

Stable All-Solid-State Sodium-Sulfur Batteries Enabled by Sodium-Antimony Alloy Anode and Confined Sulfur Cathode

Li-Ji Jhang¹, Daiwei Wang², Alexander Silver³, Xiaolin Li⁴, David Reed⁴, Donghai Wang²

¹Department of Chemical Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, United States,

²Department of Mechanical Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, United States,

³Department of Materials Science and Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, United States,

⁴Energy and Environment Directorate, Pacific Northwest National Laboratory, Richland, Washington 99354, United States

All-solid-state sodium-sulfur (Na-S) batteries are promising for stationary energy storage devices because of their low operating temperatures (less than 100 °C), improved safety, and low-cost fabrication. Using Na alloy instead of Na metal as an anode in Na-S batteries can prevent dendrite growth and improve interfacial stability between the anode and solid electrolytes to achieve long-cycling stability. A high-sulfur content cathode possessing high sulfur utilization is also important to enable an energy-dense Na-S battery. In this work, we studied Na-Sb and Na-Sn alloy anodes and demonstrated the superiority of Na₃Sb alloy undergoing a stable Na alloying/dealloying process at 0.04 mA cm⁻² for over 500 hours. Combining the optimized Na₃Sb alloy anode with sulfur-carbon composites prepared by the vapor deposition approach, the full cell shows a high sulfur specific capacity and improved rate performance. Moreover, the all-solid-state Na alloy-S battery can deliver a high initial discharge specific capacity of 1377 mAh g⁻¹ and maintain good capacity retention of 70% after 180 cycles at 60 °C. Post-cycle characterizations show that both the anode and cathode perform a reversible discharge/charge process after the 1st cycle, and the cathode undergoes significantly rearranged distributions of carbon and solid-state electrolytes after 180 cycles due to severe volume change induced by repeated sodiation/desodiation process.