Tin-Carbon Nanocomposite Enables Fast-Charging Battery

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If batteries had larger energy storage capacities, portable electronics and electric vehicles would spend less time tethered to electrical outlets. However, to make fast-charging, high-storage batteries, researchers need new electrode materials that don't degrade during use. Now a team has developed a process for making tin-carbon composites to produce battery electrodes that charge up quickly and don't break over time (Nano Lett., DOI: 10.1021 /nl303823k).

The anodes in today's lithium-ion batteries consist of graphite. To improve the batteries' storage capacity, researchers are looking to other elements including tin. In theory, a battery with a pure tin anode would store over 2.5 times as much energy as one with a graphite anode does. But there is a downside to tin: When a tin anode reacts with lithium in a battery, its volume triples. The volume change can crack the material and destroy the battery.

Researchers have tried to reduce the strain from the expansion by making composite anodes that mix carbon with nanostructured tin. "The smaller the tin particles, the smaller the strain," says Chunsheng Wang, a chemical engineer at the University of Maryland, College Park. Carbon provides mechanical support and prevents the tin particles from clumping together.

However, researchers have had difficulty making tin nanoparticles of reliable dimensions within these composites. The melting point of tin—about 232 °C—is well below the reaction temperature for making the carbon composite. So the tin particles often melt and clump together, increasing strain during the anode's use.

To make nanoparticles that wouldn't clump, Wang collaborated with University of Maryland mechanical engineer Michael R. Zachariah on a method called aerosol spray pyrolysis. The process involves rapid heating and cooling of droplets of carbon and tin reactants.

The Maryland team starts with an ethanol solution of tin chloride and the polymer polyvinylpyrrolidone, which acts as the carbon source. They aerosolize the solution and rapidly heat the droplets to 900 °C. At this temperature, the tin chloride decomposes and the polymer degrades into elemental carbon. The two elements form a powder of spherical carbon particles, each 200 to 500 nm in diameter, riddled with 10-nm-diameter tin spheres. The transformation takes less than a second, and then the powder quickly cools to room temperature.

Though the reaction happens well above tin's melting temperature, the tin nanoparticles don't have time to move through the carbon and form clumps. Doing the chemistry in droplets is much faster than in beakers of reactants, which require long times to heat and cool, says Zachariah.

The team built a test battery with a tin-carbon anode made from the composite powder and a cathode made of lithium. The battery maintained its storage capacity after charging and draining 220 times. The battery could charge and drain about 20 times in an hour—faster than a typical cell phone battery.

Most important, says Yuegang Zhang, a materials scientist who develops battery materials at the Lawrence Berkeley National Laboratory, was that the tin-carbon composite's nanostructure remained stable after these cycles. Such stability could lead to a long battery lifetime, he adds.

However, Zhang says, the anode needs more testing to prove it will last. If the composite stays stable after more than 1000 charge cycles, it would be commercially viable, he says.

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