DEVELOPMENT OF FREE STANDING ELECTRODES FOR LI-ION ANODE STORAGE

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In an attempt to reduce materials that are not directly involved in the electrochemical reactions in a lithium-ion battery, such as the current collectors, the Ångström Advanced Battery Centre (ÅABC) at Uppsala University is currently working on developing free standing flexible electrodes [1,2,3,4]. Our first attempts have been to address the negative electrode and the challenge of the large volume expansion experienced when alloying lithium with tin and silicon. We show some promising results.

Size tunable nanocrystals of SnO_2 or Si encapsulated in 3d macroporous carbon have been synthesized and tested as free-standing negative electrodes for lithium-ion batteries. The synthesis of SnO_2 is based on a rapid, scalable combustion method by using the biodegradable and recyclable polyvinyl alcohol (PVA) foam as the carbon source. The electrostatic forces between the copious hydroxyl groups of purified PVA sponge and tin precursor guaranteed the uniformly and intimate integration of tin oxide nanocrystals on the carbon matrix. The combustion process carbonized the processed PVA molecules into a 3d carbon matrix, which not only encapsulated $tSnO_2$ nanocrystals as a way to buffer the volume changes during the lithiation/delithiation process, but also served as a way to preserve the interconnected pore system for the facile electrolyte percolation. The best performing electrode based on the composite with optimized size range of SnO_2 NCs and graphitization degree of carbon delivered a rate performance up to 8 A g^{-1} and long term cycleability up to 500 cycles for Li^+ storage. Silicon nanocrystals were attached to grapheme layers with a sol gel process and then freeze dried with PVA before the combustion step. In this case the silicon particles were protected from direct contact with the electrolyte. This gave the free-standing electrode a cycling stability vs. lithium for more than 1400 cycles but also a stable cycling performance in a full cell where the cathode was $LiFePO_4$ also made as a free-standing electrode. The results will be discussed based on detailed electrochemical analysis, in-situ technique and post-mortem morphological characterizations. We confirmed and quantitatively analyzed the contributions from traditional alloying/de-alloying mechanisms and non-diffusion controlled pseudocapcitive behavior for high rate Li^+ storage.

References

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