Development and Characterization of Low Cost Double Layer Electrode

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Introduction

The problem of high cost is a large obstacle for the widespread commercialization of the supercapacitor in vehicle applications. This paper presents results from the development of a low-cost (US$ ~10/kg device [1]) double layer (DL) electrode for use in an asymmetric supercapacitor cell. The experimental results were also used in developing an agglomerate model for a supercapacitor DL-electrode.

Experimental and characterization

DL-electrodes for use in an aqueous (6M KOH) $NiOOH/Ni(OH)_2$-C asymmetric hybrid capacitor have been studied. Different activated carbons (AC) were selected from a low-cost perspective, where commercial availability was an important factor. The AC was sieved into fractions based on particle sizes: < 10 μm, 36-38 μm and 71-75 μm. Electrodes were fabricated using a dry pressing technique with various amounts of PTFE as a binder, thickness of electrodes ranging between 0.2-0.9 μm.
The electrodes were characterized electrochemically, using for instance galvanostatic charge/discharge at current densities between 1 and 400 mA/cm^2, a microelectrode technique and cyclic voltammetry. The electrochemical characterization was performed using a three-electrode setup and a $NiOOH/Ni(OH)_2$-C two-electrode asymmetric cell. Further materials characterization was performed using SEM and gas porosimmetry. An example of a sieved fraction is shown in Figure 1.

Results and discussion

The fabricated electrodes show promise as DL-electrodes in an asymmetric hybrid low-cost supercapacitor. An example of capacitances of a DL-electrode is shown in Figure 2, where the capacitance was 68-60 F/cm^3 (90 F/g) at low current densities and 50 F/cm^3 (67 F/g) at 400 mA/cm^2. However, there are still losses due to resistance at high current densities. The microelectrode measurements show that most of the resitance associated with losses at high current densities do not occur in the carbon material itself, but rather between the particles. Another major contributor to losses at high current densities is the contact resistance between current collector and electrode.
Gas porosimmetry characterization showed that Jacobi Carbon had little mesoporous structure, whereas other ACs investigated clearly showed pores in the mesoporous range. In electrochemical characterization, the lack of mesoporous structure showed no negative effect on the transport of ions.

Model

Parameters such as particle size and pore size distribution are important for the transport of active species in agglomerates of carbon particles. To gain further understanding of transport of active species, agglomerates (50-100 μm) from the fabricated electrodes have been studied using a microelectrode set-up [2], which allows for determination of effective diffusivity values in agglomerates.
The microelectrode method of characterization aids in the development of a physical model that describes the fabricated electrodes from an agglomerate-perspective. The model is based on a homogenous agglomerate macromodel but modified with a model for transport of active species in particles or agglomerates of carbon particles. The purpose of the model is to investigate and optimize the electrode parameters such as, but not limited to: pore size distribution, particle size and electrode thickness.
Simulations of the model were performed using the Femlab tool, and the model is validated using the experimental values from the fabricated electrodes.

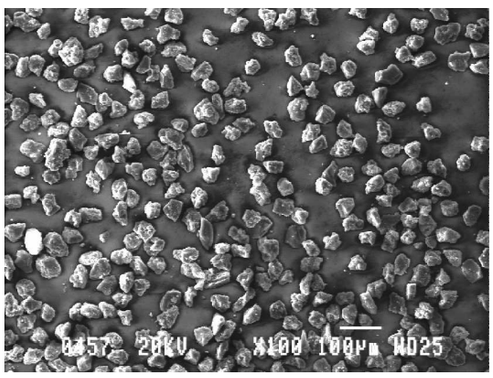

Figure 1: Micrograph of sieved particle fraction 36-38 μm.

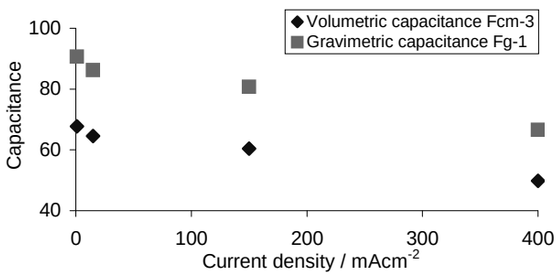

Figure 2: Volumetric capacitance of DL-electrode. AC: Jacobi Carbon BP2, particle size: <10 μm, binder : PTFE 9%.

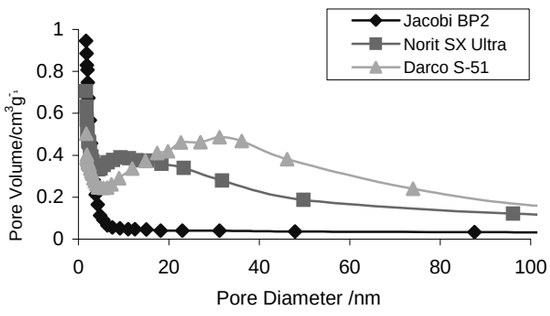

Figure 3: Pore size distribution for three ACs. BJH Adsorption.

References:

1. A. Burke, Ultracapacitors: why how and where is the technology, J Power Sources, 91(1), 2000.
2. M. Bursell, P. Bjoernbom, J. Electrochem. Soc., 363-4, 137(1), 1990.

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