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Reduced graphene oxide for Li-air batteries: The effect of oxidation time and reduction conditions for graphene oxide

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Li-air batteries hold the promise for a future generation of rechargeable batteries with very high specific capacities. The development of such batteries is important for the future of green technology. However, promising as these batteries are, much research is still needed [1], especially the development of a unique stable and light air cathode is important.

Reduced graphene oxide (rGO) has shown great promise as a cathode with high capacity [2]. We have investigated the effect of oxidation time on the structure and properties of graphene oxide (GO) and the related thermally and chemically reduced graphene oxide. GO was prepared by a modified Hummers method [3]. The oxidation time for GO formation was varied between 30 min and 3 days. XRD, Raman spectroscopy, SEM, TEM, BET and XPS have been used to characterize the GO's and both types of rGO's. Raman spectroscopy and XRD confirm the expected rGO structure, illuminating differences in the defect structure dependent on the reduction method. SEM and TEM images show very crumpled 3D structures which has a BET high surface area confirmed by nitrogen gas absorption. Figure 1 shows a TEM image of thermally reduced rGO from the GO oxidized for 3 days.

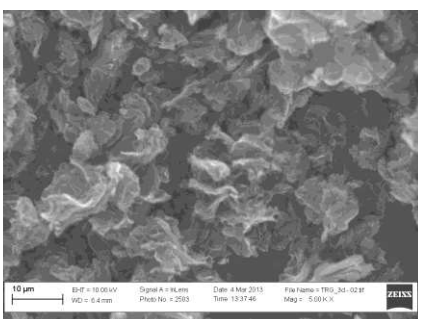

Figure 1: Tem image of themally reduced rGO

XPS indicates that the oxidation time of GO affects the composition of GO, which is partly reflected in the rGO composition.

Cathodes of the rGO materials were made by drop casting on a SS-mesh and the Li-O_2 battery was made in a home built Swagelok cell with a Li anode, 1M LiTSFI in dimethoxyethane electrolyte and the cathode. Batteries of carbon black cathodes were prepared for comparison. It is clear that the rGO cathodes are very different from the carbon black cathodes. It has been noted earlier that the discharge capacity of rGO cathodes exceeds that of carbon [2], but another difference is clearly noted when comparing the charge curves of cycled batteries, see figure 2. It is clear that the charging voltage at constant current is much more linear for rGO compared to the more exponential curve of carbon. The time dependent cycling of the battery shows that the rGO cathodes reach the time limit at a lower voltage. This combined with the observed higher capacity makes rGO a promising material for the future Li-air battery.

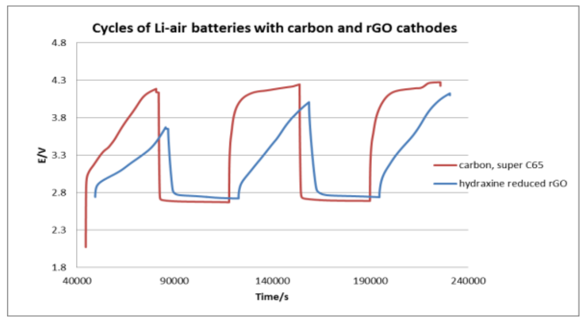

Figure 2: Charge/discharge curves of Li-O_2 batteries with rGO and carbon cathodes. The data are from first charge.

[1] Girishkumar, G. McCloskey, Bryan D. Luntz, Alan C. Swanson, S. and Wilcke, W. "Lithium-Air Battery: Promise and Challenges" Journal of Physical Chemistry Letters 1, 14 (2010) 2193-2203

[2] Xiao, Mei, Li, Xu, Wang, Graff, Bennett, Nie, Saraf, Liu and Zhang "Hierarchically Porous Graphene as a Lithium-Air battery" Nanoletters, 11 (2011) 5071-78

[3] Park, An, Piner, Jung, Yang, Velamakanni, Nguyen and Ruoff " Aqueous Suspension and Characterization of Chemically Modified Graphene Sheets" Chemistry of Materials 20, 21 (2008) 6592-6594