Development of Low Melting Temperature Molten Halogen Salt Electrolytes for Na-Based Liquid Metal Batteries with Low Operating Temperatures below 400°C

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Liquid metal battery (LMB) is a promising technology for grid scale electricity storage due to its advantages of low-cost, large-capacity and long-lifespan [1-3]. LMB has a three-layers structure due to mutual immiscibility and different densities of its negative electrode, electrolyte and positive electrode. It generally 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). The **molten salt electrolyte** serves as an isolation layer between the negative and positive electrodes, and conducts the ions such as Na^+ in the Na based LMBs. The lower chemical potential of the negative electrode metal in the alloying state with the positive electrode metal provides the thermodynamic driving force (cell voltage) for the liquid metal batteries [1].

Some LMBs such as Li-based LMBs have shown excellent electrochemical performance [1,4]. However, they generally have operating temperatures higher than 500°C, since their electrolytes are not optimized. Moreover, for Li-based LMBs, the excessive consumption of Li resource (e.g. Li-ion batteries for transport sector) will inevitably lead to a rapidly increasing price. Thus, it is of great interest to develop **low-cost Na-based LMBs**, in order to make LMBs more competitive in large scale energy storage for the future energy system. Furthermore, low operating temperatures of LMBs have the advantages of low self-discharge due to low solubility of negative electrode metal, low heat loss, low corrosion rates of the structural materials, etc. Thus, in our ongoing 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 Na-based LMBs with low operating temperatures** (e.g., below 400°C) are being developed.

Molten halogen salts are promising electrolytes for LMBs due to their high stability, superior conductivity and low prices. This work aims to develop molten halogen salts as **low temperature and sodium solubility electrolytes** for sodium-based LMBs. The molten halogen salt electrolytes are screened and selected by regarding the properties (such as melting temperature, Na solubility related to self-discharge rate, Na^+ ionic conductivity) and the material 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. Based on thermodynamic calculations of the phase diagrams, melting point measurements (via Differential Scanning Calorimetry (DSC) [5] and OptiMelt) and Na solubility measurements, the most promising molten halogen salt electrolytes are selected. Moreover, the test results of these selected molten halogen salt electrolytes in the Na-based LMB test cell will be presented.

References

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