Lightweight Supercapacitors with Porous Nanocarbon Platforms

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Purpose

The purpose of the proposed effort is to develop durable lightweight supercapacitors with high power and energy density that can be used in aeronautic applications. We will use our recently discovered porous nanocarbon (PNC) materials as plat- forms. Our Phase-I studies are devoted to obtain electrochemical (EC) performance – structure relationships of basic and modified PNC supercapacitor systems. If selected for Phase-II, we will seek the optimization of the EC performance of PNC materials with suitable designs and conditions toward a prototype demo.

Background

“Supercapacitors” (SC) is a common term referring to electrochemical capacitors, or more typically, electrical double-layer capacitors (EDLCs). These devices are often of high power density with long cycling life (millions of cycles), but suffer from low energy density. The uses of SCs have thus been restricted since they only function for a short period of time.

Compared to their use in electric vehicles for land and water, power devices for aeronautic applications [e.g., electric unmanned aerial vehicles (UAVs)] have even more demanding requirements in terms of weight and size reduction, life time cycles, and reliability. These requirements make it more imperative to develop electrochemical devices with both high gravimetric and volumetric energy and power. Although significant research has been conducted on ultrahigh energy density batteries (e.g., lithium-sulfur (Li-S) batteries, theoretical energy density >2000 Wh/kg), it has been predicted that lightweight SCs with sufficiently high specific energy (to the level of Li-ion batteries) may negate the need for batteries in certain applications. By reducing weight/volume and complexity as well as potential explosion hazard (Li batteries), these devices can be useful for applications that require long operation duration such as the main power source for small UAVs or power sources for avionics.

One of the most important pathways toward the next generation SCs is the design of novel electrode platforms and architectures in order to obtain improved energy density while also improving or at least retaining the power density and recyclability. Activated carbon has been the standard EDLC electrode material, however various nanocarbon species including carbon nanotubes (CNTs) and graphene exhibit superior EDLC performance due to their very high surface area and high electrical conductivity. The effect of porosity on EDLC performance of carbon-based electrode materials is still not well understood. In general, increasing the pore density and size of the electrode material leads to high ion

transport rates during charging and discharging with reduced electrode density and consequently better EC performance. Manipulation of nanocarbon electrode porosity while maintaining the high surface area and electrical conductivity remains to be a significant challenge.

We recently discovered a facile and scalable method to produce a series of PNC or holey nanocarbon materials. The preliminary experiments showed that the electrochemical performance of PNC materials was significantly better than their parent non-porous counterparts. Thus, the project goal is to use these PNC platforms to develop lightweight electrical energy storage systems that have potentially breakthrough performances in energy/power density and thus are suitable for next generation electric aircraft applications.

Our method is practical, scalable, and can create pores in a manner that allows for some control of pore size. These attributes make this technology highly suitable for TRL advancement and future industrial commercialization.