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著者(和文)	BELGIBAYEVA A
Author(English)	Ayaulym Belgibayeva
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Thesis outline

This study systematically investigates the synthesis of different free-standing functional carbon composite nanofiber mats for different energy storage applications using PVP as a carbon source. The main conclusions are summarized as follows.

Chapter 1 introduces the general background of the environmental issues caused by fossil fuel combustion and the importance of energy storage devices in addressing these issues. Different energy storage devices have been demonstrated from the energy storage mechanism, device structure, power, and energy density perspective. The advantages of rechargeable batteries, common electrode materials and their conventional synthesis methods have been discussed. Literature review on the functional interlayers for lithium–sulfur batteries, free-standing nanofibers for rechargeable batteries, their synthesis methods, and the role of PVP as a carbon source has been presented. Through the literature review, the scope of this work has been highlighted.

Chapter 2 reports the synthesis of the free-standing SiO_2/C composite nanofiber mats as anode materials for lithium-ion batteries by electrospinning with heat treatments using PVP as a carbon source. The effect of pre-oxidation on the structure and electrochemical performance of SiO_2/C composites has been studied. Mechanism of the PVP decomposition and carbonization under different heat treatment conditions has been proposed. Furthermore, free-standing SiO_2/C composite nanofibers with different physical properties have been synthesized. The effect of the fiber diameter and pore size on the electrochemical performance has been evaluated.

Chapter 3 presents the synthesis of $LiCoPO_4$/C composite nanofiber mats as high-voltage cathode materials by a combination of spray pyrolysis, wet ball-milling, and

electrospinning with heat treatments. Synthesis conditions have been optimized to get pure-phase fibrous, electrochemically active $LiCoPO_4$. The effect of pre-oxidation temperature on carbon content and physical properties of $LiCoPO_4$/C composites and their correlation to electrochemical properties has been studied. Furthermore, the effect of SiO_2 coating on the performance of $LiCoPO_4$/C composite nanofiber mats has been evaluated.

Chapter 4 introduces the effect of the free-standing SiO_2/C composite nanofiber mat on the electrochemical performance of sulfur-based lithium batteries. Particularly, the SiO_2/C composite nanofiber mat has been inserted as a multi-functional free-standing interlayer in lithium–sulfur batteries and lithium batteries with CuS_{1+x} cathodes. The polysulfides adsorption and catalytic effect on polysulfides conversion for SiO_2/C composite have been studied compared to commercial carbon fiber paper. Polysulfide adsorption/conversion mechanisms have been proposed based on the ex-situ physical characterizations.

Chapter 5 reports the synthesis of the free-standing cobalt phosphide-based carbon composite nanofiber mats as multi-functional interlayers for lithium–sulfur batteries. Effect of process parameters on the composition and physical properties of the composites has been studied. Furthermore, effect of the interlayer composition on polysulfide chemisorption, conversion, and electrochemical properties of lithium–sulfur batteries have been evaluated. Polysulfide adsorption and conversion mechanism in Chapter 4 helped to understand and design a more complex mechanism for cobalt phosphide-based carbon composite nanofiber mats interlayer.

Chapter 6 provides the conclusions of this study.