

# Charge mobility in nanostructured supercapacitors

Study reference number: 14-7001  
Type of activity: Standard study (25k€)

## Project Summary

### Objective

This project will investigate how nanostructured surfaces can allow supercapacitors to reach energy and power densities suitable for space applications.

### Target university partner competences

Nanotechnology, Solid State Physics, Theoretical Physics, Physical Chemistry, Material Science

### ACT provided competences

Solid State Physics, Plasma Physics

### Keywords

Supercapacitors, graphene, silicon, nanotechnology, shape-engineering, wafer processing, plasma vapour deposition, electron mobility, optical lithography, semiconductors

## Study Objective

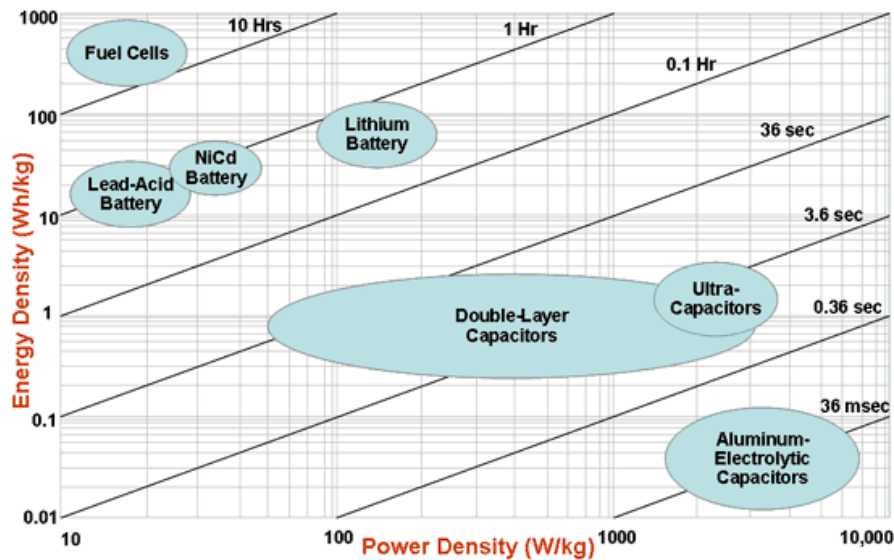
This Ariadna project will study the characteristics of nanostructured supercapacitor cells for high energy and high power density energy storage. In particular, the work is focused on understanding the charge mobility in silicon-based supercapacitors with graphene coatings and compare this to current state-of-the-art energy storage devices including a feasibility for applying this in a space environment.

## Background and Study Motivation

Electrical power on-board a space vehicle is one of the key functional requirements of a spacecraft, enabling the functioning of (scientific) equipment, propulsion, communication, etc. With the steady advancement of satellite capabilities, these power requirements have also increased from around 1W up to multiple kW's for telecommunication satellites.

Besides power generation, a key element of the on-board power management system (PMS) is to accurately balance load and demand. Various types of temporary energy storage systems are therefore used (fuel cells, batteries and supercapacitors). For example, supercapacitors can be used to maintain bus voltage control for which high power densities and high frequency discharge/recharge cycles are required.

The advantage of a supercapacitor is that, unlike electrochemical batteries, the energy is stored physically instead of chemically with the resulting benefit that much higher *power densities* (W/kg) can be achieved. Some additional benefits are also the high efficiency, longer lifetime, higher number of charge/discharge cycles and wide operating temperature range. Unfortunately, a serious drawback is the low *energy density* (Wh/kg), which is typically two to three orders of magnitude smaller than high performance Li-ion batteries and fuel cells (see figure 1).



Source US Defence Logistics Agency

Figure 1: Ragone plot for various types of (commercially available) energy storage devices. The developments of nanostructured SC's could lead to both high energy and power density devices.

Large efforts have thus been placed in developing higher energy density materials by enhancing the effective electrode surface area ( $\text{m}^2/\text{g}$ ), for example using porous active carbon [1][2], aerogels [3], graphene sheets [4][5][6] and carbon nanotubes [4][7]. Shape-engineering at the nanometer level has shown a promise to achieve higher energies densities by enhancing the surface area ( $>1000\text{m}^2/\text{g}$ ) [8]. Recently, the use of silicon wafer processing techniques has further reduced the electrode feature size of the Si/Graphene interface, thereby significantly enhancing the volumetric storage capability [9]. Although the use of silicon has the drawback of a high electrical resistivity ( $10^{-2} \Omega\text{cm}$ ) compared to aluminium ( $10^{-5} \Omega\text{cm}$ ), the small feature size (nm-level) and relative ease of manufacturing may allow significant larger devices while maintaining excellent storage capabilities.

The main challenge when going to nanostructured devices is the design and manufacturing of the required small scale structures over large areas, the subsequent graphene coating [9][10][11] and final packaging. There is currently a need to study the charge mobility characteristics of these nm-sized 3D structures (including the electrolyte) of a fully packaged device. This study will therefore investigate the charge mobility and to establish a trade-off between feature size, material choice, performance and packaging.

The development of a high power and high energy density supercapacitors would be an enabling technology for future space missions [12]. Due to their lightweight, relatively high energy and power density and multiple charging cycles, nanostructured supercapacitors could provide an operational regime not easily accessed with current energy storage devices.

## Proposed Methodology

The following methodology is proposed for this study, though applicants are invited to propose different approaches, which they see fitting better within the scope of this work.

- Model and investigate charge mobility behaviour in packaged nanostructured supercapacitors (including effects of feature size, electrode shape and material/electrolyte choice)
- Use modelling tools to investigate key characteristics of the applications and verify findings with available experimental data (e.g. [9][11])
- Assess obtainable energy and power density capacity of a fully packaged cell
- Assess potential limitation or eventual show-stoppers for the use of silicon based supercapacitors for space applications (incl. for example radiation hardness [13])

## ACT Contribution

The project will be conducted in close scientific collaboration with ESA researchers. In particular ESA researchers will provide technical expertise in power storage devices and space operating conditions.

## Bibliography

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