UV Curing of Novel Polymer Materials for Next-Generation Energy Conversion and Storage

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Solid polymer electrolytes (SPEs) play the critical dual roles of separating the electrodes in a battery (to avoid short-circuits) as well as facilitating the shuttling of ions during both battery charging and discharging. It is critical that they are sourced from robust, commercially available monomers and are prepared using rapid and scalable techniques. While solid polymer electrolytes have been prepared for lithium batteries, other attractive battery chemistries which use more Earth-abundant minerals have not been examined as extensively. One example is calcium batteries, which is an attractive next-generation, sustainable energy storage technology.[1-3]

In this research direction, SPEs were prepared through the UV curing of acrylate and epoxy based formulations which consist of a calcium salt as the electrolyte.[1-2] The samples could be rapidly cross-linked to form solid, slightly flexible, and mechanically/thermally stable materials. Figure 1 shows schematics of the polymer structures of the SPEs that have been prepared using UV irradiation. The materials are prepared through photo-crosslinking the formulations that also have dissolved in it various concentrations of calcium salt.

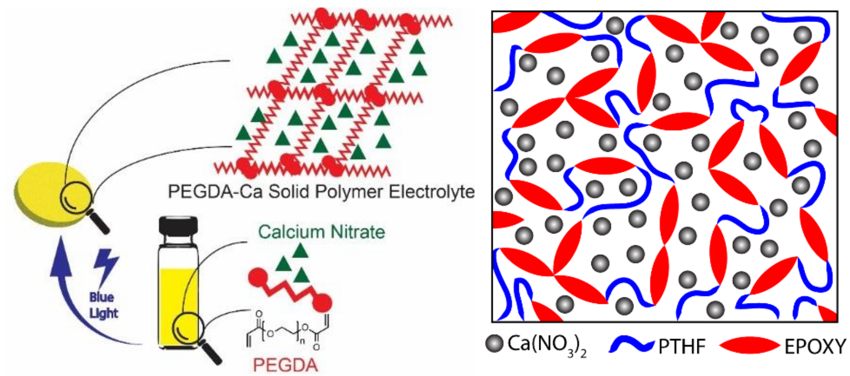

Figure 1. Schematic of solid polymer electrolytes prepared from (Left) PEGDA and (Right) Epoxy formulations towards next-generation battery separator operation.

A key finding of this work was that the SPEs had competitive conductivities on upwards of 10^{-3} S/cm, which is a critical figure of merit for it to replace incumbent liquid electrolytes. Figure 2 shows Arrhenius plots of the conductivity versus temperature, revealing that attractive room temperature conductivities which can be achieved with the optimization of the salt content. The high conductivities will also be important for high performance applications such as for electric vehicles as well as grid-scale storage. Both SPE systems studied also showed excellent thermal and mechanical stability. Further studies on ion transport showed that most of the ion carriers were the positive cations, which is critical for high efficiency battery operation.

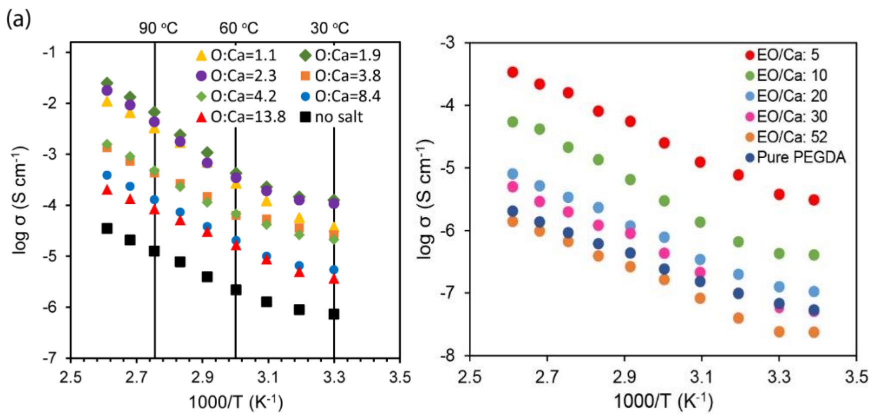

Figure 2. Arrhenius plots of the Ca^{2+} ionic conductivity in (Left) PEGDA and (Right) Epoxy based solid polymer electrolytes.

The next steps in this work is to integrate the SPEs into prototype calcium and calcium ion batteries and to investigate the battery performance. Should suitable electrochemical reactions be able to proceed with these electrolytes over 100s of cycles, the work will be close to technological and commercial realization. This work holds promise for the use of UV irradiation for the scalable production of SPEs for next-generation energy storage materials.

References

1. Genier, F. S.; Burdin, C. V.; Biria, S.; Hosein, I. D., A Novel Calcium-Ion Solid Polymer Electrolyte Based on Crosslinked Poly(ethylene glycol) Diacrylate. *J. Power Sources* **2019,** *414*, 302-307.
2. Wang, J.; Genier, F. S.; Li, H.; Biria, S.; Hosein, I. D., A Solid Polymer Electrolyte from Cross-Linked Polytetrahydrofuran for Calcium Ion Conduction. *ACS Appl. Poly. Mater.* **2019,** *1*, 1837-1844.
3. Yao, T. Y.; Genier, F. S.; Biria, S.; Hosein, I. D., A solid polymer electrolyte for aluminum ion conduction. *Results Phys.* **2018,** *10*, 529-531.