Electrophoretic Deposition for Inexpensive Carbon Nano-Composite Lithium Air Battery Cathodes

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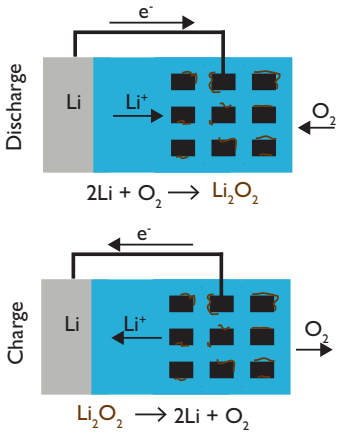
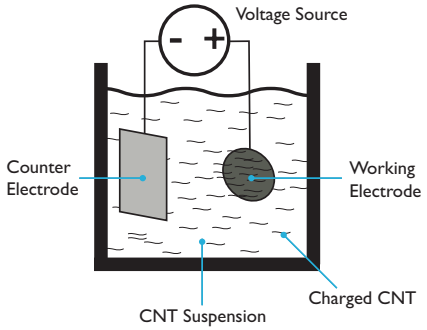
Introduction

Lithium air batteries take advantage of a reversible oxidation reaction of lithium with O2 to create a rechargeable energy source with specific capacities (stored energy per mass) that could approach that of gasoline, possibly revolutionizing EV technology [1]. The specific capacity is greatly affected by the nucleation site density of the cathode [2]. For this reason, nanomaterial conglomerates such as carbon nanotube carpets [3], show great promise as cathode materials. We believe that carbon nanohorns, because of their high edge to bulk ratio might improve the specific capacity of cathodes over CNT materials [4].



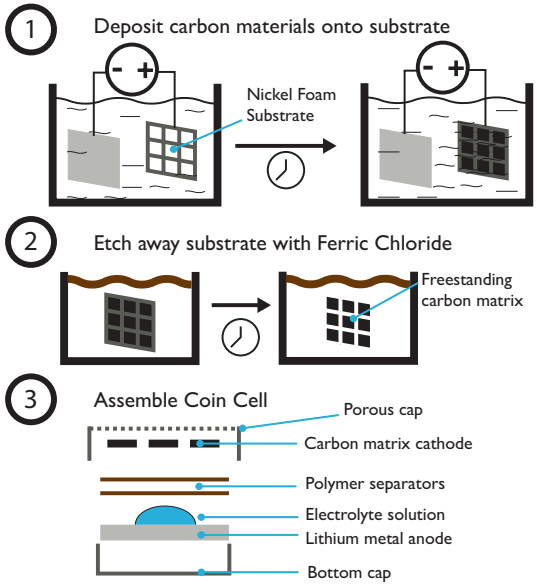
In this study we use electrophoretic deposition (EPD) to create carbon nanotube and nanotube-nanohorn composite cathodes and test batteries using them to compare discharge characteristics. EPD is an enticing technique because it is relatively inexpensive and easily scaled compared to traditional methods of nanomaterial fabrication.

Electrophoretic Deposition



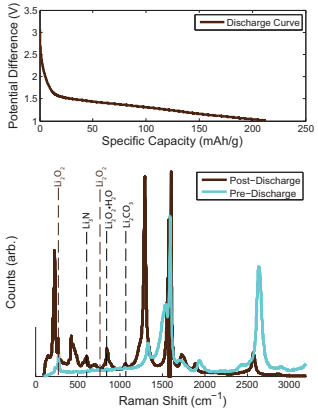
Electrophoretic deposition (EPD) is a technique which can be used to form controlled films of small particles on irregularly shaped and porous substrates. EPD occurs by the migration of charged particles dispersed in a solvent towards an electrode under an electric field. Once a suitably dense collection of particles is achieved on an electrode, they form a coagulated deposit by a number of mechanisms [5]. Carbon nanotubes typically require functionalization to create a stable dispersion suitable for EPD. In this study, we used TOAB functionalized single walled CNTs in THF.

Cathode and Cell Fabrication

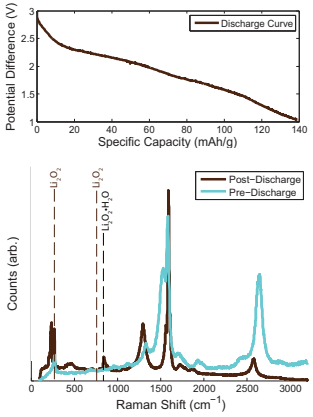


Functionalized Nanotube Cathodes

Nanotube only cathode



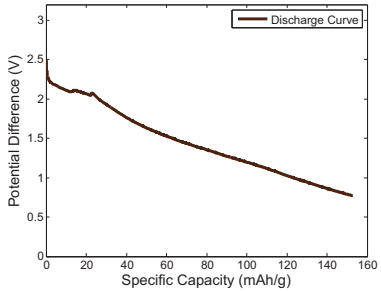
Nanotube-nanohorn cathode



The non-ideal discharge curves, low specific capacity and complicated post-discharge Raman spectrographs without Li2O2 peaks suggest that significant side reactions are occurring during discharge. This may be due to apparatus leakage, electrolyte contamination, or the effects of the TOAB remaining from functionalization.

Unfunctionalized Nanotube Cathodes

To rule out the effect of TOAB remaining from the functionalization process, we created cathodes from unfunctionalized CNT solutions. To our knowledge, this has not been successfully attempted with SWCNTs without the use of ionic surfactants which interfere with the EPD process. To do this, we used high concentration solutions of SWCNTs in NMP, a highly polar organic solvent which aids dispersion of the polar SWCNTs.



However, batteries made using these unfunctionalized CNT cathodes display a similarly non-ideal discharge curve and low specific capacity (see discharge curve right). This suggests that the primary contamination causing secondary reactions that hinder battery performance is not from the TOAB used in functionalizing the CNTs.

Conclusions

The cause of the poor battery performance is still unknown. However, these results serve as a proof of concept for the use of EPD to create composite cathode structures. Further development may make EPD a promising process for the creation of such cathodes.

Preliminary results suggest that the addition of nanohorns may actually reduce the specific capacity of lithium air batteries. However, it is likely the unknown secondary effect causing poor battery has a much larger effect than the presence of nanhorns. Thus it is much too early to make conclusions on the efficacy of nanohorn addition.

The ability to use EPD with unfunctionalized SWCNTs is, to our knowledge, a new development. This technique makes the use of EPD to create chemically active SWCNT structures much more viable.

Acknowledgements

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