

Optimizing Ni-Rich $\text{LiNi}_{0.85-x}\text{Co}_{0.04+x}\text{Ti}_{0.1}\text{Al}_{0.01}\text{O}_2$ Cathode Materials ($x = 0.00$ & 0.02) via Co-Precipitation for Lithium-Ion Batteries

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Structured Abstract

Background: Lithium-ion batteries (LIBs) are widely used in electric vehicles and renewable energy storage systems due to their high energy density and long cycle life. Among key components, cathode materials critically influence battery performance. Nickel-rich compounds, such as $\text{LiNi}_{0.85-x}\text{Co}_{0.04+x}\text{Ti}_{0.1}\text{Al}_{0.01}\text{O}_2$ ($x = 0.00$ and 0.02), have gained attention for their high energy storage capacity, improved thermal stability, and lower cost. This study focuses on synthesising and characterising these Ni-rich layered cathode materials via co-precipitation to examine how stoichiometric variation affects structural and morphological properties, with the aim of developing more efficient, stable, and durable batteries for future energy technologies.

Methods: The compounds $\text{LiNi}_{0.85-x}\text{Co}_{0.04+x}\text{Ti}_{0.1}\text{Al}_{0.01}\text{O}_2$ ($x = 0.00$ and 0.02) were synthesized via the co-precipitation method, followed by pre-sintering at 480°C for 5 hours and high-temperature annealing at 800°C for 15 hours. The samples were then washed, dried, and characterized using X-ray Diffraction (XRD), Field Emission Scanning Electron Microscopy (FESEM), and Energy Dispersive X-ray Spectroscopy (EDX) to evaluate their crystallinity, phase purity, morphology, and elemental distribution. These characterization techniques provided crucial insights into the effects of synthesis conditions on the structural and morphological properties of the materials, which are directly related to their electrochemical performance.

Results: XRD analysis confirmed the formation of a single-phase layered $\alpha\text{-NaFeO}_2$ structure (space group $R\bar{3}m$) with no detectable impurities. The sample with $x = 0.02$ ($\text{LiNi}_{0.83}$) exhibited a higher Reference Intensity Ratio ($\text{RIR} = 1.04$), indicating reduced cation mixing and better structural integrity compared to the $x = 0.00$ sample ($\text{RIR} = 0.96$). FESEM results showed that $\text{LiNi}_{0.83}$ had smaller and more uniformly distributed crystallites (~ 607 nm) compared to the larger crystallites (~ 2152 nm) in $\text{LiNi}_{0.85}$. EDX analysis confirmed the presence and homogeneous distribution of Ni, Co, Ti, and Al elements, consistent with the intended stoichiometry. These findings demonstrate that stoichiometry significantly influences the structural and crystallite size of materials.

Conclusion: The findings indicate that modifying the stoichiometry of Ni-rich cathode materials significantly influences their structural and morphological characteristics. The $\text{LiNi}_{0.83}$ material demonstrated superior crystallinity, reduced cation mixing, and enhanced morphology, making it a more promising candidate for lithium-ion battery applications.

Keywords: Lithium-ion batteries, cathode materials, Ni-rich layered oxides, co-precipitation

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