Increasing thickness of coarse-grained carbon electrodes for high device capacitance

Oleksiy Gogotsi [a, b*]
Vladimir Izotov [c, d], Xuehang Wang [e], Dmytro Havrykov[c], Illia Koltsov [a,c], Wei Han [c,d], Alla Serhienko [a], Ivan Hrysko [a], Yulia Zozulya [a], Olga Linyucheva [a], Vitaliy Balitskiy [a], Veronika Zahorodna [a,b], Yury Gogotsi [d,e]

[a] *Materials Research Center, Kiev 03680, Ukraine*
[b] *National Metallurgical Academy of Ukraine, Dnipro 49600, Ukraine*
[c] *International Center of Future Science, Jilin University, Changchun, 130012, P.R. China*
[d] *Key Laboratory of Physics and Technology for Advanced Batteries (Ministry of Education), College of Physics, Jilin University, Changchun 130012, P.R. China*
[e] *A. J. Drexel Nanomaterials Institute, and Department of Materials Science and Engineering, Drexel University, Philadelphia, Pennsylvania 19104, United States*

*alex@mrc.org.ua

Abstract

The main shortcoming of modern supercapacitors is their low specific capacitance. The main issue that engineers and scientists designing supercapacitors are facing with is to find the ways how to improve specific capacitance and increase the energy density of devices.

One way to enhance the specific capacity is by increasing the content of the active material (porous carbon and electrolyte) relative to passive materials (separator, binder, current collectors and packaging) in supercapacitor electrodes.

The increase of active materials in the electrodes and maintaining their electrochemical and mechanical properties at the same time, in practice can be achieved by using thicker electrodes without changing the current collectors or separators.

However, a saturation effect leads to a decrease in specific capacitance with increasing electrode thickness. Also, to maintain the mechanical properties of thick electrodes, it is necessary to increase the content of the binder, which leads to a decrease in the concentration of the active material. Passive materials do not contribute to the energy storage by the supercapacitor but affect its specific characteristics.

Herein we report about the effect of all the above factors on the specific capacitance of supercapacitor devices.

We show that electrodes with up to 1 mm thickness (compared to 50-200 microns in commercial devices) can be manufactured when coarse-grained activated or carbide-derived carbon is used.

An analytical expression connecting the dimensions of passive elements of the electrochemical system and the parameters describing the specific capacitance as a function of thickness of the carbon electrode is obtained. Experimental studies of the dependence of specific capacitance on the thickness of carbon-based electrodes have been carried out.

The obtained experimental data are in good agreement with the model predictions.

References

[1] P. Simon, Y. Gogotsi, Materials for electrochemical capacitors, Nat. Mater. 7 (2008), p. 84

[2] Dyatkin, O. Gogotsi, B. Malinovskiy, Y. Zozulya, P. Simon, Y. Gogotsi, High capacitance of coarse-grained carbide derived carbon electrodes. J. Power Sources 306 (2016), pp. 32-41.

[3] C. Portet, G. Yushin, Y. Gogotsi, Effect of carbon particle size on electrochemical performance of EDLC, J. Electrochem. Soc. 155 (2008), pp. A531-A536.

[4] B. Dyatkin, O. Gogotsi, Y. Zozuly, B. Malinovskiy, P. Simon, Y. Gogotsi. High Capacitance of Coarse-Grained Carbide-Derived Carbon Particles. Abstract Book of the 4th International Symposium on Enhanced Electrochemical Capacitors, June 8-12 2015, Montpelier, France, p. 143.

Acknowledgement. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 690853.