University of Nebraska Lincoln | NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

Cycle 5 – Energy Research Grants (FY10/11)

Novel Supercapacitors Based on Nano-Structured Materials

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ABSTRACT:

Development of highly efficient electrical energy storage (EES) systems is of critical importance in the national renewable and sustainable energy initiative. Supercapacitors are one of the major EES systems exhibiting distinctive features, including immediate charge/discharge, long cycle life, and negligible heat loss and low self-discharge. High-performance supercapacitors with high working voltages, high energy densities and fast charging rates are highly demanded for extensive applications including electric vehicles and fast-ramping grid storage. According to the fundamental science underpinning the supercapacitors, performance of a supercapacitor depends heavily on the electrode specific surface area (SSA) and corresponding internal resistance. Therefore, investigations are required to develop novel electrode materials with significantly increased SSAs and reduced internal resistances.

This research will focus on the development of high performance supercapacitors with increased energy/power densities, fast charging/discharging rates and affordable costs. Both innovative engineering designs and fundamental investigations will be performed in developing novel nano-structured electrode materials, including carbon nanoonions (CNOs), self-supporting carbon nano-fibers (CNFs), chemically modified graphenes (CMGs) and surface-modified conductive materials, with significantly increased SSAs and reduced internal resistances. Supercapacitors will be fabricated using the nano-structured materials as electrodes. Investigations will be carried out to reduce the use of binders and decrease electrode internal resistances. Supercapacitor aging processes will be investigated to study the degradation and failure mechanisms of the devices. Theoretical simulations will be conducted to study the dynamic behavior of the supercapacitors and establish theoretical models for performance prediction and future device design. The supercapacitors will be integrated into wind turbine generator systems for performance evaluation.

Improvements in supercapacitors will have an immediate impact on energy storage technologies, and are particularly critical to the national renewable and sustainable energy initiative based upon wind and solar energy. Due to the intermittent and fluctuating energy supply from solar and wind, EES systems are required to balance the energy production and consumption circles, level energy load, recuperate waste energy and mitigate power fluctuation. Because of their distinctive features in rapid charge/discharge and high power density, supercapacitors are ideal candidates to dynamically match the intermittency of wind and solar, and achieve efficient energy harvest and storage. Therefore, developing high-performance and low-cost supercapacitors is of critical importance to realize the full potential of the clean energy as well as the on-demand needs of extensive applications, such as electric vehicles and fast-ramping grid storage. Successful completion of this project will provide high-performance and low-cost supercapacitors for efficient energy collection, storage and regulation.