Molten Halogen Salts as Low-Temperature Electrolytes in Na-Based Liquid Metal Batteries for Low-Cost Large Scale Electricity Storage

Dr. Wenjin Ding[1,*], Dr. Thomas Bauer[2]

[1] Institute of Engineering Thermodynamics, German Aerospace Center (DLR). Pfaffenwaldring 38, 70569 Stuttgart, Germany.

[2] Institute of Engineering Thermodynamics, DLR. Linder Höhe, 51147 Cologne, Germany.

Corresponding author: Wenjin Ding, Tel.: +49 711 686 2233, E-mail: wenjin.ding@dlr.de.

Liquid metal battery (LMB) is an intriguing energy storage technology with advantages of low-cost, large-capacity and long-lifespan [1]. Recently, it has been gained great interest as a large scale electricity storage device able to integrate the intermittent renewable energy technologies like wind and solar in to the grid [2-3]. LMB consists of a low-density liquid metal negative electrode (e.g. Na, Li), a medium-density molten salt electrolyte (generally a molten halogen salt mixture), and a high-density liquid metal positive electrode (e.g. Sb, Pb), which self-segregates into three distinct layers by density due to their mutual immiscibility. The strong interaction between the two liquid metals provides the thermodynamic driving force (cell voltage) for the liquid metal batteries [1]. The **molten salt electrolyte** serves as an isolation layer between the negative and positive electrodes to replace the battery separator existing in traditional batteries.

Despite that Li-based LMBs possess excellent electrochemical performance [1,4], the excessive consumption of Li resource (e.g. Li-ion batteries for transport sector) will inevitably lead to a rapidly increasing price, which makes **low-cost Na-based LMBs** more competitive in large scale energy storage for the future energy system. However, Na halogen salts containing in the molten salt electrolytes of Na-based LMBs lead to high melting temperatures of the molten salt electrolytes and thus high operating temperatures of LMBs. However, a high operating temperature is undesirable because it results in higher rates of corrosion and detracts from overall storage efficiency, which ultimately increases cost of ownership. In our Sino-German research project funded by DFG and NSFC (cooperation with Karlsruhe Institute of Technology (KIT), Germany and Huazhong University of Science and Technology (HUST), China), **low-cost low-temperature Na-based LMBs** are being developed.

One of the major challenges for development of low-cost low-temperature Na-based LMBs is **selection of the molten salt electrolytes** with the best thermo-chemical properties (melting temperature, corrosivity, Na solubility regarding self-discharge) and the lowest cost. In this work, current research progress on selection of the best molten salt electrolytes for **low-cost low-temperature (<450°C) Na-based LMBs** will be presented. The commercial software for thermodynamic calculations – FactSage® is used to simulate the phase diagrams of molten halogen salts for screening the promising electrolytes. Furthermore, thermo-analysis *via* Differential Scanning Calorimetry (DSC) [5], immersion tests of alloy samples [6], and Na solubility measurements are performed to evaluate the selected molten salt electrolytes experimentally. The selected best molten salt electrolyte will be tested in the Na-based LMB test cell.

References

[1] H. Li, et al. Liquid metal electrodes for energy storage batteries, *Adv. Energy Mater.* 1600483 (2016) 1-19.

[2] H. Kim, et al. Liquid metal batteries: Past, present, and future, *Chem. Rev.* 113 (2013) 2075-2099.

[3] M.S. Wittingham, History, Evolution, and Future Status of Energy Storage, *Proc. IEEE* 100 (2012) 1518-1534.

[4] K. Wang, et al. Lithium–antimony–lead liquid metal battery for grid-level energy storage, *Nature* 514 (2014) 348–350.

[5] T. Bauer, et al. Overview of molten salt storage systems and material development for solar thermal power plants, *World Renewable Energy Forum 2012*, May 13.-17. 2012, Denver, Colorado, US.

[6] W. Ding, T. Bauer, et al. Hot corrosion behavior of commercial alloys in thermal energy storage material of molten $MgCl_2$/KCl/NaCl under inert atmosphere, *Sol. Energy Mater. Sol. Cells* 184 (2018) 22–30.