Electrophoretically Deposited Graphene Oxide and Carbon Nanotube Composite for Supercapacitors

National Aeronautics and Space Administration

Aida Y. Cortés-Peña[1,2], Daniel H. Gutierrez[1,3] Kevin Tang[1,4] David Peaslee[5] and Bin Chen[1,6]

[1]NASA Ames Research Center, Moffett Field, CA 94035, [2]G.W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, [3]Department of Electrical Engineering, Stanford University, CA 94305, [4]Mission San Jose High School, Fremont, CA 94359, [5]University of Missouri, St. Louis, MO 63121, [6]Department of Electrical Engineering, University of California, Santa Cruz, CA 95064

Abstract

An electrochemical supercapacitor is an energy storage device that offers significant advantages over current energy storage systems. These advantages include **rapid charge/discharge rate**, **lower mass-to-weight ratio**, **environmental friendliness**, and a potentially **limitless life cycle without maintenance**. Reduced graphene oxide (rGO) is a high specific surface-area electrode material that, when complemented with multi-walled carbon nanotubes (MWCNT), promises a high energy density surpassing those of state-of the art batteries. The objective of this research is to develop an electrochemical double layer capacitor (EDLC) using novel electrode materials deposited on conductive, semi-conductive, and flexible substrates. The modified electrophoretic deposition (mEPD) and reduction process was studied to control the electrode thickness and determine an optimal annealing profile.

Background

- Graphite is oxidized, weakening inter-layer bonds, exfoliating to monolayers of two-dimensional graphene oxide (GO).
- MWCNT serves as one-dimensional spacers between GO sheets.
- Reduced GO is formed by high temperature treatment.

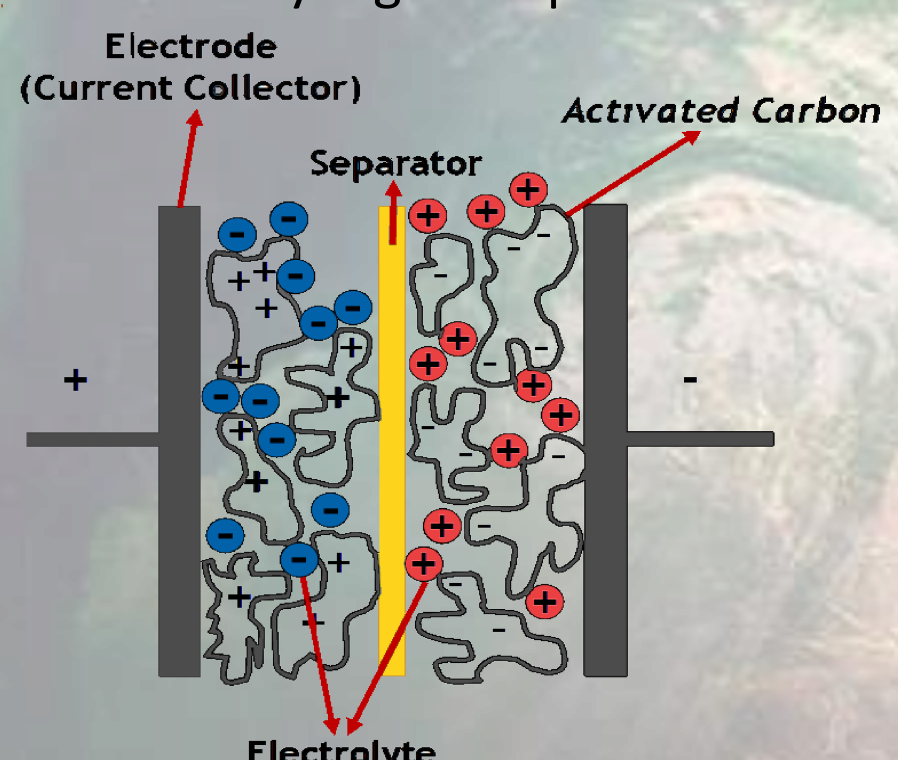

Figure 1. Electrochemical Double Layer Capacitor (EDLC)

- The high specific surface-area, thermal and electrical in-plane conductivity of rGO-MWCNT leads to ultra-high **EDL** capacitance.[1]

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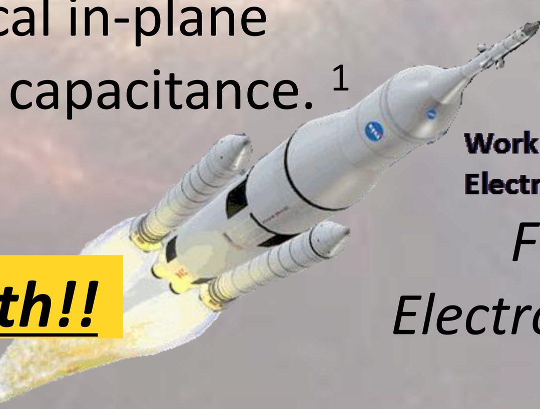


Goal: Replace Batteries in Aerospace and Earth!!

Methodology

Novel Electrode Materials

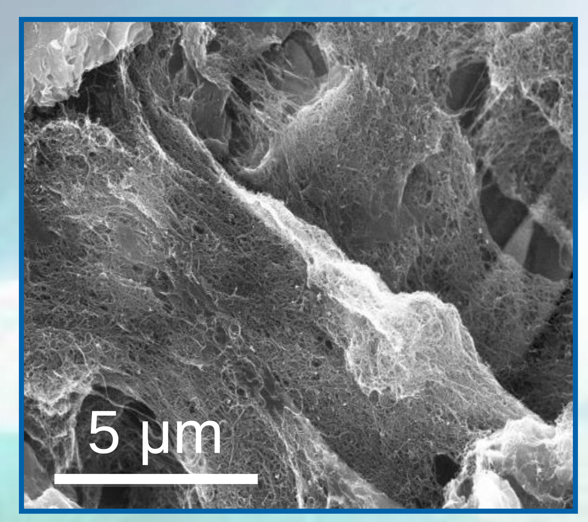


Figure 2. Networked MWCNT connecting rGO platelets.[1]

- GO and MWCNT was synthesized using a low cost and non-toxic chemical solution method that can yield bulk-scale graphene materials.
- The oxidized particles hold an electric charge which, under a DC electric field, will move to and deposit on an oppositely charged substrate.

Scalable Device Fabrication

- This method achieves device reliability, stability, and scalability.[3]
- **Electrophoretic deposition** (EPD) was modified to deposit thin films of controllable thicknesses on a variety of substrates.
- **Thermal Reduction** of electrodes was performed in air at varying temperatures (300˚C-600˚C) and durations (20 minutes-2 hours).

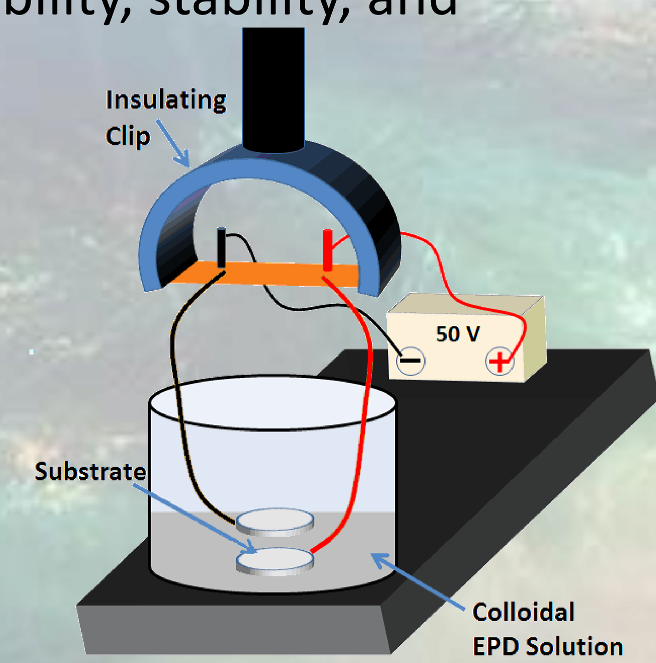


Figure 3. Electrophoretic Deposition

Ultra-High Capacitance

- The sample is submerged in a electrolyte connected to a 4-probe potentiostat and characterized for the following electrical properties:

