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Atomic Layer Deposition of V_2O_5-Carbon Nanotube Cathode with TiO_2 Protecting Layer for Lithium Ion Batteries

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Atomic Layer Deposition (ALD) coatings have been shown to enhance the capacity stability of anodes and cathodes for lithium ion batteries (LIBs) in our earlier work.[1,2] In this investigation, we have extended ALD to deposit an active high performance V_2O_5 cathode directly onto carbon nanotube (CNT) paper for lithium ion batteries. ALD offers advantages compared with other fabrication techniques because of its ability to coat high aspect ratio conductive matrices, define ultrathin film thickness and control film morphology and crystallinity at relatively low temperatures.[3]

Electrodes formed using ALD on conducting, high surface area supports are free-standing and do not need organic binder or a current collector. The lower mass achieved without an organic binder or current collector can greatly improve the specific energy density of LIBs. These ALD-coated electrodes are very flexible. Additional protective layers can also be deposited on the ALD active material. These protective layers can improve the stability of the underlying active material.

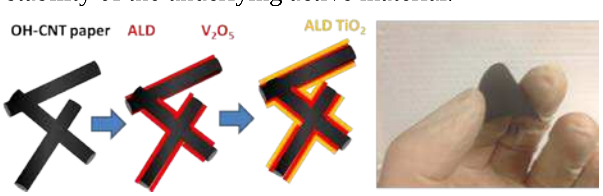

Fig. 1 Free-standing V_2O_5-CNT paper by ALD shows excellent flexibility.

In this work, V_2O_5 was grown using 50 ALD cycles of vanadium isopropoxide and H_2O onto CNT paper. The V_2O_5 ALD achieved a discharge capacity of ~260 mAh/g at a current density of 100 mA/g. This capacity is much higher than the capacity of commercial oxide-based cathodes. In comparison, the theoretical capacity of V_2O_5 is 440 mAh/g.

The V_2O_5 ALD cathode suffers severe capacity loss during cycling. However, the stability of V_2O_5 is significantly improved by applying 20 cycles of a protecting TiO_2 ALD film using $TiCl_4$ and H_2O onto the surface of V_2O_5. The TiO_2 ALD-coated V_2O_5-CNT paper displayed high rate discharge capacities of ~225 mAh/g at a current density of 1000 mA/g. This discharge capacity is ~87% of the system capacity at 100 mA/g.

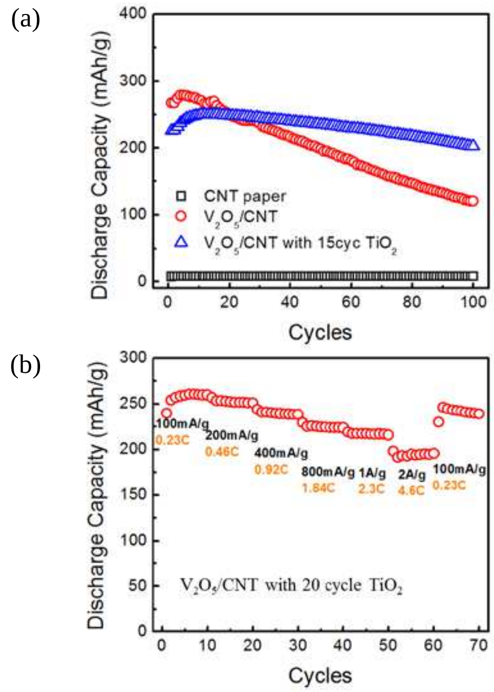

Fig. 2 (a) shows stability improvement of V_2O_5-CNT paper with 15 cycle TiO_2 ALD compared to the uncoated V_2O_5-CNT paper; (b) excellent rate performance of V_2O_5-CNT paper with 20 cycle TiO_2 ALD

The TiO_2 ALD layer protects the underlying V_2O_5 active material. The TiO_2 also does not impact the kinetics of Li ion transport because of the high lithium diffusion rate in TiO_2. We will also discuss the economic feasibility of large-scale ALD for lithium ion batteries at the end of the talk.

References

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3. S.M. George, *Chem. Rev.* **110**, 111 (2010).