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Temperature Dependent Characteristics of Activated Carbons from Walnut Shells for Improved Supercapacitor Performance

V.V. Pavlenko[1,2,3*], Q. Abbas[1], P. Przygocki[1], T. Kon'kova[4], Zh. Supiyeva[2], N. Abeykoon[5], N. Prikhodko[3], M. Bijsenbayev[3], A. Kurbatov[2], Z.A. Mansurov[3]

[1]Poznan University of Technology, Berdychowo 4, 60-965 Poznan, Poland
[2]Al-Farabi Kazakh National University, 71 al-Farabi Ave., 050040 Almaty, Kazakhstan
[3]Institute of Combustion Problems, Bogenbay Batyr str. 172, 050012 Almaty, Kazakhstan
[4]D. Mendeleev University of Chemical Technology of Russia, Miusskaya sq., 9, 125047 Moscow, Russia
[5]University of Texas at Dallas, 800 W Campbell Rd, 75080-3021 Richardson, USA

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Abstract

Activated carbons (ACs) have been prepared from chemical treatment of walnut shells (WS) precursor at various temperatures (400–800 °C) by using phosphoric acid (H_3PO_4) as activating agent. Influence of activation temperature on the porosity development and capacitive properties of resulting carbons was investigated. Thermal post-treatment of carbons previously activated at moderate temperature, e.g. 400 °C allowed further structural and porosity modification. Then, these carbons were investigated by scanning electron microscopy, Raman spectroscopy, energy-dispersive X-ray spectroscopy, electrochemical techniques and low temperature nitrogen adsorption exhibiting high BET specific surface area of approximately 2100 $m^2\ g^{-1}$ and a total pore volume up to 1.3 $cm^3\ g^{-1}$. Carbon material obtained through activation by H_3PO_4 at 400 °C and post-treated at 800 °C was used to make electrodes which were implemented to realize AC/AC capacitor using 1 mol L^{-1} Li_2SO_4. The electrochemical capacitor demonstrated high capacitance of 123 F g^{-1} per mass of one electrode, reduced cell resistance and stable capacitance for 5000 galvanostatic charge/discharge cycles at 1.0 A g^{-1}.

1. Introduction

Activated carbons (ACs) are produced in large quantities every year owing to their increased demand in environmental and energy sectors. ACs are the material of choice in the field of energy storage e.g., as electrode materials for charge storage in supercapacitors (SCs) due to high conductivity and reduced cost of large scale production. For such application, the performance of ACs depends on the surface area, structure and distribution of pores and electrochemical inertness [1]. These characteristics are directly dependent on the initial carbonaceous precursor and the method of activation to obtain ACs.

The walnut shells are suitable for preparing activated carbon owing to the low moisture content (3–4%), low ash content (1–2%), high density and easily available precursors [2–4]. Additionally, upon impregnation with less toxic phosphoric acid (H_3PO_4) as mild chemical activating agent and high-temperature treatments, carbons with good capacitive performance are produced [5]. However, the correlation between temperature of walnut shell activation in presence of H_3PO_4 and the capacitive behavior of resulting ACs has not been yet reported.

Phosphoric acid treatment promotes dehydrogenation and accelerated carbonization occurring at a moderate high temperature treatment (HTT) [6], which may be too low when other reagents such as potassium hydroxide are used. According to [6–7] activation of lignocellulosic biomass impregnated with phosphoric acid carried out in the range of 350–450 °C contributes to the formation of microporous ACs with the highest specific surface area which is in the range of 1500–1900 $m^2\ g^{-1}$.

*Corresponding author. E-mail: pavlenko-almaty@mail.ru