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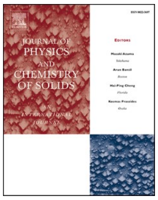

Characterization of Mg–Pb–O systems, and MgPbO–thermoplastic blend: Nanocomposites for photonic and microelectronic devices

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ABSTRACT

The synthesis of nanoparticles (NP)-reinforced polymers became an attractive approach to developing multifunctional materials used for optoelectronic and energy storage devices. In this report, two different systems of composition, $Mg_{0.75}Pb_{0.25}O$ NP (Mg75), and $Mg_{0.25}Pb_{0.75}O$ NP (Pb75) were prepared by a facile sol-gel method and characterized. Following that, the solution casting method was used to create Mg75/Poly(vinyl chloride)/Poly(vinyl acetate) PV(C/Ac) and Pb75/PV(C/Ac) nanocomposites. The HR-TEM, energy-dispersive spectroscopy (EDS), XRD, and FTIR analyses revealed the high purity of both Mg75 and Pb75 NP and their crystallite sizes were found to be 16 and 20 nm, respectively. Besides the cubic MgO, several phases of lead oxide (β-PbO, α-PbO, Pb_3O_4) were detected. The Pb, Mg, and O elements were uniformly distributed in Mg75 and Pb75, but the Pb dominated the Mg in the two systems (the atom% ratio of [Mg]:[Pb] in the two systems was 2.71:1 and 1:2.1, respectively). The width and intensity of the XRD and FTIR peaks as well as the surface morphology of the blend were influenced by the Mg75 and Pb75 NP contents. The films displayed high transmittance (70–90%), and the optical band gap (E_g) was reduced from 4.1 eV (pure blend) to 3.6 eV (4.0% Mg75/blend) and 3.7 eV (4.0% Pb75/blend). The corresponding values of the refractive index were 1.86, 3.18, and 2.50, respectively. In addition, the optical conductivity increased significantly after doping. According to the results of the thermogravimetric analysis and differential scanning calorimetry, the films were stable in the temperature range of 30–250 °C, which is suitable for various practical and space applications without damage. The dielectric constant (ϵ'), loss (ϵ''), and ac conductivity (σ_{ac}) were determined in the temperature range (30–100 °C) and frequency range of 10^2–10^6 Hz. The ϵ' values were increased after doping and influenced by the temperature, whereas the values of ϵ'' were small and stable. The improved optical and dielectric properties of the nanocomposites make these materials the best candidates for highly efficient photonic and microelectronic devices.

1. Introduction

The incorporation of a reinforcing material, with a length in the range of 1–100 nm in at least one dimension, inside a polymer blend (the matrix), is attracting considerable interest. Combining the properties of the nano-sized fillers, such as thermal stability and rigidity, with those of the matrix (ductility, processability, dielectric, and flexibility) generally yields a nanocomposite material that exhibits unique toughness, conductivity, and optical activity features suitable for various potential applications. The reinforcement mechanism depends on the size and morphology of the added nanofillers. The reinforcement effect becomes stronger as the size of the nanoparticle (NP) decreases, with the specific surface area and number of NP at the same loading increasing as the size decreases. Smaller NPs form fewer contact points in the polymer chain than larger ones, resulting in a weaker interfacial interaction. Meanwhile, there will be only transient interactions between polymer chains and ultra-small NP [1–8].

Poly(vinyl acetate) or PVAc is one of the most widely used thermoplastic polymers in the industry for biological and biomedical applications. This polymer is non-toxic to the human body, stable, forms good films, and is inexpensive. PVAc is a water-based adhesive and has a glass transition temperature (T_g) = 30 °C and melts at 70–210 °C. It is used for reinforcing wood, glass, and plastics to improve their strength and adhesion. In addition, its uses include packaging applications, and sustained drug release owing to its environmental friendliness, inertness, biocompatibility with living tissues, and adhesiveness. Moreover, to

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