications.[1,3,9,10] Polyethylene glycol (PEG) is a polyether used in various industrial and medical applications owing to its non-toxicity, biocompatibility, thermal resistance and interesting chain flexibility.[8,11] In addition, chitosan is a natural cationic polysaccharide obtained from marine chitin (shellfish waste) after deacetylation. It has antibacterial activity and a wide utility range in cosmetics and medicine.[9–11] Edward *et al.*[8] fabricated $LiClO_4$/Ce-LLZO/PEG/chitosan/agar-agar solid polymer electrolyte (Ce-LLZO, cerium-doped Li-La-Zr-O) with Li^+ conductivity of 5.2×10^{-3} S cm^{-1} and enhanced electrochemical stability. Blends composed of PEG/chitosan and PEG/PVA exhibited good performance in drug delivery and removal of NO_3 ions

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