

N-doped Carbon-coated TiO₂ Nanofibers as Anode Materials for Lithium-Ion Batteries

Sukeun Yoon, Myung-Heyun Ryu, Kyu-Nam Jung,
and Kyung-Hee Shin,

Korea Institute of Energy Research, Yuseong, Daejeon
305-343, Republic of Korea

Nanostructured materials are becoming important in the energy conversion and storage fields and have attracted interest because of qualities such as high surface area and porosities. These characteristics make it possible to enable new reactions, decrease the pass length for ion transport, reduce inner resistance, and improve both stability and specific capacity.¹ For these reasons, nanostructured materials have been favored over the past decade for use in electrochemical energy storage devices such as lithium-ion batteries. Although currently used lithium-ion batteries have become the dominant power source for portable electronic devices because of their high energy density, they cannot quite meet the requirements of next generation energy storage devices, such as automotive and stationary storage sectors, in terms of power density, cycle life, and safety. These energy storage technologies rely on innovative materials, i.e., electrode materials capable of being charged and discharged at high current density.

There are many kinds of nanostructured materials, including nanoparticles, nanofibers, nanowires, nanorods, nanotubes, nanoflowers, and nanospheres. Nanoparticles (zero-dimensional) have been intensively studied, while one-dimensional (1-D) nanomaterials have attracted attention from researchers recently. The 1-D nanostructures in lithium-ion batteries can offer high capacity, increased rate capability, and improved cycle stability. This is because they facilitate better electron and lithium ion transport resulting from a high interfacial contact area with the electrolyte and accommodate strain and volume changes without any cracking or crumbling. In this respect, 1-D nanostructured materials like the intercalation-type and the conversion-type have been investigated as alternative anode materials to replace already-commercialized carbonaceous materials.

In particular, titanium dioxide (TiO₂) has been suggested as one of the promising candidates for alternative anode materials in lithium-ion batteries because of its excellent physicochemical properties, low production cost, and low toxicity. Furthermore, with an operating voltage well above that of Li⁺/Li and less surface reactivity with the electrolyte, it prevents formation of a harmful solid-electrolyte interphase (SEI) layer, which results in better overcharge protection and safety than graphite. However, a low intrinsic ionic and electronic conductivity, which produces a poor rate capability for TiO₂ electrode, has hampered its application as anode for lithium-ion batteries. Many studies have aimed at overcoming these drawbacks by optimizing particle size and morphology to minimize lithium-ion diffusion pathways, forming composites with electronically conductive materials, and altering the electronic structure with metal or anion doping. Nanostructured materials with a large surface-to-volume ratio are expected to offer fast lithium insertion/extraction kinetics by a shorter diffusion length and increase lithium ion flux at the interface between the active material and the electrolyte, resulting in an excellent power density. The TiO₂ composite strategy, on the other hand, involves

electronically conductive agents, for example, carbon phase materials and metals. These conducting materials can improve the electron transport properties in the electrode. A wide variety of approaches have been pursued over the years for synthesizing TiO₂. Electrospinning is a particularly successful, simple, cost-effective technique that controls the chemical composition, crystallite size, and particle shape.

Here we report an electrospinning process that obtains N-doped mesoporous carbon decorated TiO₂ nanofibers with a high rate capability and good cycling performance for lithium ion batteries.

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References

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