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UNIVERSITY OF FLORIDA
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This granted funded research into the application of nanoscience to Li-ion batteries. Different synthesis strategies were employed to create a nanofiber electrode (based on tin-oxide) [1-3] and a honeycomb electrode (carbon) [4]. In both cases, we showed that the nanostructured material was capable of delivering dramatically increased specific capacity (mAh/g) upon discharge when compared to conventional film electrodes. This ability is due to the decreased solid-state diffusion distance of the Li-ion in the nanostructured electrodes.

The nanofiber-SnO_2 electrode was created by the template synthesis method. Briefly, a precursor solution impregnates the monodisperse nanoscopic pores of a sacrificial template membrane. The pores run the membrane's entire length. The precursor solution is then processed to the desired material, here using sol-gel chemistry, and the template is removed. This leaves nanostructures of the desired product intact and extending from a substrate like the bristles of a brush. This research topic combines this nanofabrication technique with the Sn-based anode.

Tin-oxide based composites have shown great promise as an alternative material for Li-ion battery anodes. This material is electrochemically converted to composite Sn/LiO_2 electrodes. In this form, they are theoretically capable of storing twice the amount of Li as carbon, the current commercial anode. We showed important improvements in rate-capabilities and cycle-life of this Sn-based nanoscale electrode compared to a thin-film electrode of the same material. Rate-capabilities are a measurement of the specific capacity able to be delivered at increasing discharge rates (1C = 1/h). Figure 1 compares the rate capabilities of the nanostructured electrode to that of the film control electrode.

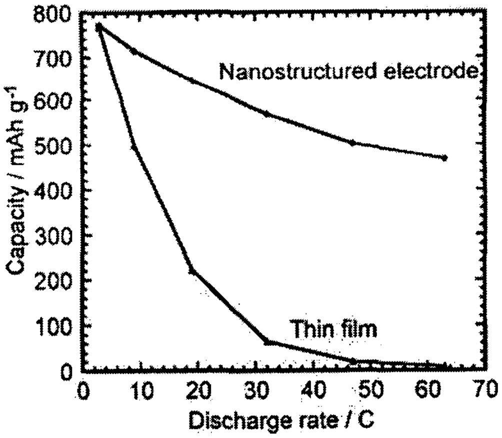

Figure 1. **Rate capabilities of nanostructured and thin-film tin-based anodes.**

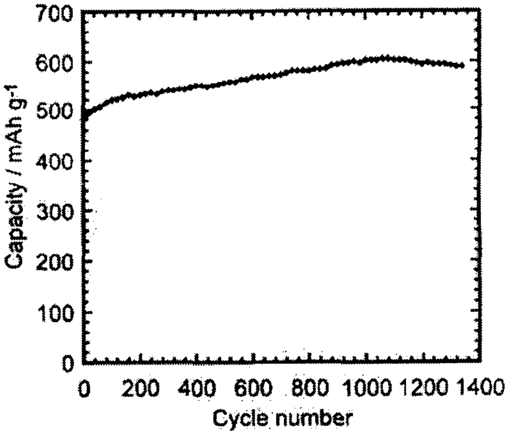

Figure 2. **Cycle-life of nanostructured tin-based anode at discharge rate of 58 C.**

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Prior investigations on this material had shown film electrodes to have poor cycle life. This is due to the large volume change associated with Li-Sn alloying of this material. The template-synthesized nanofiber electrode of this material has enough void volume (volume once occupied by the template) to accommodate this volume change. We demonstrated that the nanofiber material was able to undergo over 1400 charge-discharge cycles without showing any fade in specific capacity (mAh/g). These data are shown in Figure 2.

Another focus of this grant is to create a honeycomb anode. This honeycomb structure can serve as the first building block towards a nanoscale solid-state Li-ion battery. This structure was created by chemical vapor deposition of a carbon thin-film on a quartz substrate. An alumina template masked the carbon film. Oxygen plasma etched the carbon through the pores of the template. This creates a template pattern into the carbon. This carbon honeycomb structure is show in Figure 3.

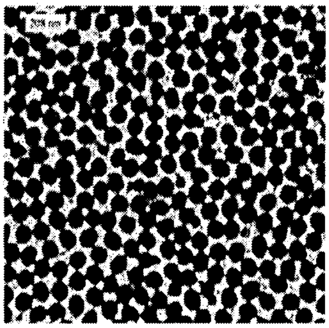

Figure 3. Electron micrograph of carbon honeycomb anode. Scale bar is 208 nm.

This honeycomb was also electrochemically characterized. It demonstrated amazing rate capabilities similar to the tin-based nanofiber electrode described previously. At low discharge rates, this carbon honeycomb structure stored 325 mAh/g. At the discharge rate of 10 C, it delivers more than 50 times the capacity of a thin-film carbon that does not have the honeycomb of pores. It was able to maintain 100 mAh/g on the 700th cycle at the discharge rates between 1 and 2 C. Therefore, a graphitic-carbon version of this honeycomb structure is an interesting, viable alternative to current anode materials.

References:

(1) Li, N.; Martin, C. R.; Scrosati, B. *Journal of Power Sources* **2001**, *97-98*, 240-243.

(2) Li, N.; Martin, C. R. *Journal of the Electrochemical Society* **2001**, *148*, A164-A170.

(3) Li, N.; Martin, C. R.; Scrosati, B. *Electrochemical and Solid-State Letters* **2000**, *3*, 316-318.

(4) Li, N.; Mitchell, D. T.; Lee, K.-P.; Martin, C. R. *Journal of the Electrochemical Society* **2003**, *150*, A979-A984.