UV-ASSISTED SYNTHESIS OF GEL POLYMER ELECTROLYTES FOR SUSTAINABLE LI-ION BATTERY DESIGN

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Résumé :

The energy transition poses novel challenges, particularly for electrochemical energy storage. Lithium-ion batteries (LIBs) are indispensable in electronic, medical, and industrial devices, as well as in electric vehicles [1]. These batteries offer significant advantages, including high energy density, long life, and low self-discharge [2]. However, the use of liquid electrolytes in conventional LIBs poses significant safety concerns, including the potential for fire, explosion, and dendrite formation. This complicates the recycling process, raising environmental and safety concerns. Solid batteries offer a viable solution to overcome these difficulties [3]. They aim to substitute or adapt the liquid electrolyte with solid materials, such as polymers, ceramics, and composites. Polymer electrolytes, in particular, provide several advantages including safety, low weight, and good mechanical properties. In order to enhance the safety and recyclability of LIBs, this study conducted the development of poly(ethylene glycol) diacrylate (PEGDA)-based gel polymer electrolytes (GPEs) that incorporate 0-60% by weight of a commercial liquid electrolyte (1 M $LiPF_6$ in a 50/50 v/v mixture of ethyl carbonate (EC) and diethyl carbonate (DEC)). The synthesis was executed in a single step by means of UV irradiation at room temperature. Infrared analysis and EDS mapping confirmed the efficient immobilization of the liquid electrolyte in the polymer matrix. The thermal stability of the GPEs was assessed by thermal analysis (ATG and DSC), revealing their stability over a wide temperature range from -40°C to 90°C. Temperature dielectric measurements (ranging from 20 to 100°C) conducted over a broad frequency spectrum (from 0.1 Hz to 10^6 Hz) have demonstrated that the ionic conductivity of GPEs exhibits an increase in proportion to the liquid electrolyte content. Specifically, GPEs comprising 60% by mass of liquid electrolyte attain a conductivity level that is consistent with the values reported in literature, measuring approximately 6.6×10^{-3} S/m at 30°C. In parallel, the addition of flame retardants (FRs) to GPEs was investigated. The objective was to evaluate whether such formulations could enhance fire safety without impacting ionic conductivity, mechanical and thermal stability. Findings demonstrate that FRs were successfully incorporated into the polymer matrix without inducing phase separation or heterogeneity. Additionally, minimal changes were observed in the mechanical and thermal properties of the samples, as well as in the ionic conductivity values. Finally, FRs produced a more controlled combustion pathway due to the absence of dripping, the elimination of secondary ignition, the formation of char residues, and the stabilization of combustion. The results obtained in this work provide valuable details into the design of GPEs that combine improved fire safety with good mechanical properties. The proposed formulations represent a promising alternative for developing safer and more reliable LIBs, contributing to the efforts to balance safety and performance in future energy storage systems.

Références :

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