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CARBON BASED MATERIALS – THEIR PROPERTIES AND APPLICATION AS ELECTRODES IN ELECTROCHEMICAL DOUBLE LAYER CAPACITORS

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Abstract: *Two types of commercially available carbon blacks were studied by cyclic voltammetry and electrochemical impedance spectroscopy as electrode materials for supercapacitors in the 0.5 M electrolyte of propylene carbonate and LiClO4. Specific capacitances were calculated from cyclic voltammograms and impedance spectra were fitted, so resistance of electrode was calculated. A correlation was found between specific capacity, electrode resistance and specific surface area of carbon materials.*

Key words: *Supercapacitor, Cyclic Voltammetry, Electrochemical Impedance spectroscopy, Activated Carbon*

INTRODUCTION

Electrochemical capacitors (ECs) are promising storage devices. Their growing interest has been stimulated by potential use in an electric vehicle to transiently provide high power. ECs are considered as the high power storage devices with very high capacity, typically several hundreds of farads. According to the storage mechanism ECs could be divided into two groups: electric double layer capacitors (EDLCs, also known as supercapacitors) and pseudocapacitors (Faradaic capacitors). Supercapacitors can accumulate more energy (per mass or volume) than conventional capacitor because: (a) very small charge separation in the electrical double layer at the electrode-electrolyte interphase and (b) high surface area of the electrode.

Considerable effort has been devoted to the development and characterization of new electrode materials with improved properties. Different carbon materials with very high specific surface area (about 2000 m^2/g), high conductivity and relatively low cost are the main ingredients of the double layer capacitor electrode. The first two of these properties are important characteristics of electrodes of supercapacitors. Measured capacitances are usually much lower than was expected. The lower values of the specific capacitance are partially caused by higher resistance and lower active and usable surface area. [1,2]

1 EXPERIMENTAL

1.1 Material and samples preparation

The main part of the electrode is carbon black (or activated carbon). It is important due to its high surface area. The two types of carbon black were investigated. The first, VULCAN® XC72R provides excellent conductivity and on the other hand the second sample BLACK PEARLS® 2000 is a very fine particle sized material with super high surface area.

Both carbon materials were boiled in water with isopropanol for one hour, then 4 wt % PTFE was added as a binder agent. After 24 hours the solution was filtered and dried at 100 ^{o}C for 2 hours. After that the electrode substance was coated on the nickel mesh.

1.2 Methods

Electrochemical experiments were performed in a three electrode cell (Fig. 1) with 0.5 M electrolyte of propylencarbonate and $LiClO_4$. Lithium electrodes were used as reference and counter electrodes, so the electrodes with carbon were measured in half cell configuration. The three electrode cell was placed in a dry box with argon atmosphere on the ground of lithium oxidation on the air.

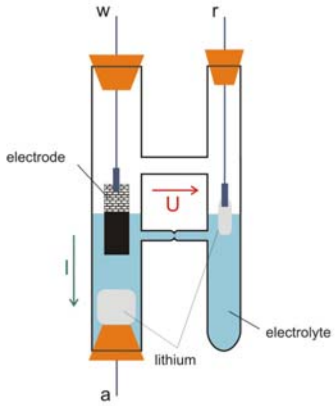

Fig. 1: The three electrode cell; w – working electrode, a – auxiliary (counter) electrode, r - reference electrode

Two electrochemical methods were used. The first method, cyclic voltammetry (CV), studied oxidation and reduction properties in the potential window from 0 to 3 V with the scan rate 10 mV/s. The electrochemical impedance spectroscopy (EIS) was used to investigate resistance of electrodes, which is given by electron (electrode) and ion (electrolyte) resistivity. EIS data were acquired after CV always at a constant dc potential of 2 V with a peak to peak 20 mV small sine pulses in a frequency range from 10 kHz to 10 mHz. Both methods were implemented at a potenciostat AUTOLAB PGSTAT 12.

2 Results and Discussion

Fig. 2 shows voltammogram (solid line) with calculated capacity (dotted line). Vulcan XC72R reached the specific capacity 48 F/g.

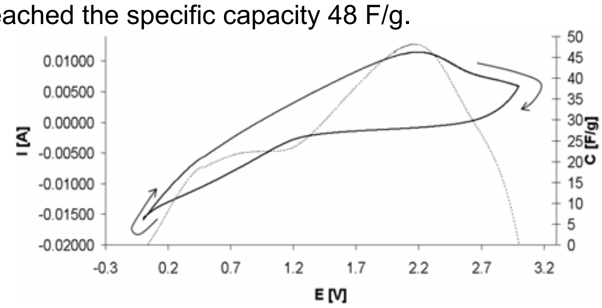

Fig. 2: Cyclic voltammogram of Vulcan XC72R

The capacity was calculated by the formula

$$C = \frac{1}{2} \cdot \frac{\Delta I}{\alpha} \quad [\mathrm{F}] \qquad (1)$$

where ΔI is a subtraction of the currents for one voltage and α is the scan rate.

In Fig. 3, a Nynquist plot of the of Vulcan XC72R is shown. At high frequencies a depressed capacitive semicircle is observed, due to the influence of the porosity on the electrode's AC response. The resistance was calculated by circular fit, a selected part of a circle curve is displayed as a result of the regression (see fig. 3, dash curve).

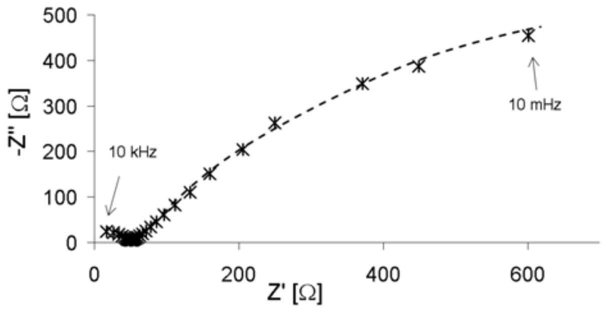

Fig. 3: Nynquist plot of Vulcan XC72R

	Vulcan XC72R	Black Pearls
Specific area	235 m^2/g	1475 m^2/g
Specific capacity	48 F/g	10 F/g
Electrode resistance	55 Ω	908 Ω

Tab. 1: Specific capacity and electrode resistance of carbon blacks

From results (tab. 1) is clear how important is resistance of the electrode. Vulcan XC72R has lower specific area than BP, but due to low resistance reached higher capacity. Black Pearls is promising material because of its surface area, but it necessary to improve electrode resistance and to assure usage of whole specific area.

3 Conclusion

There are many types of carbon materials suitable as electrode substance with different properties, like high-surface area and good conductivity. Cyclic voltammetry and impedance spectroscopy were used to study of carbon materials properties. It was show the consequence of high conductivity of electrode materials at the specific capacity.

4 References

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