HIGH ENERGY DENSITY ULTRACAPACITORS

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PROJECT TITLE: Low-Cost, High Energy and Power Density, Nanotube-Enhanced Ultracapacitors
PROGRAM: Open 2009
AWARD: $5,349,932
PROJECT TEAM: *FastCap Systems (Lead)*, Massachusetts Institute of Technology
PROJECT TERM: April 2010 – December 2013
PRINCIPAL INVESTIGATOR (PI): Dr. Ricardo Signorelli

TECHNICAL CHALLENGE

Storage-related challenges are important to the widespread adoption of hybrid electric vehicles (HEVs) and electric vehicles (EVs). EVs are propelled by an electric motor that, in turn, is powered by a rechargeable battery. The state-of-the-art Li-ion battery can store considerable power but it charges and recharges slowly, limiting the range that an EV can travel. Supercapacitors, on the other hand, can charge and discharge rapidly but store ten times less energy than a Li-ion battery. Increasing the charge storage in supercapacitors ("supercaps") at competitive cost, while retaining the charge-discharge rate would be disruptive, enabling their use in a variety of storage applications including EV's.

TECHNICAL OPPORTUNITY

The energy storage mechanism of supercaps is solely electrostatic. Since charge storage does not involve chemical reactions, as it does in batteries, supercaps can have millions of rapid charge-discharge cycles without capacitance degradation and with unlimited shelf life. The drawback of today's supercaps, however, is their low energy storage per unit volume and weight (~5% of the Li-ion battery) and their high upfront cost (~10X more than those of Li-ion batteries). Technical opportunities for increasing the supercapacitor power density result from increasing scientific understanding of how to control surface structure at a nanometer scale, as well as advances in the ability to monitor and control chemical composition.

INNOVATION DEMONSTRATION

An ultracapacitor is an electronic device where energy is stored electrostatically. The energy density that the device can store is proportional to the electrode surface area. FastCap proposed increasing the energy density of the device by introducing an electrode comprising carbon nanotubes (CNT). The narrowly spaced nanotubes would provide considerable surface area which, in turn, would translate into higher energy density. FastCap designed a composite electrode comprising purified amorphous carbon and 5-10% carbon nanotubes. The performance of the supercap with a carbon nanotube composite electrode shows a 3X improvement relative to the bare carbon electrode without CNTs.

Figure 1. Carbon nanotube fabrication line at FastCap

PATHWAY TO ECONOMIC IMPACT

Based on the development of its initial technical results under ARPA-E support, FastCap has developed its Extreme Environment™ line of supercaps, designed to enable the use of safer, lower-power batteries while providing the requisite energy and power to drive actuators with the added benefits of extending battery runtime and reducing operating costs.

FastCap's supercaps have been successfully commercialized for down-hole drilling operations in the oil and gas industry. FastCap has also developed supercaps for space and geothermal application, the former funded by NASA. FastCap Systems technology's value proposition currently provides high energy density and power density available with long life performance and a wide window of operating temperatures.

LONG-TERM IMPACTS

Fastcap has developed ultracapacitors with record supercap performance at E=18 Wh/L and P=120kW/L. Significant increases in performance may be possible if the operational voltage can be further increased.

INTELLECTUAL PROPERTY AND PUBLICATIONS

As of May 2016, the FastCap Systems project has submitted 17 subject invention disclosures to ARPA-E, filed 7 non-provisional U.S. Patent and Trademark Office (PTO) patent applications, and received 3 patents issued by the U.S. PTO.

"Energy storage media for ultracapacitors". (2015) *US Patent No. 9,218,917*. Washington, DC: U.S. Patent and Trademark Office.

"High power and high energy electrodes using carbon nanotubes". (2015) *US Patent No. 9,001,495*. Washington, DC: U.S. Patent and Trademark Office.

"In-line manufacture of carbon nanotubes". (2015) *US Patent No. 9,017,634*. Washington, DC: U.S. Patent and Trademark Office.