Synthesis of NiO Thin Film Electrodes via RF Magnetron Sputtering for In-Plane 3D Thin Film Batteries

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The use of transition metal oxides as anode materials for lithium-ion batteries (LIBs) has gained significant attention due to their high specific capacity compared to carbon-based materials. Among these oxides, NiO stands out for its affordability, ease of production, chemical stability, and high exciton binding energy. However, the low electrical conductivity and volume changes during the charge/discharge cycles limit the stability of NiO's specific capacity. To address these issues, thin-film electrodes synthesized using RF magnetron sputtering have been explored.

RF magnetron sputtering offers advantages such as the ability to produce large-area thin films suitable for industrial applications and the capability to sputter both conducting and non-conducting materials. The technique ensures the construction of dense structures and produces high-quality films with minimal contamination. The demand for LIBs has been rapidly increasing for portable electronic devices, electric vehicles, and energy storage applications. To achieve high energy density, increasing the electrode surface area is essential. Traditional planar electrode designs have limitations in terms of mass loading and thickness, which can be overcome by employing three-dimensional (3D) electrode configurations. 3D thin electrode structures allow for increased active material deposition while maintaining a smaller thickness, overcoming challenges associated with thick electrodes and volume variations during lithium-ion insertion and extraction.

Transition metal oxides, including NiO, have been investigated as replacements for graphite-based anodes due to their high specific capacities. However, they face challenges such as low cell voltage, poor charge transfer kinetics, and low initial coulombic efficiency. The low coulombic efficiency is primarily due to the formation of a solid electrolyte interphase (SEI) during the initial discharge process, as well as the volume expansion and fracture of the electrode material. To improve the initial coulombic efficiency of NiO electrodes, it is crucial to reduce the co-occurrence of the lithiation reaction and SEI formation.

This study focuses on the synthesis of NiO thin film electrodes using RF magnetron sputtering. The in-plane type 3D battery configuration, without the use of a commercial separator, demonstrates stable cycling ability with a capacity retention of 94% and a coulombic efficiency of 97% over 60 cycles. These results are promising for the development of in-plane type 3D thin film batteries, addressing the challenges associated with NiO-based electrodes.

Overall, the utilization of RF magnetron sputtering for NiO thin film electrodes in 3D battery configurations presents a potential solution to enhance the performance and stability of lithium-ion batteries. These findings contribute to the advancement of high-energy and high-power density battery systems required for various applications in the modern era.

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Dr. Aliya Mukanova is a lead researcher at PI National Laboratory Astana, Nazarbayev University and Institute of Batteries. Dr. Mukanova's scope of interests in energy storage covers a range of topics including Li-ion and Na-ion batteries with the main focus on thin films for microbatteries. Dr. Mukanova is a winner of several local and international awards, among them are two "Leader of Science" awards (Tomson Reuters-2015, Clarivate-2020) for the highly cited articles.

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