Synthesis of tin phosphide/phosphate carbon composite nanofibers as low-temperature anode for lithium-ion batteries

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Graphite anode is admitted as one of the critical limiting factors for applying lithium-ion batteries (LIBs) in low-temperature (LT) environments [1]. As an alternative, tin compounds, such as SnO_2, exhibit much better LT performance owing to the unique allotropic changes of tin and increased reversibility of lithiation-delithiation reactions at low temperatures [2]. However, to the best of our knowledge, LT performance of other tin compounds as anode for LIBs has not been reported so far.
In this work, free-standing carbon composite nanofiber mats of tin phosphide/phosphate have been successfully synthesized by electrospinning with heat treatments and applied as anode materials for LT LIBs.

First, the electrospinning solution was prepared by mixing polymer solution (PVP dissolved in ethanol) with precursor solution (different amount of tin (II) chloride dihydrate and phosphoric acid dissolved in ethanol:water (1:2 vol.) mixture). Next, the prepared suspension was electrospun on a NE300 electrospinning machine (Inovenso) at 20-22 kV with a flow rate of 0.8 mL h^{-1}, collected on a drum collector rotating at 100 rpm, and placed 10 cm away from the tip of the needle. Uniform fiber mats were dried at 150 ºC for 12 h, stabilized at 280 ºC for 4 h in the air oven, and further annealed at 700 ºC for 1 h in the flowing Ar + H_2 (4%) atmosphere.

Figure 1a shows XRD pattern of the designed material, which corresponds to tetragonal Sn with a space group of I41/amd and tetragonal SnP with a space group of I4mm. A broad bump between 20º and 30º may indicate presence of amorphous Sn_xPO_4. As seen from TEM image, tin phosphide/phosphate nanoparticles (d = 5–10 nm) are uniformly distributed within carbon fiber matrix (d = 100–150 nm).
The temperature-capability of the 1:1 sample at 100 mA g^{-1} is shown in **Figure 1b** in comparison to the commercial graphite anode. The developed electrode maintains about 200 mAh g^{-1} capacity even at -30 ºC, while commercial graphite completely loses its lithium storage capability at -20 ºC.

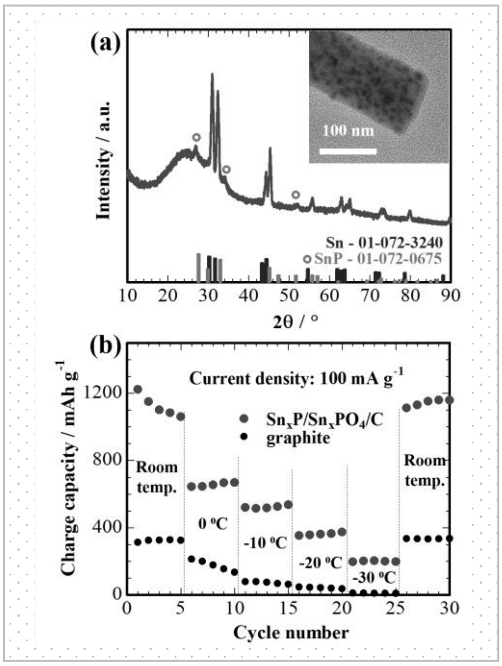

Figure 1. XRD patterns (a) and temperature-capability of the designed material. Inset: TEM image.

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Dr. Ayaulym Belgibayeva received her Ph.D. in Chemical Science and Engineering from Tokyo Institute of Technology, Tokyo, Japan, under the supervision of Prof. Izumi Taniguchi in 2021. She has joined Battery Research Group of Prof. Bakenov at Nazarbayev University, Kazakhstan, as a Postdoctoral Researcher and started new project on the development of multifunctional nanofibers as a PI. Her current research interests include development of nanocomposites for energy storage applications.

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