Journal of Molecular Structure 1343 (2025) 142893

Contents lists available at ScienceDirect

Journal of Molecular Structure

journal homepage: www.elsevier.com/locate/molstr

Developing thermally stable CuO/DPC/PVC nanocomposite films for flexible UV shielding and dielectric applications

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ARTICLE INFO

Keywords:
Organic nanocomposites
Diphenyl carbazide/CuO/PVC
UV shielding
Dielectric conductivity and relaxation

ABSTRACT

This work focuses on developing novel organic nanocomposites (ONCs) for optoelectronic devices and UV and blue light shielding applications. Films of polyvinyl chloride (PVC) modified with diphenyl carbazide (DPC) and CuO nanoparticles (NPs) were prepared by a solution-casting approach. The structure and chemical composition of the films were checked by X-ray diffraction, ATR/Fourier transform-infrared (FT-IR) spectroscopy, FE-SEM, and EDX. The CuO and DPC increased the amorphous nature of the films, and the complexation among the functional groups of PVC, DPC, and CuO was observed in the FT-IR spectra. The uniform distribution of all elements was confirmed by EDX and mapping analyses. TGA and DSC (thermal) analyses showed that the films' thermal stability, melting, and decomposition temperatures are significantly modified upon CuO and DPC addition. UV–vis spectroscopy revealed that the addition of CuO and DPC is essential for PVC to block the UV and blue light. The PVC's direct bandgap structure can be tuned from 5.15 to 3.0 eV for direct transitions and from 4.9 to 2.4 eV for indirect ones. The values of PVC's optical parameters depend on DPC/CuO addition. The relative dielectric constant and electric conductivity were improved significantly by these additives. The study of dielectric modulus and the Cole-Cole diagram revealed that the conduction in these films does not obey the Debye model. The significant improvements in the structural features, thermal and optical parameters, dielectric properties, and conductivity indicate that the prepared ONC films are the best candidates for dielectric and optoelectronic applications and utilizations where UV/blue light shielding and thermal stability are required.

1. Introduction

Organic nanocomposites (ONCs) based on polymeric materials modified with nano-sized material and/or pigments are novel compounds possessing exceptional physicochemical features and thermal stability and can be utilized for solar cells, light-emitting diodes, thin film transistors, UV and blue light shielding, and indoor/outdoor environments such as building windows, containers, syringes, automobile glasses, etc [1–4]. Polyvinyl chloride (PVC) is one of the most widely used thermoplastic polymers in various sectors. Besides the light weight, durability, ease of processing, and low cost, PVC is a polar macromolecule that exhibits improved elasticity, plasticity, flexibility, chemical inertness (highly resistant to alkalis, acids, and corrosion), and flame retardant characteristics (because of the high chlorine content and small thermal conductivity (14×10^{-3} W/m.K)). These features introduced PVC into different uses, including construction and flooring materials, pipes, cables, packaging, leather, bottles, and everyday essentials [5–12].

Filling the polymer matrix with minuscule-sized particles (1–100 nm) enhances the physicochemical properties and overall performance of the host, boosts its compatibility with other components [4,6], and results in unique features due to their high ratio of surface area/volume and higher reactivity [12]. Alruwaili et al [4] investigated the structural, dielectric, and nonlinear/linear optical constants of PVC loaded with 0.5–3.0 wt % ZrO_2 nanoparticles. Gong et al [11] employed an in situ polycondensation approach to aramid nanofiber/PVC composites with improved toughness and mechanical strength. The oxides of transition metals (OTMs), such as CuO, NiO, Cr_2O_3, V_2O_5, Fe_2O_3, Co_3O_4, etc., display special physical and chemical characteristics, and they became essential for a lot of technological and industrial applications [10,13]. PVC loaded with nano-sized Cr-doped ZnO exhibited improved thermomechanical and dielectric properties [14]. Alkhursani et al. [15] developed PVC/Co_3O_4/CNT composites with improved optical, dielectric response, and electric field distribution for medium-voltage cable

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https://doi.org/10.1016/j.molstruc.2025.142893
Received 25 April 2025; Received in revised form 1 June 2025; Accepted 3 June 2025