Powering up next-generation energy storage with beyond-lithium-ion battery systems

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Researchers led by Jennifer L. Schaefer, professor in the Department of Chemical and Biomolecular Engineering at the University of Notre Dame, analyzed how magnesium-ion-conducting solid polymer

electrolytes may work in two separate battery systems. They published their findings on Sept. 15 in *Energy Material Advances*.

"Energy storage devices need to be improved for further electrification of transportation and energy storage systems for renewable energy sources," Schaefer said. "To meet these demands, beyond-lithium-ion battery systems have gained attention. Among the beyond-lithium-ion battery systems, rechargeable magnesium metal batteries are an attractive system due to the abundance of magnesium and the high volumetric capacity of magnesium metal anodes."

Ion batteries comprise two electrodes, a negative called an anode and a positive called a cathode, with an electrolyte, typically a salt dissolved in a liquid or dissipated across a gel, connecting the two. When charge is applied to an electrode, an electrochemical reaction occurs that splits molecules into basic components. These components, typically atomic ions and electrons, separately travel to the opposite electrode to recombine in a way that either discharges energy to a connected devices or draws in energy from a power source.

According to Schaefer, magnesium metal batteries with non-liquid electrolytes have been understudied, as they suffer from serious ion transport and/or interfacial chemistry issues. Magnesium metal batteries with liquid electrolytes offer promise, Schaefer said, yet they suffer from the same issues as lithium-ion batteries—volatility, flammability, and possible leakage—plus corrosivity and/or reversibility issues.

"Solid polymer electrolytes are potentially advantageous due to higher thermal, mechanical and electrochemical stability compared with liquid electrolytes as well as lower cost and density relative to inorganic solid-state electrolytes," Schaefer said. "While lithium ion-conducting solid polymer electrolytes have been widely researched, reports on successful magnesium ion-conducting versions are relatively limited."

As such, understanding of how ions react and transport through the system is also limited, Schaefer said. Her team analyzed how magnesium polymer electrolytes made of a magnesium-based salt in polymer, known as PCL-PTMC, compared to the common polyether electrolyte. Both electrolytes were studied in contact with magnesium metal anodes. The ion speciation of each were examined via spectroscopy techniques, revealing that magnesium ions in the PCL-PTMC exist as ion complexes, bonded to other ions instead of as free magnesium ions.

"As previously reported with lithium salts, the interaction between positively charged ions and the polymer chain in PCL-PTMC was weaker than for the other polymer," Schaefer said, noting that weaker interactions can improve conduction of the positively charged ions. "However, polarization of cells containing the magnesium PCL-PTMC electrolyte resulted in highly dispersed, particle-like deposits."

Schaefer hypothesized that the magnesium complexes identified via spectroscopy decomposed on the electrodes after they were involved in conduction, which inhibited the electrodes from further interactions. Next, her team plans to explore other salts, as well as other electrolyte interfaces, to protect the magnesium electrode from undesirable chemical deposits.

"Our future work will focus on methods to overcome the interface issues and to quantify the magnesium conduction," Schaefer said.

More information: Bumjun Park et al, Ion Coordination and Transport in Magnesium Polymer Electrolytes Based on Polyester-co-Polycarbonate, *Energy Material Advances* (2021). DOI: 10.34133/2021/9895403