



# The ionic conductivity and electrochemical performance of Alginate-PVA based polymer electrolyte with Li<sup>+</sup> charge carriers for supercapacitor

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## ARTICLE INFO

### Keywords:

Alg-PVA polymer blend  
Li<sup>+</sup> ions carrier  
Electrochemical properties  
Symmetry supercapacitor

## ABSTRACT

This study presents the synthesis and characterization of solid polymer blend electrolytes (SPBEs) using alginate (Alg) and polyvinyl alcohol (PVA) as host polymers, incorporating lithium bis(trimethanesulfonyl)imide (LiTFSI) as the ion-providing salt for potential application in EDLCs. The surface morphology of the SPBEs was revealed using scanning electron microscopy (SEM), while thermal gravimetric analysis (TGA) demonstrates enhanced thermal stability, characterized by reduced weight loss and a shift toward higher decomposition temperature. Complexation between Alg-PVA and LiTFSI was indicated by Fourier-transform infrared spectroscopy (FTIR), as evident by the transitions and intensity changes in FTIR bands corresponding to functional groups. Increasing LiTFSI content reduces bulk resistance, with Alg-PVA containing 20 wt% LiTFSI (Li-20) showing maximum room temperature ionic conductivity ( $3.31 \times 10^{-4} \text{ S cm}^{-1}$ ) and the lowest activation energy (0.05 eV). Transport properties, analyzed using the Arof-Noor (A-N) method, reveal that ionic conductivity in SPBEs is governed by ionic mobility and ions' diffusion coefficient. Sample Li-20 displays predominantly ionic transport with a transference number ( $t_{ion}$ ) 0.98 and electrochemical stability up to 2.55 V. The EDLC, employing activated carbon electrodes and the most conductive electrolyte, demonstrates notable performance features, including specific capacitance (87.51F/g at 2 mV/s, assessed from CV), energy density (25.17 Wh kg<sup>-1</sup>), and power density (1038.92 W kg<sup>-1</sup>). Testing at various current densities reveals the highest specific capacitance values associated with the lowest current density, measuring 51.15F/g for the EDLC cell based on the Li-20 sample.

## 1. Introduction

Electrochemical capacitors have been widely investigated for energy storage applications for several decades. The discovery of electrical charge storage on surfaces dates back to ancient times when phenomena related to rubbing amber were observed. Still, the understanding of such effects only emerged in the mid-eighteenth century with the establishment of static electricity physics [1–3]. The Leyden jar's development, particularly the principle of charge separation and storage on its surfaces, became pivotal for the advancement of electricity physics and later played a significant role in electrical technology, electronics, and electrochemical engineering [4,5]. The utilization of this principle for practical energy storage purposes was first proposed and patented by Becker in 1957 [6], introducing the concept of a capacitor using high surface area carbon. Subsequently, in 1969, SOHIO made initial efforts to commercialize such devices [7]. Generally, electrical capacitors can be categorized into two primary types according to the mechanism of

their charge storage: (i) electrical double-layer capacitors (EDLCs) and (ii) pseudo-capacitors, also known as electrochemical redox capacitors. An EDLC stores electrical energy by creating an electric double layer with layers of cations and anions adsorbed at the electrode–electrolyte interfaces. In contrast, a redox capacitor enables a Faradaic or charge-transfer reaction between the electrode and the electrolyte within an appropriate potential range [8,9]. Compared to conventional rechargeable batteries, EDLCs demonstrate a higher power density and prolonged cycle life because of their distinctive charge storage mechanism [10,11]. These devices usually comprise two porous electrodes that sandwich an electrolyte solution, with the electrode material usually being activated carbon, valued for its substantial surface area and chemical stability.

EDLCs utilize either aqueous or non-aqueous electrolytes, which can be in liquid or solid states. While solid electrolytes are less common, traditional electrochemical capacitors often rely on corrosive liquid electrolytes such as acids, bases, or salts dissolved in aqueous or organic

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<https://doi.org/10.1016/j.jelechem.2024.118463>

Received 8 May 2024; Received in revised form 17 June 2024; Accepted 22 June 2024

Available online 24 June 2024

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