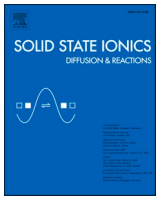
Solid State Ionics 414 (2024) 116650

Contents lists available at ScienceDirect

Solid State Ionics

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



Enhancing electrochemical performance of alginate–PVA solid blend electrolytes via H^+ ion doping for supercapacitor applications

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ARTICLE INFO

Keywords:
Polymer blend
Grotthus mechanism
Electrochemical properties
H^+ carriers-based supercapacitors

ABSTRACT

This study investigates the enhancement of electrochemical performance in alginate–polyvinyl alcohol (PVA) solid blend electrolytes through H^+ ion doping for supercapacitor applications. Employing the solution casting method, we tailored electrolyte systems doped with nitric acid (HNO_3). Impedance studies reveal a substantial increase in ionic conductivity (2.71×10^{-4} S cm^{-1} at room temperature) with 3 M HNO_3 doping. Fourier-transform infrared spectroscopy and transference number measurements confirm the effective protonation of the polymer matrix. Temperature-dependent behavior analysis demonstrates robust performance across various thermal conditions. Linear sweep voltammetry studies showcase excellent electrochemical stability, while galvanostatic charge-discharge profiles exhibit reliable cyclic performance, with an average specific capacitance of approximately 6.76 F/g. This research underscores the potential of tailored solid blend electrolytes doped with H^+ ions to elevate supercapacitor technology.

1. Introduction

Polymer electrolytes have emerged as a highly promising frontier in the realm of electrochemical devices, owing to their cost-effectiveness, environmental friendliness, and biodegradability. The exploration of polymer electrolytes in electrochemical devices represents a dynamic field with substantial potential for expansion and practical applications [1]. The synthesis of these electrolytes involves a diverse range of biopolymers, encompassing materials such as cellulose [2], agar-agar [3], and pectin [4]. Notably, investigations into solid biopolymer electrolytes (SBEs) have demonstrated remarkable efficacy in electrochemical devices, particularly in electrical double-layer capacitors (EDLCs) [5,6]. With a manufacturing process that is both accessible and affordable, EDLCs have emerged as a compelling alternative to conventional batteries [7]. The ionic conductivity of the electrolyte stands out as a pivotal factor influencing the performance of EDLCs. A high bulk ionic conductivity ($\geq 10^{-4}$ S cm^{-1}) at ambient temperature is a coveted characteristic for an ideal electrolyte [8]. Beyond its role as a physical barrier between electrodes, the electrolyte is crucial for facilitating efficient ion conduction in the electrochemical system.

The effectiveness of the polymeric matrix hinges on the incorporation of polar groups, notably nitrogen (N), sulfur (S), and oxygen (O), which play a pivotal role in generating a dipole moment, influencing dielectric polarization. Recent attention has turned towards proposals for developing electrolyte systems using biopolymers derived from alginate. Alginate, sourced from the cellular wall of brown algae, is a polysaccharide characterized by a robust polymer chain composed of two uronic acids—α-L-guluronic acid and β-D-mannuronic acid—connected through a glycosidic bond (Fig. 1) [9]. Beyond its distinctive structural composition, this polymeric material has gained significant interest across industries such as food [10], pharmaceutical [11], and textile [12], owing to its remarkable sustainability and biodegradability. Notably, the hydroxyl (-OH) and carboxyl (-COO) groups inherent in alginate offer unique coordination sites [13]. Moreover, alginate possesses essential film characteristics desired for solid-state electrolyte systems, including high solubility, flexibility, non-toxicity, and biocompatibility [14]. Despite these advantages, it is noteworthy that alginate exhibits a comparatively lower ionic conductivity, presenting a challenge for its application in high-performance electrochemical devices.

Therefore, the strategic approach of polymer blending emerges as a practical solution to augment ionic conductivity at ambient temperature. Poly(vinyl alcohol) (PVA) assumes the role of a secondary polymer host, complementing alginate due to the shared presence of hydroxyl

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https://doi.org/10.1016/j.ssi.2024.116650
Received 20 May 2024; Received in revised form 12 July 2024; Accepted 28 July 2024
Available online 7 August 2024