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Synthesis, structural, optical and electrical characterization of Y_2O_3/poly(ethylene glycol)–poly(vinyl chloride) based nanocomposite solid polymer electrolytes

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Abstract

Nanocomposite solid polymer electrolytes (NCSPEs) have attracted a lot of attention as excellent candidates for future electronics, photonics and energy storage devices. In this work, Y_2O_3 (YO) nanosheets were prepared by a free-template sol–gel method and incorporated inside a poly(ethylene glycol)–poly(vinyl chloride) (blend) matrix via solution casting. NCSPE films were then prepared by adding $NaClO_4$ (NC) or LiCl (LC) to the nanocomposite solutions. XRD and field emission SEM showed that YO has a body-centered cubic structure and a crystallite size of 24.8 nm, and looks like nanosheets with a high purity. The XRD results of the films showed that YO loading and salt complexation increase the films' amorphous structure. SEM was used to study the surface morphology and film thickness. Fourier transform infrared spectra confirmed the complexation and interactions between the YO/blend and NC or LC. UV–visible spectroscopy revealed that the films display low transmittance (<17%), an extinction coefficient k between 0.2×10^{-3} and 1×10^{-3} and a comparatively high refractive index. The band gap of the blend decreased from 4.3 to 4.0 eV on loading YO, and NC exhibited a higher impact on E_g compared with LC. A significant increase in σ_{ac} with complexing was reported and the maximum value was 7.4×10^{-4} S cm^{-1} for the 10 wt% NC/YO/blend structure. The NCSPE films are ionic conductors and have a non-Debye type of conductivity relaxation, and the applied AC conduction mechanism is correlated barrier hopping.

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

Keywords: nanocomposite solid polymer electrolytes; Y_2O_3 nanosheets; PEG–PVC; optical constants; dielectric properties

INTRODUCTION

Recently, various approaches have been established for modulating the electrical, mechanical and optical properties of polymeric materials, i.e. blending technology, plasticization, reduction of crystallinity, adding inorganic salts, and doping with nanofillers.[1,2] The polymer blend can be considered a mixture of two or more structurally different polymers in which the interaction is governed by secondary forces such as hydrogen bonding, dipole–dipole and ionic interaction, and there is no role for covalent bonding.[2] Nanocomposite solid polymeric electrolytes (NCSPEs) (polymer or polymer blend loaded with nano-sized material and modified with inorganic salts) exhibit extraordinary properties, which encourage their use in fabricating modern devices and instruments such as high-energy-density rechargeable batteries, super-capacitors, electrochromic smart windows and devices, and transistors.[3–5]

One of the most common plastics is poly(vinyl chloride) (PVC). Because of its high tensile strength and elasticity, excellent chemical resistance to acid and alkaline environments, insulation features, ease of preparation and low cost, it has been used in the automobile, packaging fields, building construction, and is suitable for use as a membrane.[2,6] Alghamdi *et al.*[7] prepared Fe_3O_4/PVC nanocomposite membranes for water desalination performance, and the films exhibited 37%–40% improvement towards NaCl, LiCl, $MgSO_4$ and Na_2SO_4 salt rejection compared to the pure PVC. However, because of its poor hydrophilic properties, non-degradability and recent environmental requirements, PVC has become essential to reduce the amount of plastic waste. Therefore, familiar additives for PVC, such as non-toxic and biodegradable poly(ethylene glycol) (PEG), should be used. PEG is used for various fields such as a pore-forming agent for membrane fabrication, lubricants, binders, and intermediates and coatings in

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