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Enhancement on H^+ carriers in conduction properties with addition of 1-butyl-3-Methylimidazolium chloride based alginate polymer electrolytes

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ABSTRACT

A solution casting technique was used to fabricate a bio-based polymer electrolytes (BBPEs) system in the form of a solid film that is composed of alginate as the host polymer network, glycolic acid (GA) as the charge carrier, and 1-butyl-3-methylimidazolium chloride ([Bmim]Cl) ionic liquid (IL) as an additive. The peak changes in IR spectra revealed the complexation of adding ionic liquids with the enhancement of H^+ carriers, while XRD and TGA studies revealed that adding IL suppressed the crystallinity and improved the thermal stability up to ~100 °C. The free-standing BBPEs sample exhibited the highest ionic conductivity of 2.03×10^{-3} S cm^{-1} at 6 wt % [Bmim]Cl composition at ambient temperature and achieved an H^+ transference number of 0.47. These results suggested that the addition of ILs as an additive into alginate-based BBPEs is a promising strategy for developing proton-conducting solid BBPEs for use in electrochemical devices.

1. Introduction

The demand for electronic device production has increased significantly in recent decades, with many of these items becoming essential in modern society. The successful commercialization of lithium (Li)-ion batteries (LiBs) by Sony in 1991, triggered a surge in portable electronics manufacture, hastening the development of high energy density devices [1]. The components of these devices are mainly made out of petrochemicals, inorganic semiconductors and synthetic polymers. Liquid electrolytes (LEs) are commonly used in LiBs. In order to meet the demands of modern society and address ecological concerns, innovative, affordable, and environmentally friendly energy storage solutions are required. Solid polymer electrolytes (SPEs) have been introduced in the last 40 years to replace LEs. Fenton [2] first discovered in 1973 that the SPEs combination consisting of PEO and alkaline salts (Li^+, Na^+, K^+) possesses exceptional ionic conductivity. SPEs have several advantages over LEs, including greater safety due to their non-flammable nature, proper electrode–electrolyte contact, no leakage, light weight, greater tolerance to high temperatures, provide greater electrochemical stability window which increases energy density for development of high-voltage energy devices, and lower production cost [3]. SPEs can be defined as a thin film of appropriate polymer with dissolved ionic salts that enhance the amorphous structure and enable conduction of ions at ambient temperature [4]. Flexible thin layer SPEs film can be fabricated into desired shapes by numerous methods such as the casting technique [5], spin coating [6], hot-pressing [7], 3D printing [8] and electrospinning [9]. Each method has its own advantages. For example, Chang and Lai [10] reported the electrospinning method using PEO polymer incorporated with $LiClO_4$ as the dopant showed ionic conductivity to 3.13×10^{-5} S cm^{-1} at room temperature. Among these methods, solution casting, in particular, has emerged as a popular approach to producing flexible thin-layer solid polymer electrolyte (SPE) films. This method entails dissolving the polymer in an appropriate solvent to create a homogeneous solution, which is then cast onto a substrate and allowed to evaporate, leaving a well-defined film forming ability.

In the pursuit of suistanable energy solutions, the convergence of bio-based polymers with hydrogen energy and recent technological advancements marks a significant leap forward. Bio-based polymer electrolytes (BBPEs) composed of natural polymers offer an ecologically friendly option that combines the inherent benefits of biodegradability and renewability with the necessity for efficient hydrogen energy storage and conversion [11,12]. Bio-based polymers can serve as a polymer host for applying polymer electrolytes. The structure of bio-based polymers possess hydrophilic functional groups, such as $–NH_2$, $–COO^-$, –OH, $–CONH^-$, $–CONH_2$, and $–SO_3H$ that causes polar solvent molecules to have a high absorption affinity for the bio-based polymers [13].

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