

Graphene-Based Ultra-Light Batteries for Aircraft

Investigator(s): Carlos I. Calle, Ph.D., NASA Kennedy Space Center and Richard B. Kaner, Ph.D., University of California Los Angeles

Purpose

The purpose of this project is to develop a graphene-based battery/ultracapacitor prototype that is flexible, thin, lightweight, durable, low cost, and safe and that will demonstrate the feasibility for use in aircraft. These graphene-based devices store charge on graphene sheets and take advantage of the large accessible surface area of graphene to increase the electrical energy that can be stored. The proposed devices should have the electrical storage capacity of thin-film-ion batteries but with much shorter charge/discharge cycle times as well as longer lives. The proposed devices will be carbon-based and so will not have the same issues with flammability or toxicity as the standard lithium-based storage cells.

Background

There are two main established methods for the storage and delivery of electrical energy: batteries and electrochemical capacitors. Batteries store energy with electrochemical reactions that produce high energy densities with slow charge/discharge cycles. Electrochemical capacitors store energy in electrochemical double layers that allow for fast charge/discharge cycles but with low energy densities. Batteries are then widely used in applications that require relatively large amounts of energy. Electrochemical capacitors are used in applications that require fast charge/discharge cycles without the need for large amounts of energy, such as electronic devices.

Because of their need for high energy densities, aircraft use batteries rather than capacitors. Most aircraft batteries use nickel cadmium or lead acid chemistries. Lead acid batteries are typically used in light and general aviation aircraft while nickel cadmium batteries are used in larger aircraft and in helicopters [1]. Aircraft manufacturers are beginning to use lithium ion batteries due to their larger capacitances per unit weight. But even these larger capacitance batteries suffer from their low power densities. The performance of lithium ion batteries is mainly controlled by the diffusion of Li ions and by electron conductivity in the electrolyte. Recent approaches to increase their performance involve the use of nano-structured electrodes that provide shorter ion diffusion distances and the introduction of dopants to increase ion transport efficiency. However, stable performance over thousands of charge/discharge cycles has not been achieved [2].

The graphene-based ultracapacitors that we are developing with this project use graphene electrodes in an electrolyte. They retain the high power densities of standard ultracapacitors but, due to the increased surface area of graphene (up to 2630 m²/g [3]), they achieve energy densities that approach those of the best performing thin-film ion batteries.

Construction of graphene-based ultracapacitors requires the production of high quality graphene in sheets large enough to generate suitable electrodes. Several methods for the production of graphene have been developed in recent years. The most promising techniques for the production of high-quality bulk graphene-based devices begin with graphene oxide (GO). Several methods to reduce GO have been developed, including chemical [5], thermal [6], and flash [7] reduction. Not all of these methods produce high quality graphene and the ones

that do, use relatively expensive equipment. A new and inexpensive solid state method developed by this proposal's co-investigator at UCLA [8] produces high quality graphene films that are mechanically strong, have high electrical conductivity and specific surface area, and can be used directly as electrodes in energy storage devices. These lightweight, flexible energy storage prototypes have charge/discharge rates that are 10 times faster than thin-film-ion batteries and are approaching their energy densities.

We are also investigating the use of pulsed laser to reduce graphene oxide using a technique similar to the method developed by UCLA, but with a substantial decrease in reduction time and an increase in the area of the graphene sheets produced.

A robust, lightweight, flexible, thin, and inexpensive energy storage device with energy and power densities superior to those of state-of-the-art lithium-ion batteries will greatly benefit NASA and the nation's aeronautics. Such revolutionary energy storage devices will radically reduce the mass and weight of energy storage and supply devices resulting in more efficient aircraft. GO, the precursor for the production of graphene, is manufactured on the ton scale at low cost as opposed to lithium, which is a limited resource that must be mined throughout the world.