D-glucose derived micro/mesoporous carbons for ultra-high rate supercapacitor application

T. Thomberg, T. Tooming, T. Romann, R. Palm, A. Jänes, E. Lust
Institute of Chemistry, University of Tartu
14A Ravila Street, Tartu 50411, Estonia
e-mail: thomas.thomberg@ut.ee

Decrease of fossil fuel resources and environmental impact of combustion of the fuels have been forced the materials chemists to develop new technologies and materials for novel energy storage and conversion devices. Recently, some attention has been paid how to produce functional carbonaceous materials by hydrothermal carbonization (HTC) method and various carbonaceous materials with different particle size, shape and functionality have been synthesised [1]. So far, relatively little attention has been paid for the use of HTC carbons as the electrode materials for the electrical double–layer capacitors (EDLC), so-called supercapacitors, and only some papers have been published [2,3].

However, development of EDLCs and synthesis methods of carbon materials for novel EDLC applications is important because of their high power performance that fills the gap between dielectric capacitors and traditional batteries [3,4]. Differently from batteries, the EDLCs store energy within the electrical double–layer, where the adsorption of ions is based mainly on the electrostatic interactions, showing good coulombic reversibility (98% or higher) and excellent cyclability (over 10^6 cycles) [1-4]. The unique characteristics of EDLCs allow them to replace or combine with batteries and fuel cells in applications, where high power pulses are important, such as peak power sources, digital communication devices, mobile phones, hybrid electric vehicles, etc. [3,4].

In the present work, activated carbons were synthesised from D-glucose using HTC method followed by pyrolysis and activation with some reagents in order to optimize the specific surface area, pore size distribution, and ratio of micro- and mesopores.

X-ray diffraction, Raman spectroscopy and high-resolution transmission electron microscopy data revealed that synthesised carbon materials were mainly amorphous and only minor changes in the structure were observed during activation step. Scanning electron microscopy studies demonstrated the interconnected, mainly spherically shaped micrometer scale particles, maintaining their shape and structure throughout pyrolysis and activation processes (Fig. 1).

Fig. 1. Scanning electron microscopy image for porous glucose derived activated carbon.

Based on the low-temperature N_2 sorption experiments micro/mesoporous carbons with the specific surface area up to 1900 $m^2 g^{-1}$ were synthesized.

Electrochemical characteristics obtained for porous glucose derived activated carbon electrodes in 1 M $(C_2H_5)_3CH_3NBF_4$ in acetonitrile show that cyclic voltammetry curves have a nearly rectangular shape up to scan rates 500 mV s^{-1} and HTC carbons based EDLCs retain about 60% of its initial capacitance (160 F g^{-1}) even at scan rate 1000 mV s^{-1}, thus, showing excellent characteristics for electrode materials for a ultra-high rate supercapacitor applications (Fig. 2).

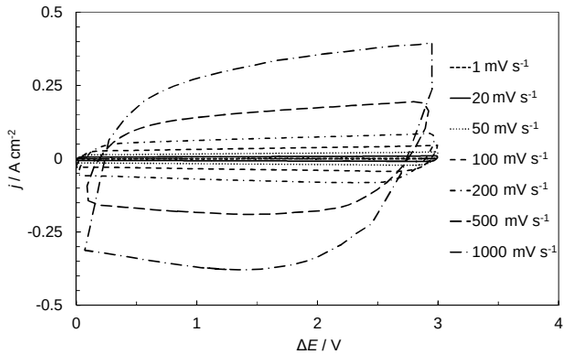

Fig. 2. Cyclic voltammetry curves vs. cell potential dependencies for EDLCs based on glucose derived activated carbon electrodes in 1 M $(C_2H_5)_3CH_3NBF_4$ in acetonitile solution at different potential scan rates.

Acknowledgements This work was supported by the Estonian Science Foundation under Projects Nos. 8172 and 9184, Estonian Ministry of Education and Research project SF0180002s08, European Regional Development Fund Project SLOKT10209T and Estonian Centre of Excellence in Research Project 3.2.0101-0030 "High-technology Materials for Sustainable Development".

References

[1] M.M. Titirici, R.J. White, C. Falco, M. Sevilla, Energy Environ. Sci. 5 (2012) 6796-6822.
[2] L. Wei, M. Sevilla, A.B. Fuertes, R. Mokaya, G. Yusin, Adv. Energy Mater. 1 (2011) 356-361.
[3] T. Tooming, T. Thomberg, T. Romann, R. Palm, A. Jänes, E. Lust, High rate supercapacitors based on the activated D-glucose derived carbon electrodes in non-aqueous electrolyte solution, J. Power Sources, under review.
[4] B.E. Conway, Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications, Kuwer Academic/Plenum Publisher, New York, 1999.