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I-CReST 2025:075-045 – Highly Conductive Gel Biopolymer Electrolyte Based on Newly Synthesized Glutaryl Kappa-carrageenan for Energy Storage Application

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ABSTRACT

Abstract. A novel kappa-carrageenan derivative, glutaryl kappa-carrageenan (G-κCar) was successfully produced via nucleophilic substitution reaction. The introduction of glutaric anhydride (GA) into the kappa-carrageenan (κCar) matrix has markedly altered its chemical and electrochemical properties. Elemental analysis showed that the GA substitution led to an increased oxygen percentage in G-κCar compared to pure κCar. The highest degree of substitution obtained was 4.14 in 3gGA-κCar/48h synthesized sample. The successful substitution of GA molecule into κCar polymeric chain was confirmed by the FTIR analysis based on the formation of a new carbonyl (C=O) bond in the G-κCar spectra. The 1H NMR analysis further proved the GA substitution by the appearance of new multiple resonance peaks at δ = 1.70 ppm – 2.75 ppm, which belong to the characteristic signals of protons in the anhydride group. TGA thermograms showed lower degradation temperature in the synthesized G-κCar due to disruption of both inter and intramolecular hydrogen bonds in the G-κCar polymeric chains. The substitution of GA also improved the ionic conductivity of G-κCar up to 4.63 × 10-3 S cm-1 at ambient temperature. Cyclic voltammetry plots demonstrated that the 3gGA-κCar/48h sample had a larger background current than κCar that indicated that the synthesized 3gGA-κCar/48h biopolymer has an improved effective surface area. Linear sweep voltammetry (LSV) analysis revealed the increased electrochemical potential in G-κCar compared to the pristine κCar. The highest potential obtained was 1.95 V for 3gGA-κCar/48h sample. The transference number for 3gGA-κCar/48h is calculated to be 0.98 over five continuous hours. This implied that ionic conduction in the gel is predominantly driven by ions, with the contribution of electrons being minimal and therefore negligible. These results suggest that G-κCar exhibits excellent electrochemical properties, establishing it as a potential new biopolymer derivative for gel biopolymer electrolyte applications.

Keywords: kappa-carrageenan; biopolymer derivative; glutaric anhydride; gel electrolyte; conductivity