Nano-Structured Composite Electrodes for Ultrafast Double Layer Capacitors

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Electrochemical capacitors (ECC) are a new type of energy storage device. Their energy density and rate capability are between that of batteries and conventional capacitors. These properties make them interesting candidates for numerous applications ranging from load management systems in electric vehicles to pulse power sources.

ECCs store electric energy in the electrochemical double layer formed at the electrode/electrolyte interface. The capacity of an ECC can be further enhanced by coating the electrode surface with a thin layer of an electrochemically active material. The capacity enhancement by the active material is not truly capacitive as it involves faradaic charge transfer reactions and is therefore generally termed pseudo-capacitance.

A conventional ECC setup consists of two sheet-like porous electrodes and a separator soaked with electrolyte. In this setup the ionic charge carriers need to diffuse over rather large distances from one electrode side to the other to build up the electrochemical double layer. Due to the poor ionic conductivity of organic electrolytes, which are used for voltages exceeding 1.2 V, significant ohmic losses occur at high charge or discharge currents.

The aim of the proposed project is to establish new concepts for the ECC design, which effectively reduces the ionic diffusion path and hence ohmic losses. A reduction of the ionic diffusion path may be achieved by an array or network of oppositely charged micro- or nano-scaled electrodes separated only by a thin film of electrolyte. Since, depending on the concentration and type of electrolyte, the electrochemical double layer is only about 1-10 nm thick, the electrolyte film, i.e. the diffusion path, between two adjacent oppositely charged electrodes may be reduced to less than 100 nm. This should reduce ohmic losses considerably and hence allow higher charge and discharge rates.

For the nano-scaled electrodes carbon nano-tubes or carbon fibres may be used, since they can be grown on substrates in a highly ordered manner. However, other nano-structured carbon materials, if suitable, may be used as well. In addition to the fabrication and electrochemical testing of the new ECC design, it is planed to investigate the effect of surface functionalization and surface coating on the pseudo-capacitive behaviour of the device.