2016-05

MEMS Solar Generators

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Energy Harvesting and Storage

MEMS Solar Generators

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Overview:

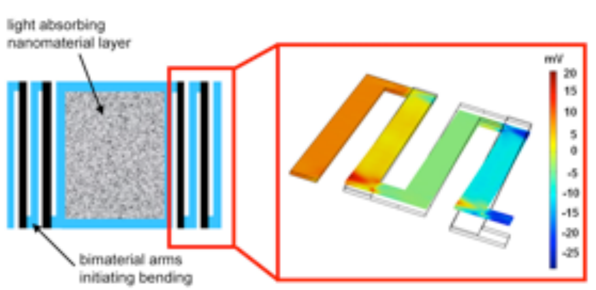
Using MEMS bimaterial structures to build highly efficient solar energy generators. This is a novel approach that utilizes developments in the area of bimaterial sensors and applies them in the field of solar energy harvesting.

Project Description

Harvesting energy from the sun offers clean solutions to growing energy challenges and can help decrease our dependence on fossil fuels, particularly foreign oil. Solar power is also the preferred candidate for powering autonomous systems, such as sensors and actuators in remote areas. However, in order to meet the demanding energy needs of modern devices, high solar conversion efficiencies are required.

Conventional solar cell technologies suffer from low efficiencies and are spectrum-dependent. State-of-the-art multi-junction solar cells employ a variety of layered materials in order to broaden the range of photoactive wavelengths. This significantly complicates microfabrication and the devices become economically unfeasible for commercial applications. The ideal solution would be a solar device that is spectrum-insensitive and converts a large fraction of the incident solar radiation into electricity.

We propose a new approach to solar energy harvesting in the form of bimaterial piezoelectric MEMS structures. MEMS solar devices can harness the energy from the sun by absorbing radiation over a wide spectral range, and converting the resulting heat into electricity using the piezoelectric effect. Unlike in solar cells, the efficiency of piezoelectric materials can reach up to 90%. Therefore, we believe that these highly efficient MEMS-based solar generators are ideal for powering small sensors but can also be used in large arrays to replace costly, less-efficient solar cells.



Solar generators in the form of bimaterial MEMS devices convert radiative energy into heat, which is then used to produce electricity through the piezoelectric effect. The concept of the proposed technology is shown in Figure 1. A bimaterial device, consisting of a piezoelectric layer (quartz or similar) and a broad-range absorptive layer (carbon nanomaterial), is used to convert solar radiation into electrical energy. When illuminated, the nanomaterial layer, which exhibits excellent absorption properties, will absorb solar energy and transform it into heat (Figure 1a). As a consequence, the temperature of both layers increases. Due to the mismatch in thermal expansion coefficients, both materials expand at different rates causing the structure to deform and generate a potential difference at ends of the structure (Figure 1b). Once the deformation reaches its maximum, the structure contacts a heat sink, which removes heat from the bimaterial layer causing it to cool and relax towards its initial position (Figure 1c and 1d). Solar radiation will then heat the structure again and the conversion cycle is repeated. This continued oscillation generates the electrical energy.

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Plasma and Expansion-Reduction Synthesis of Graphene: Electrode Materials for Energy Storage Devices

Claudia C. Luhrs

Project Description

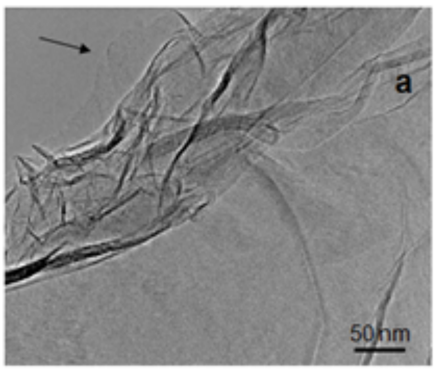
Energy storage devices are key components needed to retain energy harvested from wind and solar sources, or to supply energy for applications such as transportable electrical and electronic devices. Supercapacitors, also known as electric double-layer capacitors (EDLC), represent one type of such devices, which use is crucial anywhere there is a demand of energy to be supplied with reliability and without major disruptions or fluctuations. Despite advances in supercapacitor developments in recent years, in particular related to the use of graphene and other high surface area carbonaceous materials, more fundamental knowledge is required in order to fine tune or tailor their carbon electrode characteristics, surface groups included, for an optimal performance.