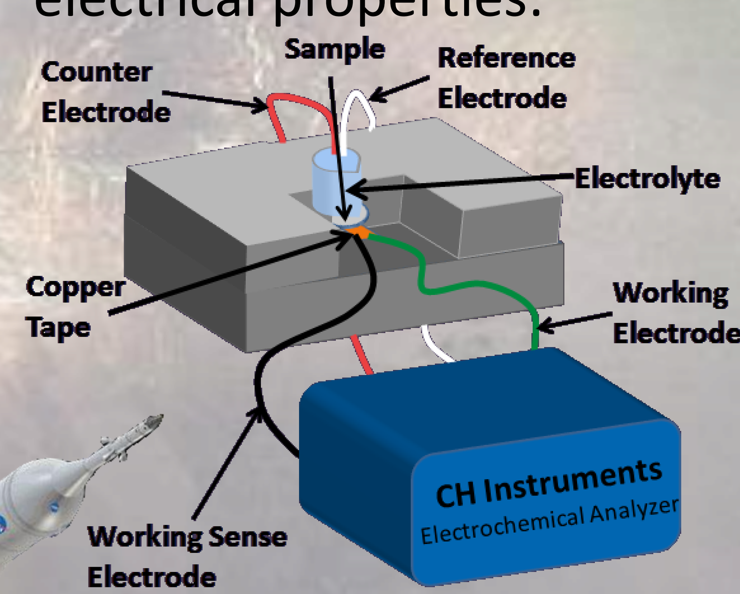
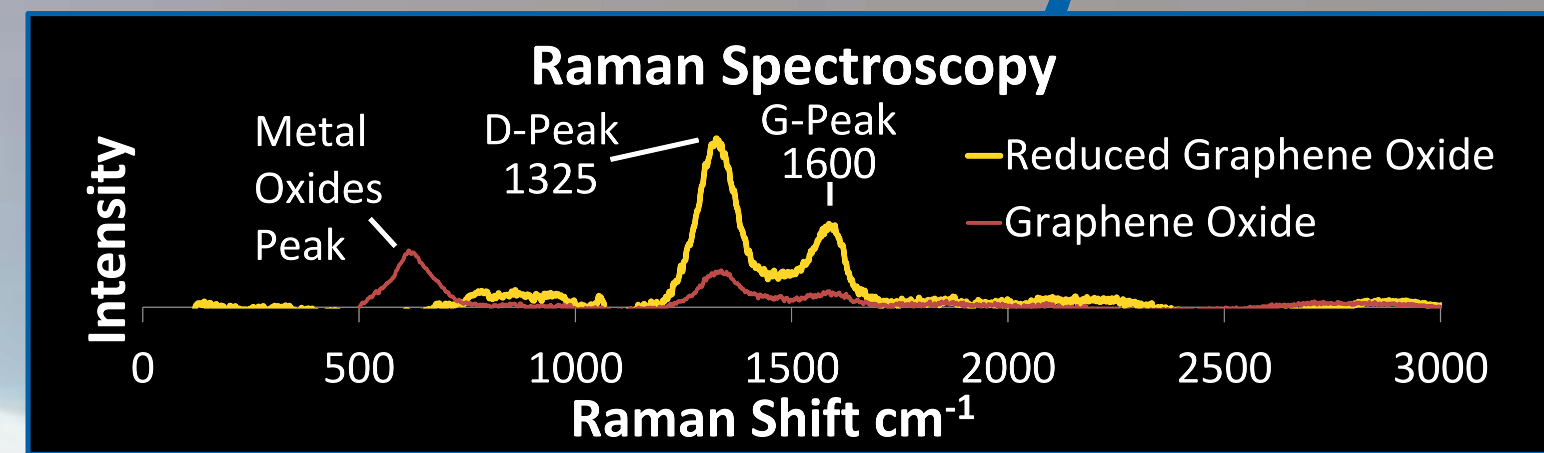


