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Boosting the optical and electrical properties of PVA/Na-CMC blend by Cr_2O_3 nanoparticles for photonic and energy storage applications

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A B S T R A C T

This work is an attempt to leverage the physicochemical properties of nano-sized Cr_2O_3 (chormia) to fabricate flexible nanocomposites, using the polyvinyl alcohol/carboxymethyl cellulose (PVA/Na-CMC) blend, for advanced applications related to the energy storage and photonic devices. Chromia nanoparticles (NP) were prepared by a simple sol-gel method and loaded into a PVA/Na-CMC blend utilizing the solution casting technique. The structural properties of the samples were evaluated using XRD, HR-TEM, FE-SEM, and FTIR techniques. The measurements showed the high purity of the prepared materials and confirmed the successful incorporation, uniform distribution, and complexation of the nanofillers with the blend matrix. UV–vis-NIR spectra revealed that the transmittance in the visible region decreased from 88 to 46 % and blocked UV rays. The optical band gaps of the materials decreased from 5.3 eV to 3.7 eV and the refractive index increased from 1.74 to 4.44. Dielectric measurements were performed in the frequency and temperature ranges of 0.5 kHz–3.0 MHz and 303–393 K, respectively. The dielectric constant and AC conductivity were improved with increasing chromia NP ratio and the dielectric loss exhibited a relaxation peak influenced by the applied frequency, temperature, and chromia content. The activation energy, energy density and the conduction mechanism in the studied materials were studied. The improvements in the optical features and dielectric properties and conductivity make chromia/PVA/Na-CMC suitable for more advanced applications that require flexible nanocomposites for photonic devices and energy storage applications.

1. Introduction

Currently, there is considerable interest in combining two or more polymers and loading the organic blend with inorganic nano-fillers. This approach aims to address the limited uses of the polymers by producing new polymeric nanocomposites with improved physical, chemical, and biological features [1–6]. A blend composed of poly(vinyl alcohol), and carboxymethyl cellulose sodium salt, PVA/Na-CMC, is expected to have thermal stability, reasonable homogeneity, tensile strength, toughness, flexibility, efficient charge storage capacity, facile film forming, and serve as an effective wound dressing material [3,7,8]. Na-CMC is a water-soluble anionic polysaccharide derived from cellulose by reacting sodium hydroxide with chloroacetic acid [9,10]. The vital role of Na-CMC in the blend arises from its capacity to form a continuous matrix rich with water content and with exceptional viscosity and hence used as a thickener, stabilizer, and bonding linkages [3]. Besides its biodegradability, high transparency, non-toxicity, safety for the environment, and low cost, Therefore, Na-CMC is widely employed in the food packaging and pharmaceutical industries [5]. However, due to its limited processability, Na-CMC is mostly used with another polymer [2,3,11]. Besides the carboxylate (COO) group in the Na-CMC, the backbone of PVA and Na-CMC is a carbon chain companied by hydroxyl groups that act as a source of hydrogen bonding, which facilitates the formation of nanocomposite complexes [6,10,12].

Nano-sized metal oxide materials in the form of nanoparticles (NP) are preferred for a wide area of applications including the medical field, drug delivery, cosmetics, catalysts, high-performance supercapacitors, and other energy-related applications [13]. Among these materials, the chromium oxides Cr_3O, Cr_2O_3, CrO_2, Cr_6O_{13}, Cr_5O_{12}, Cr_2O_5, Cr_3O_8, and CrO_3. Among them, the trivalent phase Cr_2O_3 (chormia or Eskolaite) is the most stable magnetic–dielectric oxide [14–16]. Chromia NP was prepared by several physical and chemical routes, such as thermal decomposition, mechanical grinding, sol-gel, solvothermal, micro-emulsion, hydrothermal, co-precipitation, and chemical vapor deposition [14,16,17]. Chormia NP shares outstanding roles in modern technology which include corrosive and high-temperature resistance, thermal protection coatings, green pigment, heterogeneous catalysts, water treatment, methanol synthesis, sensors, antigen and pathogen

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