A Layered Carbon Nanotube Architecture for High Power Lithium Ion Batteries

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We have developed a new multi-layered electrode architecture for Li-ion batteries. This architecture consists of alternating layers of carbon nanotubes and active lithium ion electrode particles stacked together on a current collector. The intermittent layers of carbon nanotubes form a highly conductive and porous matrix which facilitates electron transport and lithium ion diffusion throughout the electrode, and enhances bulk conductivity of the electrode. Using commercially available micron-sized spinel lithium manganese oxide ($LiMn_2O_4$) and commercially available multi-walled carbon nanotubes (MWNT), we have demonstrated in increase in power density by 4-6 times over conventional cathodes (Figure 1).

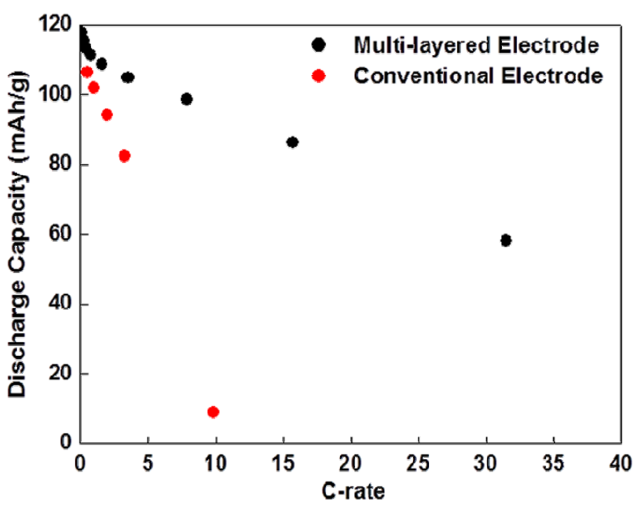
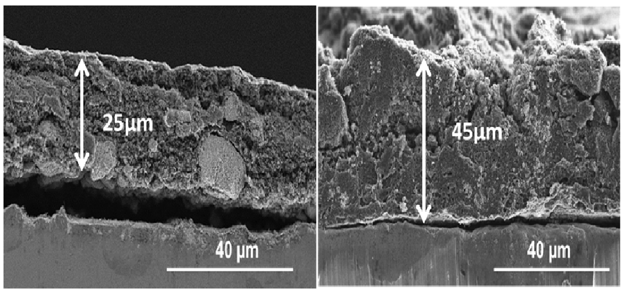


Figure 1. Rate capability of multi-layered electrode (black) and conventional electrode (red).

Furthermore, the use of nanomaterials does not have a detrimental impact on the packing density of the electrode as we demonstrate improvement in volumetric density by a factor of 3 over conventional cells (Figure 2).



(a) (b)

Figure 2. (a). Cross-section of multi-layered electrode with an active material loading of 9 mg/cm^2. (b). Cross-section of conventional electrode with active material loading of 5.6 mg/cm^2.

Utilizing a well-characterized fabrication method, we demonstrate the high-rate fabrication of the multi-layer structure using a room temperature and atmospheric pressure process. Through the multi-layer structure, we demonstrate a significant increase in power density of a lithium ion cathode with high active material loading in the range of 8-10mg/cm^2 and low carbon contents of 10% and 20%. We also demonstrate the versatility of the multi-layer structure when used in conjunction with a low-rate lithium ion cathode material, such as the high capacity lithium-rich lithium nickel manganese cobalt oxide, $0.3Li_2MnO_3$ $0.7LiMn_{0.333}Ni_{0.333}Co_{0.333}O_2$. When the architecture is applied to the $0.3Li_2MnO_3$ $0.7LiMn_{0.333}Ni_{0.333}Co_{0.333}O_2$ electrode, we observe a cycle life of greater than 500 full- depth cycles at a discharge rate of 1C. We have identified improved porosity and conductivity of the intermittent carbon nanotube layer as the mechanism of performance enhancement from data obtained from galvanostatic cycling, impedance spectroscopy, scanning electron microscopy (SEM), atomic force microscopy (AFM), and 4-point probe DC conductivity measurements. They will be discussed.

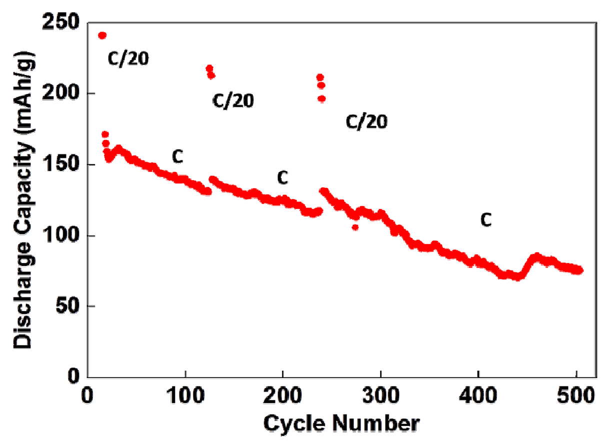


Figure 3. Cycle life of multi-layered electrode composed of CNTs and $0.3Li_2MnO_3$ $0.7LiMn_{0.333}Ni_{0.333}Co_{0.333}O_2$ active material. Active material loading is 9.1mg/cm^2

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