29 - Synthesis of silicon nanowire powder in mass for lithium-ion batteries

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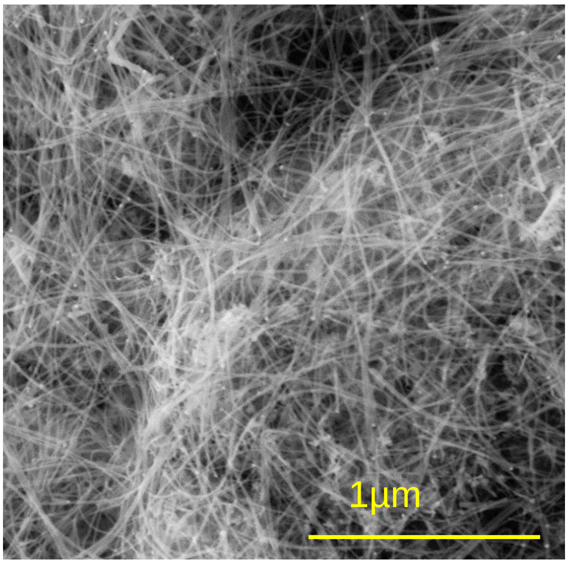
First produced by thin film technologies (CVD growth or etching), silicon nanowires (SiNWs) have shown great promises in nanoelectronics, sensors and energy storage. In lithium-ion batteries, silicon is a promising material in replacement of graphite at the anode as it can absorb as much as 10 times more lithium. This huge lithium absorption induces fractures in the silicon crystal after a few charge-discharge cycles, unless the crystal size is tuned below 100nm to allow for an elastic behavior. SiNWs of small diameters do withstand hundreds of cycles in batteries, and their wire shape help maintain electrical connection within the electrode. SiNWs are also interesting material for thermoelectric applications.



To use SiNW as a material in 3D components such as battery electrodes or thermoelectric legs, high quantities are required. We recently patented [1] a new technology of SiNW synthesis that allows for the preparation of large quantities of SiNWs in bulk in a small, simple reactor within a few hours at medium temperature (450°C). Our SiNWs are grown from metal nanoparticles deposited on an unreactive nanopowder of NaCl from an air-stable organosilane oil as Si source. After synthesis, the NaCl powder is dissolved in water to recover a dense mat of pure SiNWs. The process is currently scaled-up in the lab up to the gram scale, as compared to the mg scale accessible to CVD growth.

NaCl particles play a critical role as a “solid solvent”, keeping catalysts available to reactive gases and apart from each other during growth. Bulk grown SiNWs behave differently from SiH_4-fed CVD-grown SiNWs: long and very thin (10nm in diameter), they are strongly hydrophobic and show a low oxygen content even after exposure to air. We study the mechanism of silane decomposition through systematic sub-product analysis and chemical kinetics of SiNW growth to improve the yield and quality of SiNWs. It appears that several reactions compete for the Si source in the reactor, in which the organic part of the organosilane reagent plays a significant role. The organosilane reactivity thus offers new ways of tuning SiNW growth and physical properties.

The students will prepare a batch of SiNWs and characterize their structure by electronic microscopy and check their chemical composition by different spectroscopies.

Reference :

[1] O. Burchak, P. Chenevier, P. Reiss, 'Procédé de préparation de Nanofils de Silicium', Patent query FR 1455431, 2014.