Intermediate Temperature Molten Salts for use in Na-based Liquid Metal Batteries

Brian Spatocco, Kimberly Aziz, Paul Burke, Donald R Sadoway
Department of Materials Science & Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 4-211
Cambridge, MA 02139-4307

Growing interest in renewable energy integration coupled with the aperiodic and stochastic nature of such intermittent resources has driven many researchers to propose that the final bottle-neck to a sustainable future may be grid-scale energy storage[1]. Though a variety of solutions are emerging, the aggressive cost targets of large-scale grid penetration continue to challenge electrochemical energy storage (EES) solutions due to high up-front capital costs and constrained lifetimes[2].

To meet these challenges, our group at MIT is developing the Liquid Metal Battery (LMB), a novel EES device that leverages three liquid layers to store energy using earth abundant materials at potentially lower costs than existing technologies when amortized over the device lifetime[3]. A guiding research principle unique to LMB research has been the decision to employ a cost-driven design from the onset, instead of relying on economies of scale to make the product economically viable during development. One major variable that impacts cost is the operational temperature of the cell. This single variable has cascading impacts upon cell containment and sealing, corrosion and lifetimes, and thermal and power management – all variables that contribute to the cradle-to-gate levelized cost of energy.

This study intends to share recent research results and future directions with molten salt systems at intermediate temperatures, ranging from 150 – 350°C. Because many low-temperature and low-cost eutectic electrode chemistries are available, the molten salt not only sets the operational temperature of the system but also plays a significant role in the active material cost of the system. In addition to optimizing for temperature and cost, LMB electrolytes must also demonstrate a number of other important properties including >1 S/cm conductivities, a suitable electrochemical window, compatibility with active components and containment, and long-term stability after prolonged cycling.

We have identified and characterized the NaOH-NaI eutectic system as a system for consideration. In addition to demonstrating a >2.0 V (vs. Na) window (Fig 1) the system also exhibits high conductivity (Fig. 2). Lowering the operational temperature below 300°C would enable simpler polymer seals, reduce corrosion, and suppress solubility-driven leakage currents when compared to existing literature for higher temperature sodium halide melts. Such baseline systems also provide a valuable starting point for tailoring and characterization of other salt mixtures. Some of these multicomponent salts will be discussed in addition to the NaOH-NaI binary eutectic.

Identifying suitable intermediate temperature Na-itinerant molten salt electrolytes not only benefits the market positioning and longevity of LMB systems but also advances our knowledge of molten salt systems in temperature regimes previously underexplored. In spite of these opportunities, relatively little work[4] has explored the landscape of novel ternary salts. This presentation aims to not only present some initial results but also motivate future research in the field.

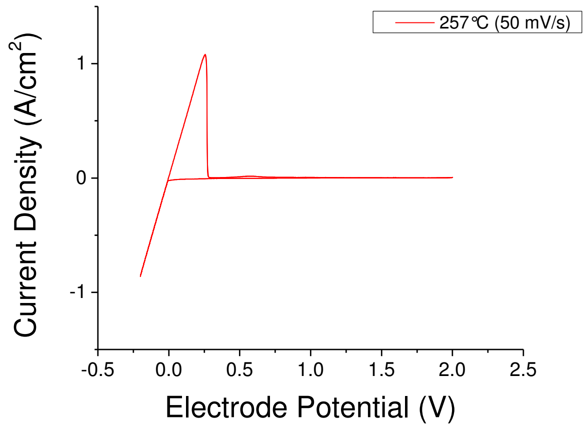

Figure 1- Cyclic voltammetry of eutectic NaOH-NaI (80-20 mole %) at 257°C on a silver working electrode vs. pure sodium

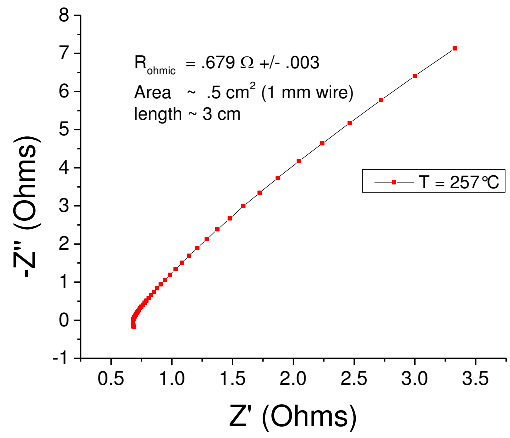

Figure 2 - Electrochemical Impedance Spectroscopy at 257°C for NaOH-NaI (80/20 mole %) on .5 cm^2 of silver wire

1 Yang, Z. G. et al. Electrochemical Energy Storage for Green Grid. Chemical Reviews **111**, 3577-3613, doi:10.1021/cr100290v (2011).
2 Barnhart, C. J. & Benson, S. M. On the importance of reducing the energetic and material demands of electrical energy storage. Energy & Environmental Science **6**, 1083-1092, doi:10.1039/c3ee24040a (2013).
3 Kim, H. et al. Liquid Metal Batteries: Past, Present, and Future. Chemical Reviews **113**, 2075-2099, doi:10.1021/cr300205k (2012).
4 Li, G. S. et al. Novel ternary molten salt electrolytes for intermediate-temperature sodium/nickel chloride batteries. J. Power Sources **220**, 193-198, doi:10.1016/j.jpowsour.2012.07.089 (2012).