Transport Properties of Chemically Cross-Linked Pectin Hydrogel Electrolytes as Bifunctional Mediator-Separators

Efimovich, Maria (School: Staten Island Technical High School)
Yee, Jacob (School: Staten Island Technical High School)

Hydrogel polymer electrolytes (HPEs) have gained considerable popularity in energy storage. Hydrogels are hydrophilic polymeric networks that can be extended multi-dimensionally via cross-linking. HPEs, hydrogels with a conductive salt, can combat some of the safety issues associated with liquid electrolytes and act as bifunctional mediator-separators. This research examines the transport properties of chemically cross-linked pectin HPEs using a 1:2 pectin to cross-linker ratio. The cross-linkers tested were Citric Acid, Glucose, Sucrose, Glutaraldehyde, Urea, Tannic Acid, Boric Acid, and Ethylene Diglycidyl Glycol Ether. Samples were prepared by cooling 1 M. $ZnSO_4$ (aq.) in ice for 24 hours, then by dissolving the specified cross-linker and pectin. Electrochemical impedance spectroscopy was performed across a temperature range of 298 to 358 K to obtain resistance values. Five of six HPE samples (Null, Citric Acid, Urea, Sucrose, and Glutaraldehyde) displayed superior conductivities across the entire temperature range compared to the industry-standard aqueous electrolyte. At 298 K, all samples demonstrated high conductivity values (>15 $mS \cdot cm^{-1}$). The Null achieved a peak conductivity of 36.735 $mS \cdot cm^{-1}$, a 71.49% improvement. Additionally, it reduced activation energy by 1.0 $kJ \cdot mol^{-1}$, highlighting pectin's energy efficiency as a biopolymer. Glutaraldehyde and Urea showed moderate improvements but were outperformed by cross-linkers like Sucrose due to unstable conductivity and toxicity concerns. Overall, engineers can leverage these characteristics to optimize zinc-ion batteries. This study highlights the cost-effectiveness and electrochemical performance of pectin HPEs, introducing sustainable alternatives to liquid electrolytes for energy storage and flexible electronics.

Awards Won: