Conference Paper

Graphene-based energy storage devices for space applications

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Abstract of paper to be presented at the *2014 Fourth International Symposium on Graphene Devices*:

Graphene-based energy storage devices for space applications

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Abstract: The state-of-the-art energy storage device for electric automobiles, large and small electronic appliances, and even modern aircraft is the lithium-ion battery. These batteries have energy densities of the order of 100 Wh/kg. However, lithium-ion batteries have relatively long charging times. Ultracapacitors, on the other hand, can be recharged in seconds. But their energy densities are lower than that of lithium-ion batteries. Recent approaches to both batteries and ultracapacitors have resulted in performance increases for both types of devices. The addition of nanostructured electrodes to lithium-ion batteries, for example, provides shorter ion diffusion distances and the introduction of dopants increases the ion transport efficiency. But charge/discharge stability over thousands of cycles has not been achieved. The use of activated carbon in ultracapacitor electrodes has resulted in increases in their energy densities, but they still are about one order of magnitude lower than those of lithium-ion batteries.

We have been developing thin film ultracapacitors with graphene electrodes that achieve energy densities comparable to those of thin-film lithium ion batteries and power densities comparable to those of activated carbon ultracapacitors. The surface area of graphene matches or exceeds that of activated carbon, allowing for ultracapacitors with very large capacitances. However, the extremely large electrical conductivity of graphene, which surpasses the conductivity of any type of activated carbon by a factor of two, produces ultracapacitors with much larger capacitances. Testing of these devices shows that they remain stable after 10,000 charge/discharge cycles. An energy storage device with these characteristics could be used for NASA robotic and human Martian exploration missions and crewed habitats.

Completed Project (2014 - 2015)

Large Scale Reduction of Graphite Oxide Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)

ABSTRACT

This project seeks to develop an optical method to reduce graphite oxide into graphene efficiently and in larger formats than currently available. Current reduction methods are expensive, time-consuming or restricted to small, limited formats. Graphene has potential uses in ultracapacitors, energy storage, solar cells, flexible and light-weight circuits, touch screens, and chemical sensors. In addition, graphite oxide is a sustainable material that can be produced from any form of carbon, making this method environmentally friendly and adaptable for in-situ reduction.

ANTICIPATED BENEFITS

To NASA funded missions:

High energy density devices produced with this technology will benefit all future funded NASA exploration missions.

To NASA unfunded & planned missions:

Graphene-based supercapacitors made possible with this technology will benefit NASA planetary exploration missions, NASA human exploration missions, NASA aeronautics.

To other government agencies:

Graphene-based supercapacitors with high energy densities and power densities made possible with this technology will benefit other agencies.

To the commercial space industry:

Graphene-based supercapacitors with high energy densities and power densities made possible with this technology will benefit the commercial space industry.

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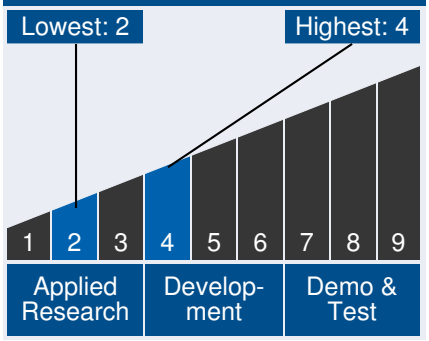
Technology Maturity



Completed Project (2014 - 2015)

Large Scale Reduction of Graphite Oxide Project

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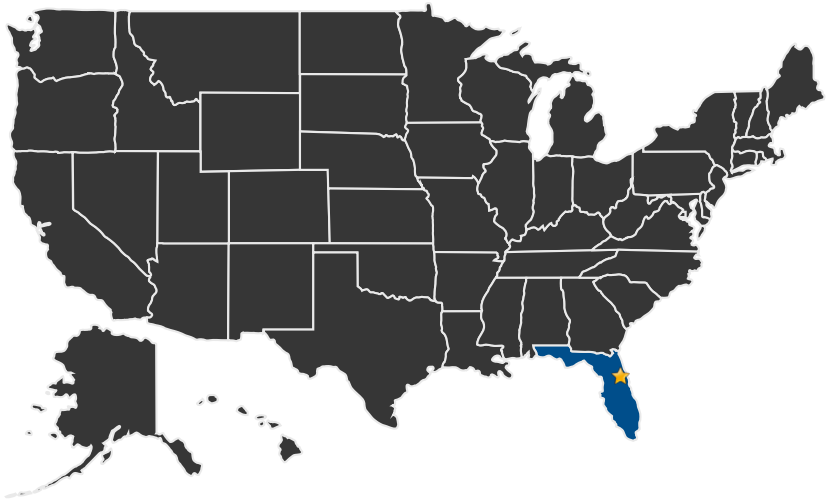
To the nation:

Graphene-based supercapacitors with high energy densities and power densities made possible with this technology will benefit thd nation by providing the technology to produce light weight, high cycle, durable, and safe eneregy storage devices that can be used by NASA and byprivate industry.

