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Original research article

Evaluation of the optical properties of photoconductive Eosin/PMMA nanocomposite film for flexible optoelectronic applications

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ABSTRACT

The maturity of flexible photoconductive polymeric composites through the incorporation of novel photoconductive pigments in the nanosclae into the polymer matrices have been recognized as promising nanocomposites for future organic optoelectronic. Here, we report the synthesis of new class of nanocomposites with promising optoelectronic features. These nanocomposites have been developed through the incorporation of Eosin as photoconductive filler into poly(methyl methacrylate). Thin films of these novel nanocomposites were made via spin coating technique. The topography and the distribution of the Eosin nanoparticles into the PMMA were appraised by the scanning electron microscopy (SEM) and the atomic force microscopy (AFM). Films with average thickness of 50 nm and root mean square roughness of 1.7 nm have been obtained. The optical behavior of these films has been studied based on various theoretical models. The optical behavior of the prepared nanocomposite films followed the single oscillator model. The spectral distribution of the index of refraction, extinction coefficient and permittivity was fitted by Wemple–DiDomenico model. The optical parameters such as lattice dielectric constant (ε_∞), volume energy loss (VELF) and surface energy loss functions (SELF) were estimated. At all incident photon energies, the VELF values were larger than that of SELF, implying the opportunity of using these films as photoconductive optical lenses.

1. Introduction

The introduction of photoconductive nanomaterials in the polymer matrices has shown attentions in the field of optoelectronic devices [1,2] due to ease of designing at molecular level, lightweight and flexibility [3]. This class of nanocomposites exhibited remarkable mechanical [4–6], electrical [7–10], dielectric [11], Piezoresistive [12], thermal [13], and optical characteristics [14]. The photoconductive pigments are usually used to manufacture photo-receptors, electro-photography and hybrid photovoltaic applications [15–17]. The incorporation of conductive fillers into the polymers resulted in a unique characteristics which enable the polymer to be used in diverse application potentials such as gas sensors [18], compressive strain and pressure sensors [19–22], magnetic recoverable catalysis [23,24], solid polymer electrolytes [25–27], photovoltaic solar cells [28–31], photodiodes [32], electromagnetic wave shielding [33], photodetectors [34], fluorescence probes for detection metal ions [35–37], PTCC and NTCC sensors [38], radiation shielding [39], and corrosion protection [40]. Among these polymers, poly(methyl methacrylate) (PMMA) has shown promising optical features and index of refraction around 1.49 that

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enable it to be employed as flexible lenses, optical fibers and optical disks [41]. However, Eosin (Y) is one of the promising photoconductive pigments with unique molecular structure render it to be promising organic compound for development of dye-sensitized solar cells with high conversion efficiency [42]. Therefore, the incorporation of Eosin (Y) into PMMA may be open a new avenue for developing flexible hybrid nanocomposites for optoelectronic applications. From this regard, it is important to evaluate the optical behaviors these novel nanocomposites. Here, we report for the first time the preparation of novel photoconductive nanocomposites based on the introduction of Eosin into PMMA. Thin films of these nanocomposites have been made by spin coating technique. The topography of these films was investigated. The optical behavior of these films was studied and various theoretical models were used to estimate the optical constants such as lattice dielectric constants, dispersive energy, harmonic oscillating energy and volume and surface loss energy. However, the index of refraction and coefficient of extinction were determined based on Wemple–DiDomenico model.

2. Experimental

A nanocomposite films made of Eosin doped PMMA was prepared by spin-coating technique on quartz substrates. In a typical synthesis, about 1.2 mg of Eosin (Y) powder (purchased from Sigma-Aldrich) and 18.8 mg of PMMA (average $M_w \sim 15{,}000$, Sigma-Aldrich) was added to 20 ml of dichlorobenzene. This ratio was selected after many trials because it showed the best optoelectronic properties. This mixture stirred for 30 min at 55 °C till a homogeneous solution has been formed. The solution left to cool naturally. About 2 ml of the formed solution was spin coated on quartz substrate via spin coating machine (Model WS-650-23B, Laurell Tech. Co.). The speed of rotation was around 2500 rpm for 1 min. The film baked at 80 °C for 2 h, then annealed at 110 °C for 2 h. The surface morphology of eosin doped PMMA films was evaluated by scanning electron microscope (JOEL-F-2010-SEM). The topography of these films and roughness was studied by the atomic force microscope (Horiba-AFM). The optical behavior was studied by UV–vis spectrophotometery (JASCO-V-570).

3. Results and discussions

3.1. Surface morphology and topography

The morphology of the formed thin film was studied by scanning electron microscope (SEM). Fig. 1a reveals the SEM of the pure eosin film and Fig. 1b shows the SEM image of eosin doped PMMA film for comparison. It is noteworthy that the pure eosin film has rough surface with large grains along the substrate while the eosin doped PMMA film showed a smooth

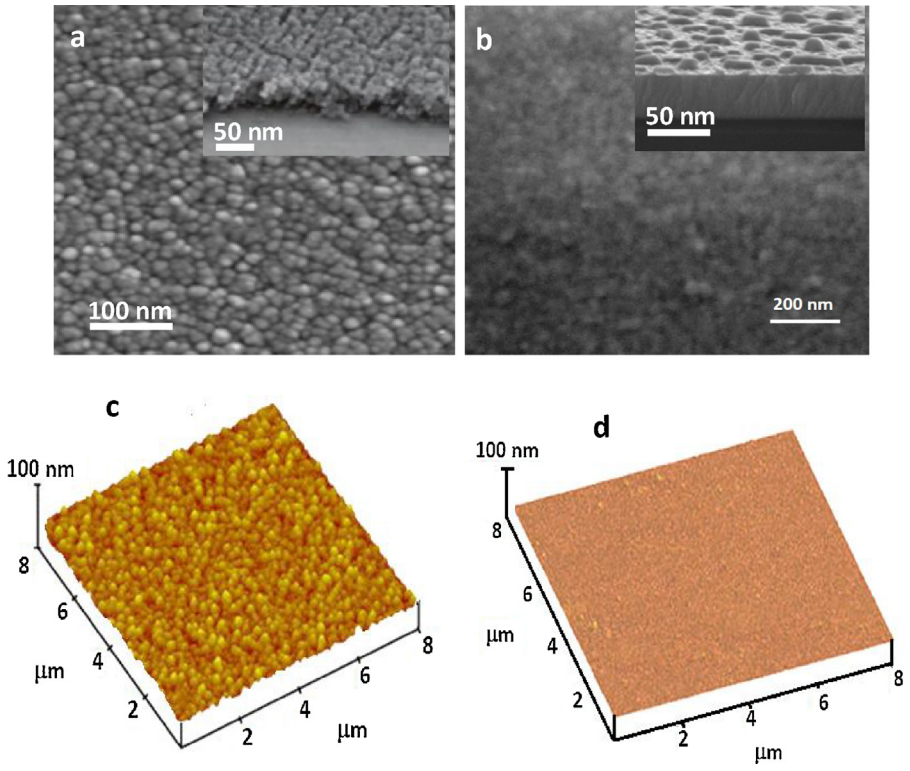

Fig. 1. (a) & (b) SEM photography (inset side view) and (c) &(d) AFM topography of Eosin before and after doping into PMMA thin film.