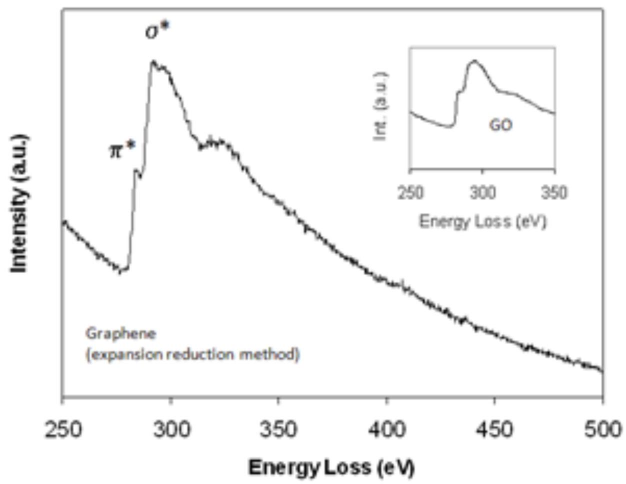
The objective of this research is to investigate the effects of carbon electrodes particulate morphology, crystalline structure and impact of surface groups identity (imprinted by the synthetic method) on the basic mechanisms that take place at the electrodes, electrolytes and their interfaces. Fundamental understanding of these effects will allow the development of fast charging, more robust and reliable supercapacitors able to withstand large number of charge-discharge cycles and wide range of operating temperatures.

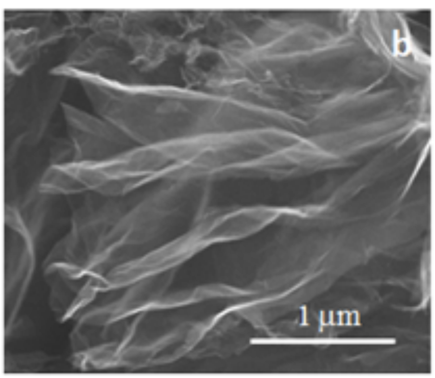
In particular, this investigation will generate carbon nanomaterials (ca. graphene) with specific morphologies and surface functionalities using microwave plasma processes and a novel expansion-reduction approach. This work will take advantage of the very particular and highly tunable structural and surface characteristics that the plasma and expansion-reduction synthetic methods can promote in the materials generated. The use of such an approach will allow us to tailor-made carbon nanomaterials to study the effects of morphological, structural and surface functional characteristics to create a new generation of supercapacitor electrodes with enhanced properties.

The intellectual merit of this work is related to i) evaluate the influence of morphology and accessible surface area / pore distributions of plasma and expansion-reduction prepared materials on their electrochemical behavior, ii) study the degree of graphitization: fractional component of amorphous versus crystalline phase, of carbon samples as impact factor on the material properties; and iii) determine the effect of synthetic method and surface conditioning pretreatments (and their surface functionality implications) on these particular carbon nanostructures cycle life, stability and self-discharge characteristics.

More specifically, this investigation will enlarge the existent basic knowledge that relates the electrochemical behavior of supercapacitor devices based on graphene and other carbon nanomaterials with their microstructural and surface characteristics, and in particular, demonstrate the advantages of novel plasma and expansion-reduction produced materials. A successful outcome to this investigation will establish novel approaches to generate materials, based on plasma and expansion-reduction synthesis, as feasible technologies to engineer the new generation of carbon electrodes for supercapacitor devices.







Graphene preparation and characterization

a) Transmision Electron Microscopy image of graphene sheets. b) Scanning Electron Microscopy study of the same. c) Energy Electron Loss Spectroscopy spectra of a graphene sample generated by urea mediated expansion-reduction method. Inset: EELS spectra of Graphite Oxide.