Investigation of Polymers Used in Lithium Oxygen Batteries as Electrolyte and Cathode Materials

A thesis presented for the degree of Master by Research

By

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2013

Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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May 2013

Acknowledgements

Although it's only been one and half year since I started my Master research, I have received many help from many people who supported me finishing this Master degree project. First of all, I would like to express my sincere gratitude to my supervisor, Prof Guoxiu Wang, for the guidance, support, and encouragement. I cannot thank you enough for all the advice that leads to the improvement of me, all the patience when I made a mistake, and all the concern about my research and life. I'm really grateful to have you as my teacher and supervisor.

I wish to thank all my colleagues in the research team of Centre for Clean Energy Technology, Dr Hao Liu, Dr Xiaodan Huang, Dr Bei Wang, Dr Bing Sun, Dr Ying Wang, Mr Dawei Su, Mr Kefei Li, Mr Anjon Kumar Mondal, Mr Shuangqiang Chen, Mr Yiying Wei, and Mr Xiuqiang Xie for the help both in my research and life during my Master period. Special thanks would address to Dr Yueping (Jane) Yao, for the administrative assistance and lab management as well as the great support for our life. It is a great pleasure to work with all of you and I wish you all the best luck.

I wish to thank Rochelle Seneviratne for the assistance and patience during my study. I am also grateful for the training and support in Faculty of Science from Dr Ronald Shimmon, Dr Linda Xiao, and all the MAU staff. The help from all the teachers and professors from school of chemistry and forensic science are much appreciated.

Financial support provided by the Australian Research Council (ARC) through the ARC Linkage project (LP0989134), and ARC Discovery Project (DP1093855) is gratefully acknowledged.

Finally I would like to thank my family, my parents and my brother, for your help and support for me. You always have faith in me even when I was confused about my life and future in the toughest time. It is your loves that make me the person I am and allow me to chase my dreams. Thank you and I love you all.

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Abstract

It has been well established that the electrolytes and cathodes have a significant effect on the electrochemical performance of lithium oxygen batteries. In this Master project, polymers were employed as electrolyte and cathode materials due to their unique superior properties. Using different methods, we synthesized suitable gel polymer electrolytes and conducting polymer catalysts for lithium oxygen batteries. Techniques such as field emission gun scanning electron microscopy, X-ray diffraction, and Fourier transform infrared spectroscopy were used to characterize the physical properties. Electrochemical analyses including the galvanostatic discharge and charge method, the cyclic voltammetry, the linear sweep voltammetry and the impedance spectra were conducted to determine the electrochemical performance for the as-prepared materials.

Gel polymer electrolytes based on low molecular weight polyethylene glycol were prepared and used as electrolyte in lithium oxygen batteries. The as-prepared polymer electrolytes showed improved stability compared with liquid electrolytes and exhibited good performance in lithium oxygen batteries. Additionally, the addition of ceramic filler SiO_2 was found to reduce the stability of polymer electrolyte towards oxygen reduction reaction although higher ionic conductivity was obtained. Polyethylene glycol based gel polymer electrolyte without SiO_2 addition exhibited excellent cycling performance and it could be used for achieving long-life lithium oxygen batteries.

Poly(vinylidene fluoride-co-hexafluoropropylene) based gel polymer electrolytes were prepared by solvent casting and employed as electrolytes in lithium oxygen batteries. The stability of the gelled electrolyte with tetraethylene glycol dimethyl ether has been greatly increased than the liquid one. The as-prepared polymer electrolyte was demonstrated excellent cycling performances. This thesis also investigated the effect of

different plasticizers on the performance of lithium oxygen batteries. The reason could lie on the interactions among the components when the gelled structure was set. The tetraethylene glycol dimethyl ether based gel polymer electrolyte showed the best electrochemical performance and can be used for long-life lithium oxygen batteries.

Polypyrrole conducting polymers with different dopants have been synthesized and applied as the cathode catalysts in lithium oxygen batteries. Polypyrrole polymers exhibited an effective catalytic activity for oxygen reduction in lithium oxygen batteries. It was discovered that dopant significantly influenced the electrochemical performance of polypyrrole. The polypyrrole doped with Cl^- demonstrated higher capactity and more stable cyclability than that doped with ClO_4^-. Polypyrrole conducting polymers also exhibited higher capacity and better cycling performance than that of carbon catalyst.

Conducting polymer coated carbon nanotubes were synthesized and used as catalysts in lithium oxygen batteries. It was found that both polypyrrole and poly(3,4-ethylenedioxythiophene) coated carbon nanotubes could provide high cycling performance while polypyrrole based one exhibited higher capacities. The ratio of conducting polymer coating also affected the electrochemical performance of lithium oxygen batteries. The conducting polymer coated carbon nanotubes also showed better performance than the bare carbon nanotubes.