



Effect of carbon powder thermal activation on characteristics of supercapacitor electrodes



Žydrūnas Kavaliauskas^{a, c, *}, Liutauras Marcinauskas^{a, b}, Mindaugas Aikas^a,
Vitas Valinčius^a, Mindaugas Milieška^a, Arūnas Baltušnikas^a

^a Lithuanian Energy Institute, Breslaujos Str. 3, LT-44403 Kaunas, Lithuania

^b Kaunas University of Technology, Studentu Str. 50, LT-51368, Kaunas, Lithuania

^c Kauno Kolegija/University of Applied Sciences, Pramonės Str. 20, LT-50468, Kaunas, Lithuania

ARTICLE INFO

Article history:

Received 13 April 2017

Received in revised form

5 September 2017

Accepted 12 September 2017

Keywords:

Plasma

Thermal treatment

Carbon powder

Specific capacitance

ABSTRACT

The capacitors are increasingly being used as energy storage devices in various power systems. The scientists of the world are trying to maximize the electrical capacity of the supercapacitors. This research aims to use plasma spray technology in order to develop carbon electrodes with carbon powder thermally treated in the temperatures ranging from 100 °C to 900 °C in the environment of argon gas. The BET research on primary carbon powder reveal that the largest surface area is obtained at 100 °C heating temperature – 577 m²/g, and at 900 °C – 507 m²/g. Meanwhile, at 300–700 °C heating temperatures the powder surface area decreases up to 2.2 times. The measurements of supercapacitor specific capacitance indicate that the largest values, 15 F/g and 8.7 F/g, were obtained when the respective specific surface area of primary powders equalled 577 m²/g and 261 m²/g.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Currently, most of the industry fields including sectors of mobile phones, computers, transport are facing an ever increasing problem of energy demand. Different batteries usually are used as energy accumulators; however, the main and biggest shortcoming of batteries is that their capacity decreases after a certain number of charge/discharge cycles, which shortens their lifespan. In addition, the process of charging accumulators takes considerable amount of time. Besides, such energy accumulators are not able to produce a powerful impulse. The mechanism of accumulating electrical charge in batteries is based on chemical processes; that determines the above mentioned drawbacks. Battery manufacturing often involves the use of different aggressive chemical substances (acids, alkalis), which are considerably expensive and harmful to the environment, as well as metals of scarce resources (lithium, ruthenium, etc.) [1].

In the search of alternatives to batteries, ever increasing attention is paid to the research of supercapacitors. The mechanism of

accumulation of charge in supercapacitors is based not on chemical processes but on the impact of electrostatic field. The construction of a supercapacitor is very similar to that of a standard capacitor, but a supercapacitor can accumulate up to 2000 F/g. As the mechanism of accumulating charge in supercapacitors is not based on chemical processes, the number of their charge/discharge cycles is practically unlimited [2,3]. After a million of charge/discharge cycles the capacity only diminishes by about 5%. Supercapacitors can also generate a very powerful impulse of electric current. In addition, the price of supercapacitors is significantly lower than that of accumulators, and their lifespan is almost unlimited. Activated carbon is one of the most commonly used materials in the production of electric double layer capacitors (EDLC). Carbon is highly suitable for the production of electrodes for the following inherent properties: high electric conductivity, large specific surface area (from ≈ 1 to > 2500 m²/g), corrosion resistance, chemical stability in combination with other materials and relatively low price [3].

The process of increasing carbon porosity is called activation. Non-activated carbon usually has low porosity; its structure consists of small particles which together form a lot of “pockets”. Gaps among particles are filled with a finer carbon fraction. During the process of carbon activation, pores are cleaned, which increases the surface area. By changing the activation conditions such as gas

* Corresponding author. Lithuanian Energy Institute, Breslaujos Str. 3, LT-44403 Kaunas, Lithuania.

E-mail address: zydrunas.kavaliauskaslei@gmail.com (Ž. Kavaliauskas).

medium, the process temperature or its duration, it is possible to get the required pore size, structure and surface porosity. Carbon can be activated in two ways: thermal (heating it from 100 °C to 900 °C and higher) in different gas environments (nitrogen, argon, water vapour, etc.) and chemical (treating with chemical substances) [4–7].

This research aims to use plasma spray technology in order to produce carbon electrodes with carbon powder thermally treated in the temperatures ranging from 100 °C to 900 °C in the environment of argon gas. The aim is to produce supercapacitors with carbon electrodes and analyse the effect of thermal treatment of primary carbon powder on electrical characteristics of supercapacitors.

2. Experimental set-up

The plasma spray technology was used to deposit supercapacitor electrodes. An experimental setup consisted of power generator, gas feeding, water cooling systems and plasma torch [8]. The argon was used as both the primary gas (flow rate of 0.295 g/s) and the carbon powder carrier gas (flow rate of ~0.008 g/s). The flow rates of argon gas were controlled by the flow meters (FL-3439ST and FL-3445C). Argon as plasma forming gas was chosen in order to prevent additional reactions between carbon and high temperature gas environment. The activated carbon powders were injected into the anode zone through the blowhole. More details about the deposition system is given in Refs. [8,9]. The voltage of plasma generator was 29 V, arc current – 55.4 A. The distance between the plasma generator output and the steel substrate was 3 mm, the deposition duration was 60 s. Carbon electrodes were fabricated using carbon powder thermally treated in argon environment with the temperature set at 100, 300, 500, 700 and 900 °C. The steel substrate was moving in the x-axis direction forward and back during the carbon powder deposition. The samples before deposition and after were weighted in order to calculate the difference of mass. The graphite was sprayed as bonding layer in order to increase the adhesion between the activated carbon and steel substrate. More details about the formation of graphite sublayer is given in Ref. [10].

