MEtal-ion SupraMolecular Electrolyte membRanes for energy storage applications: desIgn, synthesiS, and charactErization

(MESMERISE)

Energy as a strategic resource determines humankind's economic, social, and cultural development but also sets the military state security of countries. Currently, the primary energy source comes from fossil fuel combustion, which generates vast pollution and greenhouse gases that devastate our planet. Therefore, alternative zero-emissive and clean energy sources become the priority of research worldwide. As a result, renewable and sustainable energy technologies were developed based on natural forces like solar, tidal, wind, and biofuels. However, the access to them is heavily dependent on seasons and weather. To solve this issue, a new type of high-performance and effective energy storage system that is able for large scaling needs to be developed. **The currently leading technology of Lithium-ion batteries (LIBs), effectively marketed and extensively utilized in a wide range of applications, is facing severe problems** concerning the safety, high costs, flammability, and explosivity, but most of all, the scarce resources of lithium on Earth. The S&P Global Commodity Insight reported that the price for this element had risen over 500% compared to 2021. **The solution for this situation can be alternative multivalent metal-ion rechargeable batteries based on elements like Zinc, Calcium, Magnesium, or Aluminum**. They are all characterized by **high energy density, high capacity, less complicated electrochemistry, higher safety, non-harmful nature, and, most of all, plentiful reserves**. Designing new ion conductive materials allows the **development of the next generation of Metal-ion batteries. Taking advantage of nanotechnology, chemical engineering, and the self-assembly phenomena in a bottom-up approach with low molecular weight gelators (LMWG)** allows us to obtain renewable supramolecular electrolyte membranes (rSEM) as solid-state electrolytes for utilization in rechargeable energy storage systems.

The current technology of solid electrolytes is based on polymers or complex solid-state composites, which carries a heavy burden on the natural environment and a costly production process. Designing and synthesizing gelators to create renewable supramolecular electrolyte membranes with defined internal structures will reduce the negative environmental impacts and increase the application potential. To achieve this development stage, **it is necessary to determine the mechanisms of metal-ion transport through supramolecular structures** and study the ion systems' thermal properties. The specificity of the intermolecular interactions in rSEM causes them to be renewable materials that are easy to recycle.

Using a comprehensive approach in the field of chemical engineering and physical sciences with the use of living radical polymerizations and its methods (ATRP, RAFT), nuclear magnetic resonance spectroscopy (HR ssNMR, liqNMR, eNMR), thermal analysis (TGA/DSC) and electrochemical properties (CV, EIS) ensure successful design and preparation of rSEM for next generation of Metal-ion batteries.