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Enhancing H^+ conduction through glycolic acid-doped alginate-PVA based biopolymer electrolytes

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ABSTRACT

This study investigates the development of a biopolymer blend electrolyte composed of alginate and poly (vinyl alcohol) (PVA), doped with glycolic acid (GA) to enhance H^+ conductivity. The addition of GA significantly impacts the biopolymer blend's physicochemical properties and ionic conduction performance. Fourier transform infrared (FTIR) spectroscopy verified the intricate interactions and hydrogen bonding between the alginate-PVA matrix and GA. The addition of GA was shown to increase the amorphous phase, as observed through X-ray diffraction (XRD) and scanning electron microscopy (SEM) analysis. This increase in the amorphous phase was found to enhance the thermal stability. Impedance analysis demonstrated a significant increase in ionic conductivity from approximately $\sim 10^{-8}$ S cm^{-1} for the undoped blend to 3.45×10^{-5} S cm^{-1} with 30 wt% GA (sample GA-30). The enhanced H^+ conduction behaviour was consistent across various temperatures, adhering to the Arrhenius rule. These findings suggest that the alginate-PVA-GA system is a promising candidate for efficient proton transport applications.

1. Introduction

The swift progress of technology has resulted in a substantial rise in the need and manufacturing of electronic devices. These functional devices have revolutionized various aspects of human life, offering remarkable enhancements in convenience and value. However, this surge in production also brings substantial environmental challenges, including properly disposing hazardous chemicals and compounds like non-biodegradable polymers and heavy metals. Consequently, the reliance on conventional energy sources such as fossil fuels, coal, oil, and gas has resulted in the swift exhaustion of these resources, alongside significant ecological destruction, the loss of biodiversity, and pervasive environmental contamination [1,2]. These underscore the urgent need for renewable and clean energy sources [3–5]. Maiti et al. [6] have highlighted the pressing need for portable, intelligent, and wearable electronics constructed from biodegradable, environmentally friendly, and non-toxic materials. This shift towards sustainable materials is crucial for a sustainable future. Consequently, there has been a global push towards low-cost, energy-efficient, carbon-based green materials over the past decade. Particularly, cost effective and environmentally benign green energy is the most essential means for increasing the sustainable technological development and industrial productivity as well as people's living standard in a society [7]. Noor & Isa [8] emphasize that the performance of electronic devices heavily depends on the electrolyte component. The qualities of the electrolytes significantly influence the performance of the electrochemical devices. Liquid electrolytes were mainly utilized due to their notable conductivity in spite of their limited range of operational voltage [5]. However, most commercialized organic liquid electrolytes are combustible and pose leakage risks, as noted by Cheng et al. [9]. This has led to extensive research on bio-based polymer electrolytes, which offer solutions to the limitations of liquid electrolytes and avoid releasing toxic liquids into the environment due to their renewable sources, such as plants, crustaceans, and bacteria. Biopolymers have garnered significant attention in recent years owing to their numerous advantages over synthetic counterparts which include biocompatibility, biodegradability, renewability, and cost-effectiveness [10]. Amongst these biopolymers, alginate has exhibited a plausible candidate as the backbone polymer matrix in a bio-based polymer electrolytes system. It was reported to have good conduction when added with appropriate ionic dopants. Alginate is also known as alginic acid, where linear copolymer of uronic acid (β-D-mannuronic acid and α-L-guluronic acid) are residue [11]. Due to

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