Figure 4. CHI 650B Electrochemical Workstation

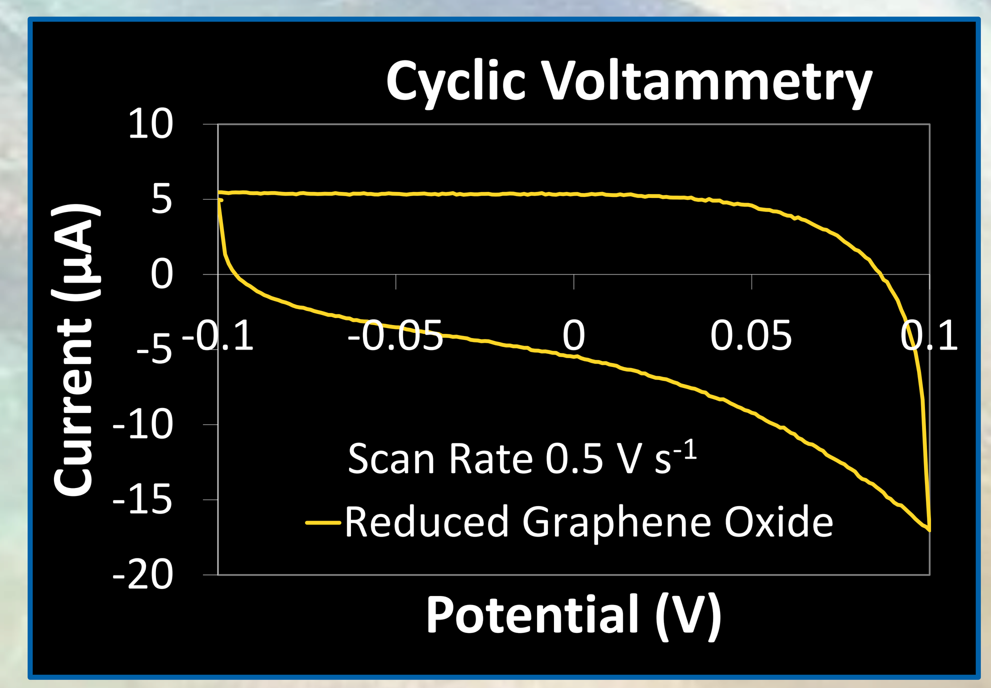
- **Specific Capacitance:** Is the ability to store electrical charge per unit mass.
- **Sheet Resistance:** causes current leakage, consuming and wasting power in the idle state.

These parameters must be optimized and controlled to obtain a high **Energy Density** and **Power Density.**

Data Analysis



- Raman spectroscopy uses laser light scattering to observe chemical composition and structure.
- The *D* to *G* (I_D/I_G) intensity ratio in the Raman spectra indicates the ratio of existing 2 dimensional sp^2 graphene structure to 3 dimensional sp^3 diamond structure.



- Cyclic voltammetry (CV) is used to predict device life cycle and measure capacitive response.
- Scan rate is varied to study frequency response.

Specific capacitance is calculated from the CV curve.

Future Work

- Study the reduction process by varying annealing temperature and durations.
- Modify synthesis and deposition thickness to determine an optimal electrode surface area.
- Deposit electrode material on conductive, semi-conductive, and flexible substrates.
- Image the electrode morphology using scanning electron microscopy (SEM) and atomic force microscopy (AFM).

References

1. Ajayi, Obafunso A., et al. "Electrophoretically Deposited Graphene Oxide and Carbon Nanotube Composite for Electrochemical Capacitors." Submission pending (2014).
2. Marcano, Daniela C., et al. "Improved synthesis of graphene oxide." *ACS nano* 4.8 (2010): 4806-4814.
3. Gutierrez, Daniel H., et al. "Phoretic Deposition of Graphene on Manganese-Cobalt Oxide Composites for Supercapacitor Electrodes." *Advances in Science and Technology* 77 (2013): 302-306.