DETAILED DESCRIPTION

We plan to expand the existing the collimated laser beam used in the reduction of graphite oxide into graphene to cover an area of 30 cm x 30 cm. The laser power output and scan rate will be experimentally modified to determine the optimum values for the even reduction of the graphite oxide film. Samples will the examined with XPS and Raman spectroscopy to determine the level of graphene production and its homogeneity.

U.S. LOCATIONS WORKING ON THIS PROJECT



U.S. States With Work

Lead Center: Kennedy Space Center

Realized Benefits

1 Conference Paper

Management Team

Program Executive:
- John Falker

Program Manager:
- Nancy Zeitlin

Project Manager:
- Carlos Calle

Principal Investigator:
- Carlos Calle

Co-Investigator:
- Paul Mackey

Technology Areas

- Space Power and Energy Storage (TA 3)

Large Scale Reduction of Graphite Oxide Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)

PROJECT LIBRARY

Conference Papers

- Graphene-based energy storage devices for space applications

DETAILS FOR TECHNOLOGY 1

Technology Title

Large format reduction of graphite oxide

Technology Description

This technology is categorized as a material for other applications

Reduction of graphite oxide into graphene in sizes up to 30 cm x 30 cm using scanning laser beam.

Capabilities Provided

Ability to produce graphene sheets suitable for supercapacitors in AA-battery format.

Potential Applications

Graphene has been used to prototype high performance, flexible ultracapacitors on a small scale. It shows promise in many other areas such as flexible electronics and chemical sensors. In addition, graphene-based devices are flexible, extremely thin and lightweight, and can be incorporated on astronaut garments and equipment without adding appreciable weight or bulk to the spacesuit.

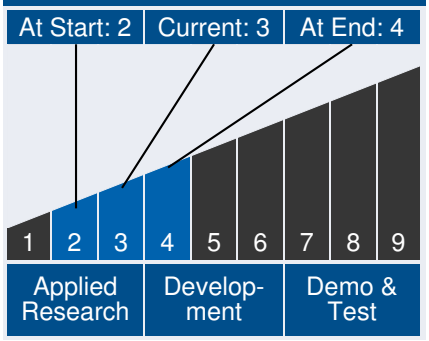
Graphite oxide, which is a starter material for graphene, is readily manufactured from any form of carbon utilizing a well-established, inexpensive process. It is feasible that GO could be produced on planetary surfaces with carbon extracted from regolith or waste products.

Graphene-based devices will substantially reduce NASA

Technology Areas

Primary Technology Area:
Space Power and Energy Storage (TA 3)

Technology Maturity



Large Scale Reduction of Graphite Oxide Project

payloads mass and volume, resulting in simpler designs and cost reductions.

Crew exploration missions, habitats, planetary probes, rovers and landers, orbiters, and life support systems will benefit from these revolutionary devices.

There is a clear and stated need for such flexible, lightweight and low volume devices for commercial and military applications.

Performance Metrics

Metric	Unit	Quantity
Graphene with 96% carbon content	1	2

DETAILS FOR TECHNOLOGY 2

Technology Title

Large Scale Reduction of Graphite Oxide

Technology Description

This technology is categorized as a material for ground scientific research or analysis

Development of an optical method to reduce graphite oxide into graphene in sizes of 30 cm x 30 cm, much larger than currently available.

Capabilities Provided

- Project will provide the ability ot manufacture high energy electrochemical supercapacitors for efficient energy storage

Potential Applications

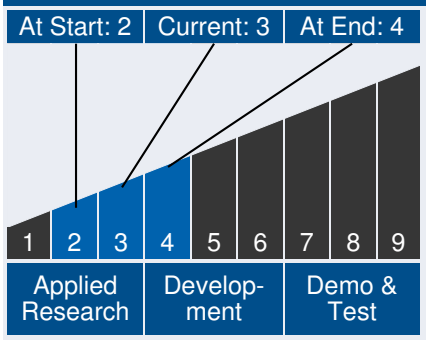
Graphene has potential uses in ultracapacitors, energy storage, solar cells, flexible and light-weight circuits, touch screens, and chemical sensors. In addition, graphite oxide is a sustainable material that can be produced from any form of carbon, making this method environmentally friendly and adaptable for in-situ

Technology Areas

Other Technology Areas:

- Space Power and Energy Storage (TA 3)

Technology Maturity



Large Scale Reduction of Graphite Oxide Project

reduction.

Performance Metrics

Metric	Unit	Quantity
Graphene with 96% carbon content	1	2

DETAILS FOR TECHNOLOGY 3

Technology Title

Large scale reduction of graphite oxide

Technology Description

This technology is categorized as a material for other applications

Large scale reduction of graphite oxide with the use of a scanning laser.

Capabilities Provided

Supercapacitors with hight energy density and power density in a AA battery format.

Potential Applications

Supercapacitors with hight energy and power density in a AA battery format that can be used in spacecraft, aircraft, and other commercial applications.

Performance Metrics

Metric	Unit	Quantity
Graphene with 96% carbon content	1	2

Technology Areas

Primary Technology Area:
Space Power and Energy Storage (TA 3)

Technology Maturity