Monolithic supercapacitor fabricated by screen-printing method

Supercapacitors are electrical energy storage systems with high power density and long lifetime. The high capacitance achieved through an electrical double layer and the high surface area of electrodes separate supercapacitors from conventional capacitors. Despite the high capacitance, the energy density of supercapacitors is smaller compared to batteries. However, electrochemical pseudocapacitance materials, such as metal oxides and conductive polymers, can be used to improve the energy density of the supercapacitors. One electrically conductive polymer is polyaniline which is used for supercapacitor electrodes and was researched in the InComEss project by Leibniz Institute of Polymer Research Dresden (IPF). The composite of polyaniline and carbon was prepared, which was combined with a chitosan binder in a water medium to form electrode ink.

Supercapacitors consist of two electrodes, an electrolyte, a separator, and current collectors. The separator is placed between the electrodes to prevent electrical contact, but it allows ions to pass through it between the electrodes. Current collectors are connected to electrodes to provide good conductivity to external junctions. The materials for the InComEss supercapacitors have been chosen by the requirement that the total system should be non-toxic, recyclable, and incinerable while providing high capacitance and energy density. Current collectors were printed with graphite ink on PET film. Electrodes were made of carbon/polyaniline composite and separators of talc and cellulose fibers. Both electrodes and separator had the same chitosan binder, and the electrolyte was an aqueous sodium chloride salt solution.

A common way to fabricate a stacked supercapacitor is to assemble two electrodes and a separator together. Meanwhile, monolithic supercapacitors are stacked structures on a single substrate. With additive manufacturing methods, supercapacitor layers can be applied directly on top of each other forming a monolithic structure. Interest in monolithic supercapacitors arises from more feasible fabrication as the complex assembly step where electrodes are aligned can be eliminated. One suitable technique is screen printing as supercapacitors benefit from thick layers. In screen printing inks are pushed through screen with a squeegee. Screens have patterned meshes which determine the printed areas and influence the thickness of the printed layers. Furthermore, screen printing is an up-scalable manufacturing technique and is suitable to be used from sheet to sheet as well as roll to roll.

Monolithic supercapacitor fabrication requires compatibility of the materials with respect to adhesion and wettability. Ink shall be prepared to enhance printability and stability so that the printing process is feasible. Significant challenges in the printed monolithic supercapacitors were found in the

This project receives funding in the European Commission’s Horizon 2020
Research Programme under Grant Agreement Number 862597

repeatability of the prints, especially with the separator layer that is required to prevent electrical contact between the two electrodes.

In the InComEss project, Tampere University (TAU) was able to prepare screen printable separator ink and achieve a repeatable fabrication process for the monolithic supercapacitors with sheet-to-sheet screen printing. Centre for Nanotechnology and Smart Materials (CeNTI) further optimized the fabrication process and was able to demonstrate the fabrication process with roll-to-roll screen printing. With IPF's carbon/polyaniline composite specific capacitance of supercapacitors was improved compared to the pristine carbon.

Details

Project title: INnovative polymer based COmposite systeMs for high efficient Energy Scavenging and Storage

Project ID: 862597

Start Date: 01/03/2020

Project Duration: 48 months

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