Spinel Glass Nanofibers for Application in Solid-State Batteries

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Abstract

Lithium-ion batteries (LIBs) are a prominent industry, primarily due to their wide use, especially in electric vehicles (EVs). With the increasing expansion of EVs, demand is growing for recycling and reusing materials, especially valuable metals like lithium, nickel, manganese and cobalt. The demand for these metals is rising and spent LIBs can potentially serve as a secondary source. The predominant cathode materials used in LIBs for EVs are part of a category of layered mixed transition metal oxide compounds. These compounds are represented by the formula LiNixMnyCo1-x-yO2 (NMC).
NMC spinel appears as a promising material for use in solid-state batteries, representing a safer alternative to commonly available batteries with liquid electrolytes. The formation of glass nanofibers enhances safety and improves mechanical properties. The nanofiber structure is advantageous due to its flexibility and resilience, crucial during charging and discharging processes. NMC nanofibers were prepared using cathode material from commercial batteries from EVs; this reuse contributes to material recycling.

The LIB pouch cell was disassembled into individual layers of cathodes, anodes and separators. The cathode material including aluminium foil was manually cut into square pieces with a size of 25 × 25 mm. These layers were then placed in a porcelain crucible and heat treated in an electric furnace at a temperature of 400 ◦C for 60 min with a temperature rise of 5 ◦C/min in air atmosphere. Following thermal exposure and spontaneous cooling to laboratory temperature, the layers were placed in a container with distilled water, and using an ultrasonic probe, the active material was separated from the aluminium foil, serving as the current collector, on which the material is pressed. After drying, the material was prepared for nanofiber production. Electrospinning was employed, creating fibres using electrical voltage from polymeric precursors. For this experiment, a solution was prepared from tetraethyl orthosilicate (TEOS) and polyvinylpyrrolidone (PVP), enriched with NMC particles. The viscosity of the prepared solutions was measured, and the flow rate of polymeric precursors with particles during the spinning process was examined.

The final step in nanofiber preparation is high-temperature calcination. The individual fibre layers were pressed, and the electrochemical properties were measured. The resulting fibres were characterized using various methods. X-ray diffraction (XRD) and X-ray fluorescence (XRF) were used to verify composition. Fibre thickness was measured on a laser confocal microscope and scanning electron microscope, which also allowed to measure the thickness

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of individual layers.

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