Functional Materials and Nanotechnology

Development of a Sustainable, Inexpensive Supercapacitor for Energy Storage (SuperCap)

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Introduction

The progression towards replacement of energy sources based on fossil fuels and other finite resources with renewable types results in an increasing demand for energy storage both because of the inability of most renewable energy sources to follow the variation in demand and the limited mobility of these technologies do to the nature of the resources they are based on. Many of the renewably energy production technologies are able to produce electricity directly and it would therefore be convenient and likely most efficient to store this with as few conversion steps as possible.

The most direct way of storing electrical energy is almost certainly as a charge in an electrostatic field as it is done in a capacitor. Traditional capacitors however are not able to store great amounts of charge and their energy density is consequently very limited. Supercapacitors also known as Electrochemical Double Layer Capacitors(EDLCs) on the other hand is able to store great amounts of charge and especially research trends from recent years have indicated that it is possible to achieve quite respectable energy densities with supercapacitors. Nevertheless it is still not possible to achieve energy densities as high as that of the best batteries today and there are also other issues with the current supercapacitor technologies, which needs to be resolved, before they are ready for widespread use in energy storage systems.

Graphene and other nanomaterials

The currently highest reported energy densities for EDLCs comes from systems based on advanced carbon nanostructures, typically with graphene like structure. The use of these materials results in very high capacitances because of their very high useful surface area. This combined with a wide voltage window obtained using ionic liquids result in energy densities of up to 150 Wh/kg [1].

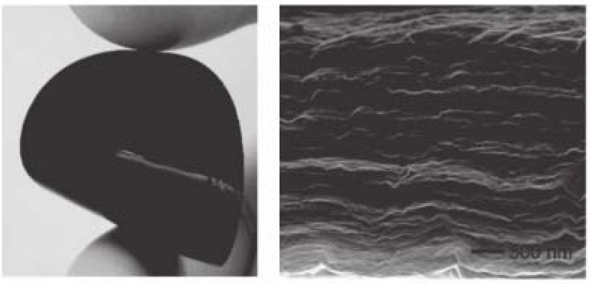

Figure 1 – Example of graphene based electrode [1].

Asymmetric hybrids

Another approach that might end up actually having a better performance when the economical aspect is taken into consideration, is asymmetric hybrid systems based on aqueous electrolytes, where the use of specialized electrodes can increase both capacitance and voltage handling. Most pseudocapacitive materials(see below) also only work in aqueous electrolytes.

Pseudocapacitance

Capacitance arising from other storage mechanism, typically faradic, are denoted pseudocapacitance. Using electrode materials with pseudocapacitive properties can lead to a significant increase in capacitance.

Characterization

Supercapacitors are typically characterized using cyclic voltammetry(CV), chronopotentiometry, and impedance spectroscopy. This is done using both complete systems and single test electrodes. While these techniques are generally quite suited for this, there is a widespread lack of generalized standards for the used methodic and terminology for the characterization of supercapacitors. This is especially the case for pseudocapacitive materials, where the assumed linearity is only rarely present.

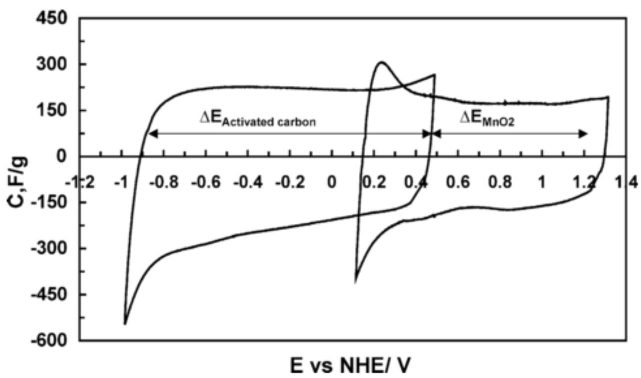

Figure 2 – Example of CV of electrode materials for asymmetric EDLC [2].

Strategy

Because a main focus of this project will be on the development of a supercapacitor technology with the best possible charge storage economy, a dual approach is chosen, were both the high performance systems based on nanostructured electrodes in ionic liquids, and simpler materials in asymmetric hybrids is studied. Furthermore proper standards for the characterization of supercapacitors needs to be established. The final result of this project should be one or more prototypes based on the developed systems.

References

[1] X. Yang, J. Zhu, L. Qiu, and D. Li, "Bioinspired Effective Prevention of Restacking in Multilayered Graphene Films : Towards the Next Generation of High-Performance Supercapacitors," pp. 2833–2838, 2011.

[2] V. Khomenko, E. Raymundo-Piñero, and F. Béguin, "Optimisation of an asymmetric manganese oxide/activated carbon capacitor working at 2V in aqueous medium," Journal of Power Sources, vol. 153, no. 1, pp. 183–190, Jan. 2006.

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