Strategies To Enhance The Fast-charging Performance Of Conversion Anodes For Lithium-ion Batteries

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The development of high-capacity anodes that are stable at high rates is of immediate interest as a potential alternative to the commercial graphite anode in lithium-ion batteries (LIBs). Conversion-based transition metal oxides and sulfides, known for their high theoretical capacities, have been extensively studied in this regard. In this work, two strategies have been explored in order to enhance the high-rate performance of conversion-based anodes – first, is the suitable design of a nanostructured composite, and the second, is the creation of heterostructures. A ternary FeOOH-rGO-MnO_2 composite has been designed by a simple low-temperature synthesis method to address the limitations of the bare FeOOH anode (theoretical capacity ~1000 mAh g^{-1}) arising from poor conductivity and volume expansion. While cycling at high rates, the modified composite anode delivered capacities of 956, 842 and 688 mAh g^{-1} at 1, 2, and 5 A g^{-1} respectively for 200 cycles along with a cycling stability of 900 mAh g^{-1} at 1 A g^{-1} for 100 cycles. The rGO matrix effectively improves electron conduction and aids in stable SEI formation while the amorphous MnO_2 sustains the structural integrity of the electrode by controlling volume expansion. The exceptional stability of the anode at high rates was attributed to the marked increase in capacitive contribution in the ternary composite anode, due to the presence of amorphous MnO_2, paving the way for faster electrode kinetics. Further, FeOOH, which is a metastable precursor by itself, was made to undergo sulfidation in the presence of H_2S gas. The resultant FeS_2/FeS/rGO in-plane heterostructures delivered an exceptionally high capacity of 713 mAh g^{-1} at 20 A g^{-1} with a cycling stability of 1400 mAh g^{-1} at 0.5 A g^{-1} for 250 cycles. The robust performance of the anode can be attributed to the hetero-interface between FeS_2 and FeS which provides favourable pathways for facile Li^+ diffusion. The values of specific capacities reported for the FeOOH and FeS_2 anodes are amongst the highest in current literature, and the strategies developed in this work can be extended to other conversion-based anodes to obtain long-lasting anodes with good cycling performance at high rates.

References

[1] Savithri Vishwanathan, Sreejesh Moolayadukkam, Vijaya Kumar Gangaiah, and H. S. S. Ramakrishna Matte, ACS Appl. Energy Mater., 3 (2023) 2022-2030.

Figures

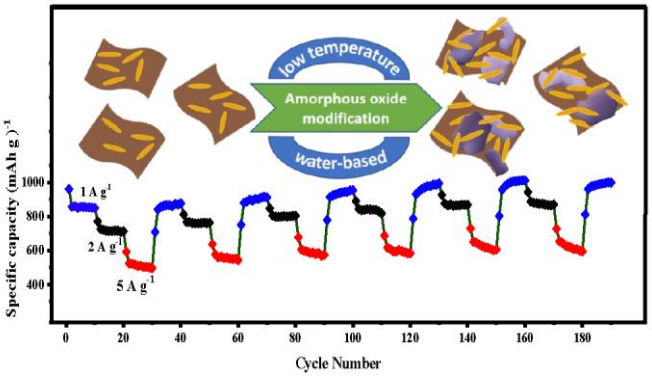

Figure 1: High-rate capability of FeOOH-rGO-MnO_2 anode due to amorphous oxide modification.