The morphology of carbon electrode surface was evaluated using an electronic scanning microscope Hitachi S-3400N with magnification ranging from 20 to 100000 times, with 5 nm resolution. Carbon and oxygen amount was measured using the energy dispersive X-ray spectroscopy (EDS) system Bruker X FLASH QUAD 5040. The information on the percentage of carbon and oxygen was received from the 1.13 mm² area, taking an average result of 3 measurements. The FTIR spectra of the thermally treated carbon samples were measured at room temperature using attenuated total reflectance (ATR) and an internal reflection element made of diamond using ALPHA series Platinum spectrometer. Measurements were done in the 375–4000 cm⁻¹ range, spectral resolution 2 cm⁻¹, one spectrum is calculated by taking the average of 24 measurements. X-ray diffraction (XRD) patterns of deposited coatings were collected using a DRON-UM1 diffractometer with a Bragg–Brentano geometry in the 2θ range of 10–70° using Cu-Kα radiation. The anodic voltage was set at 30 kV, the current at 20 mA, the detector measurement interval at 0.5 s, the step – 0.02°. The specific surface area of carbon powders was estimated applying the Brunauer-Emmett-Teller (BET) method (Sorptometer KELVIN 1042). Porosity and specific surface area were measured at the degassing temperature of 150 °C for the duration of 60 min. The supercapacitor capacity was measured on a standard charge/discharge stand. Supercapacitors were charged using a 5 V voltage source of stabilised current, a resistor of stable resistance (18 kΩ) and an electronic circuit relay connected to an impulse generator,

which forms a capacitor charge/discharge cycle. The change in the values of supercapacitor charge/discharge voltage and electric current force at different times was registered by the digital multimeter Agilent 34972A, which has a data transfer interface with a personal computer.

3. Results and discussion

The FTIR measurements of carbon powder have shown that, in spite of different powder annealing temperatures, spectrum shapes are quite similar. When the wavenumber value rises from 400 cm⁻¹ to 4000 cm⁻¹, the transmittance values of all powder decrease from 55–65% to 16–22%. It is worth mentioning that the lowest transmittance to IR rays was obtained when powder was annealed at 100 °C temperature (Fig. 1). All powder lowest transmittance spectrums have low intensity absorption zones at ~1600 cm⁻¹, 1200 cm⁻¹ and 1000 cm⁻¹. In order to evaluate the variation in the intensity and location of these absorption zones depending on heating temperature, spectrums are analysed more in detail in the 700–1700 cm⁻¹ range (Fig. 2).

It is worth mentioning that IR spectrums of pure graphite do not have typical absorption bands. Different functional groups can exist due to thermal effect, moisture absorption and other reasons [11,12]. In powder IR spectrums, zones typical for sp² C = C (1560 cm⁻¹) and C–O (~1415 cm⁻¹) bonds are observed. A wide absorption band in the 900–1200 cm⁻¹ range reveals the existence of C–O and/or C–O–C stretching vibration modes (1090 cm⁻¹ and 1050 cm⁻¹) in all powders [12–14]. The intensity of absorption band attributed to oxygen bonds slightly decreases when the heating temperature is increased. Performed EDS measurements have revealed that when the heating temperature increases from 100 °C to 900 °C, the amount of oxygen falls from 7.9 at.% to 5.4 at.%. The intensity of absorption peak typical for sp² C = C bonds increases with the temperature decrease until 300 °C and decreases again at 100 °C (Fig. 2).

BET methodology was used to measure the specific surface area of primary carbon powders. The dependency of powder specific surface area on heating temperature is shown in Fig. 3. As can be seen from Fig. 3 the highest surface area (~577 m²/g and 507 m²/g) was obtained at 100 °C and 900 °C temperatures. At 100 °C temperature, some oxygen is removed from the primary carbon powder surface, thus it is possible to propose that some pores become empty; besides, oxygen is removed from carbon derivatives, which

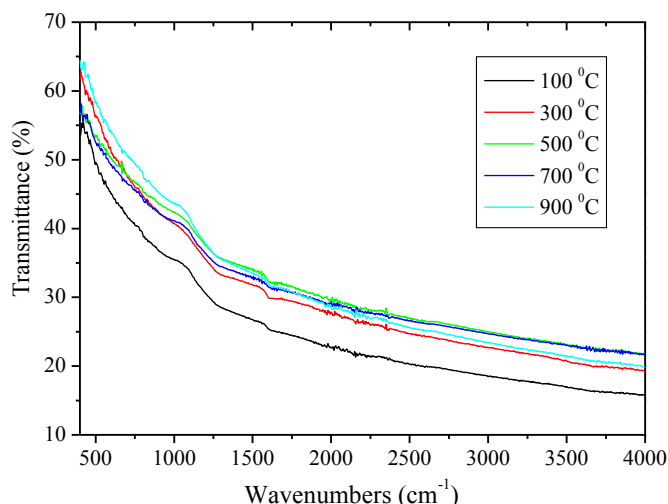


Fig. 1. IR transmittance spectra of carbon powder heated at different temperatures.

Download English Version:

<https://daneshyari.com/en/article/7117174>

Download Persian Version:

<https://daneshyari.com/article/7117174>

[Daneshyari.com](https://daneshyari.com)