Abstract

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Today's society is currently performing an exit from fossil fuel energy sources. The change to sustainable alternatives requires inexpensive and environmentally friendly energy storage devices. However, most current devices contain expensive, rare or toxic materials. These materials must be replaced by low-cost, abundant, nontoxic components.

In this thesis, I suggest the production of paper-based electric double-layer capacitors (EDLCs) to meet the demand of low-cost energy storage devices that provide high power density. To fulfill the requirements of sustainable and environmentally friendly devices, production of EDLCs that consist of paper, graphite and saltwater is proposed. Paper can be used as a separator between the electrodes and as a substrate for the electrodes. Graphite is suited for use as an active material in the electrodes, and saltwater can be employed as an electrolyte. We studied and developed different methods for the production of nanographite and graphene from graphite. Composites containing these materials and similar advanced carbon materials have been tested as electrode materials in EDLCs. I suggest the use of cellulose nanofibers (CNFs) or microfibrillated cellulose (MFC) as a binder in the electrodes. In addition to improved mechanical stability, the nanocellulose improved the stability of graphite dispersions and the electrical performance of the electrodes. The influence of the cellulose quality on the electrical properties of the electrodes and EDLCs was investigated. The results showed that the finest nanocellulose quality is not the best choice for EDLC electrodes; MFC is recommended for this application instead. The results also demonstrated that the capacitance of EDLCs can be increased if the electrode masses are adjusted according to the size of the electrolyte ions. Moreover, we investigated the issue of high contact resistances at the interface between porous carbon electrodes and metal current collectors. To reduce the contact resistance, graphite foil can be used as a current collector instead of metal foils.

Using the suggested low-cost materials, production methods and conceptual improvements, it is possible to reduce the material costs by more than 90 % in comparison with commercial units. This confirms that paper-based EDLCs are a promising alternative to conventional EDLCs. Our findings and additional research can be expected to substantially support the design and commercialization of sustainable EDLCs and other green energy technologies.