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Carbon nanocomposites for electrochemical capacitors

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Abstract

Carbon-carbon (C/C) nanocomposites based on nanodispersed carbon black and pyrolytic carbon obtained with matrix synthesis are investigated. The work presents the results of electrochemical tests on prototype samples of C/C nanocomposites as the components of electrochemical capacitors electrodes with the solutions of sulphuric acid (H_2SO_4) in water and tetraethylammonium tetrafuoroborate ($TEABF_4$) in acetonitrile acting as electrolytes. The research demonstrated the interrelation of the electrode components size factor and the supercapacitor electrochemical properties, and also the prospects of C/C nanocomposites application as the basis for supercapacitors electrodes with high-energy electrolytes.

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Keywords: carbon nanocomposites; matrix synthesis; supercapacitror; size factor; porous structure; electrolyte

1. Introduction

Recently, the attention of numerous scientists has been directed to development of more efficient autonomous electrochemical equipment (batteries, power cells, power sources, etc.) to generate and store electrical energy.

Nowadays, electrochemical capacitor with double electric layer, or supercapacitor, is considered as a promising rechargeable power source, the supercapacitor being the most suitable unit for storing and delivery of electrical energy. Due to high operational parameters of the supercapacitors, such application areas as storage devices of abnormal amount of energy, hybrid vehicles, fault-free engine starting devices for motor and railway transport, as well as the usage of combined power facilities have developed extensively. Also military equipment, aerospace and medicine industries are among the promising application areas [1].

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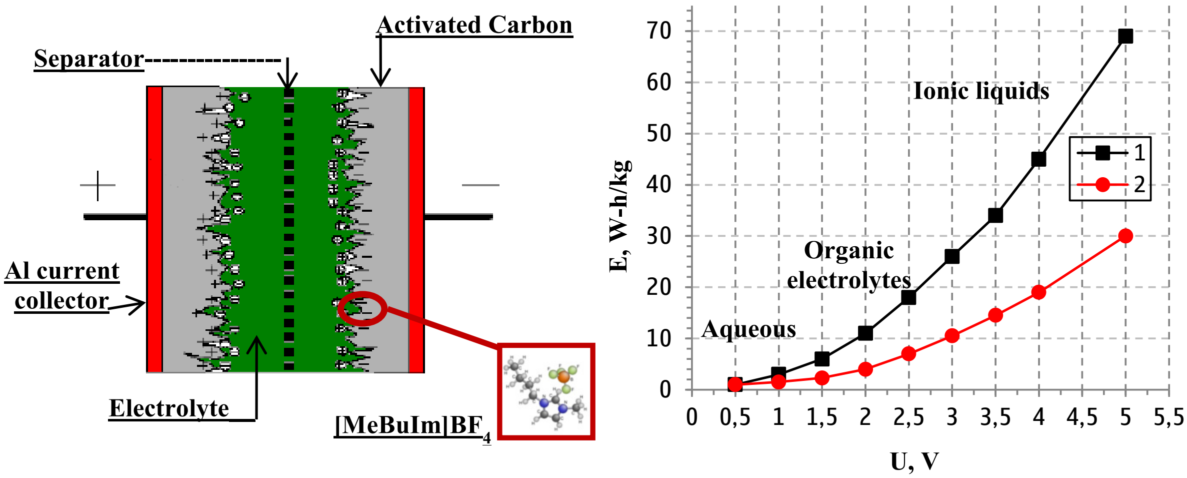
Electrochemical capacitors production is a dynamically developing area of worldwide industry of electrochemical power supplies production and it is notable for the variety of design and end-product properties. That is mainly connected to the usage of a wide range of the supercapacitors basic elements (electrode and electrolyte) properties [2, 3]. The variety of electrode materials and electrolytes calls for selecting special material combinations and allows to achieve the necessary parameters of the end-product specific energy and capacity (Fig. 1a, b).

As a whole, the main purpose of the supercapacitors specific energy properties improvement is the replacement of aqueous electrolyte with organic one, and, as well, optimization of active mass couples properties, such as porous structure and surface chemistry of carbon porous material. Whereby the most relevant investigations are those focused on the search for new types of electrolytes with improved operational characteristics (non-toxic, with operating voltage not less than 3.5 V, wide operating temperature range, etc.) The use of new high-energy electrolytes will result in sufficient increase of specific energy properties of the supercapacitors till 40 kJ/kg and specific capacity up to 20 kW/kg.



a b

Fig. 1. (a) Supercapacitor schematic diagram; (b) The dependence of specific energy on operating voltage: 1 - theoretical model, 2 - actual supercapacitor [4]

The most promising in developing supercapacitors of new generation and the substitution of traditionally used electrolytes ($TEABF_4$/acetonitrile) are ionic liquids (IL) [4-6]. However, despite high individual operational characteristics of IL ([MeBuIm]BF_4), its combination with standard active carbons does not result in maximum efficiency of a double electrical layer. It mainly depends on the size factor, i.e. the ratio between the pore size and the electrolyte cations and anions sizes (Fig. 2).

2. Experimental

In developing ideal supercapacitor of new generation, the electrode material selection is determined by the size factor, and the requirements for carbon component porous structure parameters can differ significantly due to the electrolyte type [7-9].

In this regard there is the task for developing a new generation of nanostructured carbon materials with predetermined porous structure and surface chemistry through their controlled synthesis with the use of algorithms based on molecular-dynamic modeling of a dual electric layer. Such material are to be optimized for usage with high-energy electrolytes based on ionic liquids and achievement of maximum value of dual electrical layer surface.