

List of Figures

Figure 1. Basics of battery operation.	3
Figure 2. Key issues of lithium-sulfur batteries.	17
Figure 3. Comparison of sodium-ion anode capacities.	24
Figure 4. Failure of high-volume-change materials.	26
Figure 5. UV-Vis calibration for polysulfide solution.	45
Figure 6. Synthesis and characterization of MNCS/CNT composite.	49
Figure 7. Lithium polysulfide adsorption of tested adsorbents.	51
Figure 8. PDF plot of as-synthesized MNCS and MNCS with lithium polysulfides.	53
Figure 9. Effect of MNCS/CNT interlayer on cycling performance.	55
Figure 10. Characterization of MNCS/CNT-S composite.	56
Figure 11. Electrochemical performance of cells with MNCS/CNT-S cathodes and MNCS/CNT interlayers.	58
Figure 12. Conductivity and rate performance of MNCS-based materials.	59
Figure 13. Bis(2,2,2-trifluoroethyl) ether structure.	70
Figure 14. Electrochemical performance and self-discharge of cells with low-sulfur-loading cathodes. .	73
Figure 15. Electrochemical performance and self-discharge of cells with high-sulfur-loading cathodes. .	75
Figure 16. Post-cycling SEM images of lithium anodes.	76
Figure 17. Post-cycling FTIR spectra of lithium anodes.	78
Figure 18. Electrochemical performance of cells with P/C electrodes.	87
Figure 19. Characterization of material deposited on P/C electrodes during cycling.	89
Figure 20. Electrochemical impedance spectroscopy of cells with P/C electrodes.	91
Figure 21. SEM images of sodiated P/C electrodes with cycling.	93
Figure 22. SEM images of desodiated P/C electrodes.	94

Figure 23. FTIR spectra of P/C electrode cycled with FEC-free electrolyte and of relevant sodium metal reference samples.....	97
Figure 24. FTIR spectra of P/C electrode cycled with FEC-containing electrolyte and of relevant sodium metal reference samples.....	99
Figure 25. FTIR spectra of fresh P/C electrode and related references.....	101
Figure 26. Comparison of VC and FEC effect on the sodium metal SEI.....	102
Figure 27. FTIR of sodium metal deposit.....	103
Figure 28. XPS C 1s spectra.....	107
Figure 29. XPS O 1s spectra.....	109
Figure 30. XPS F 1s spectrum.....	110
Figure 31. XPS Na 1s spectra.....	111
Figure 32. XPS P 2p spectra.....	112
Figure 33. Sample holder for SEM imaging of air-sensitive samples.....	140
Figure 34. Sample holder for XPS analysis of air-sensitive samples.....	141

List of Tables

Table 1. Element wt. % in MNCS and MNCS/CNT by elemental analysis.....	51
Table 2. Physical properties and polysulfide adsorption of tested adsorbents.....	52
Table 3. Calculated adsorption energies for Li ⁺ ions on various sites of nitrogen-free and nitrogen-doped carbon with selected functional groups.....	55

Acknowledgements

I would like to extend my sincere thanks to the many that have helped me to reach this point. To my adviser, Prof. Donghai Wang, who trusted me to be one of his first students, for his unflagging support and for all that he has taught me. To Prof. Chao-Yang Wang, Prof. Hosam Fathy, and Prof. Sulin Zhang, for graciously serving on my committee. To the other members of my lab, past and present, for the hard work, new ideas, and camaraderie we have shared, and for the many things I have learned from them. To my other collaborators both inside and outside of Penn State, for the exciting work we have done together. To the staff of Penn State's Materials Characterization Lab, for their incredible help in turning my work from ideas into results, and helping me learn how to do so myself. To Philip Irwin, for masterfully building tools which enabled a large chunk of the research herein. It has been a great pleasure and an amazing learning experience to together shape our contributions to science and technology.

My deep thanks to my family and friends for all their kindness, patience, and support. Without them, I would have been in no state to complete any work at all.

Finally, I would like to express my thanks to the United States Department of Energy and to the Ben Franklin Technology Partners of Pennsylvania for their funding and support, without which my work and that of many others could not have been realized.