Enabling fast-charging via layered ternary transition metal oxide design as anode materials for lithium-ion batteries

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Abstract
Lithium-ion batteries remain at the forefront of battery technology – however, a new generation of electrode materials are required to satisfy new demands in large-scale and more advanced energy storage systems [1]. The application of transition metal niobates as battery anode material has attracted research interests due to their higher operating voltage, capacities, and rate capabilities compared to niobium oxides and conventional graphitic anodes [2]. Current battery technology utilizes cobalt as part of the electrode material, which is one of the most expensive transition metals with strained supplies from the growing demand for electric vehicles [3]. To distribute the use of transition metals, ternary transition metal oxides may have great potential for more cost-effective and high-rate anode materials. Furthermore, a trimetallic mixture of transition metal oxides as an anode material may provide multiple redox pathways for a speedier diffusion of Li^+ ions and higher theoretical capacity, enabling synergistic effects [4]. In this work, a ternary transition metal oxide based on Ni-Mn-Nb has been synthesized for the first time through a thermo-mechanochemical synthesis method. The as-prepared Ni-Mn-Nb anode was characterized and electrochemically evaluated as an anode material against Li/Li^+ (half-cell) and against NMC and LFP cathodes (full cells). For comparison, niobium pentoxide and binary transition metal oxides (Ni-Nb and Mn-Nb) were also prepared and tested as anode materials. The first discharge and charge capacities delivered by Ni-Mn-Nb anode at 0.1 A g^{-1} were 550 and 400 mAh g^{-1}, respectively. The ternary metal oxide design greatly enhanced its cycling performance after 7000 cycles with a reversible capacity of 93.8 mAh g^{-1} at a high current density of 2 A g^{-1} (10C) - the highest among the other anode materials in this work at a very high rate, synonymous to fast-charging. Post-mortem analysis revealed a stable SEI layer on the anode after cycling, which enabled the extremely stable cycling in 7000 cycles.

References

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Figures

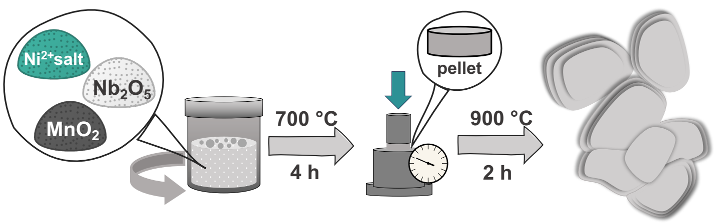

Figure 1: Schematic diagram of the thermo-mechanochemical synthesis used to prepare the layered ternary transition metal oxide (Ni-Mn-Nb).

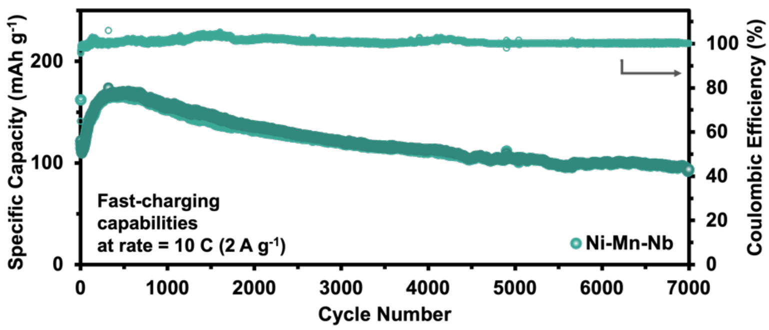

Figure 2: Long-term cycling performance of Ni-Mn-Nb oxide as anode material at a fast-charging rate of 10C.