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Improving the characteristic of electric double layer capacitors using oxidized carbon nanoballoon

Yuta Okabe[a], Yoshiyuki Suda[a,*], Hideto Tanoue[a], Hirofumi Takikawa[a], Hitoshi Ue[b], Kazuki Shimizu[c]

[a] Department of Electrical and Electronic Information Engineering, Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi 441-8580, Japan
[b] Fuji Research Laboratory, Tokai Carbon Co., Ltd., 394-1 Subashiri, Oyama, Sunto, Shizuoka 410-1431, Japan
[c] Shonan Plastic Mfg. Co., Ltd., 31-27 Daikan, Hiratsuka, Kanagawa 254-0807, Japan

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ABSTRACT

Carbon nanomaterials are used as an electrode of electric double layer capacitors (EDLCs). In this research, we used arc black (AcB) and carbon nanoballoon (CNB) as the electrode material. AcB was produced by an arc discharge of graphite in N_2 atmosphere, and CNB was formed by a heat treatment of AcB. CNB is graphitic, and the particle shape is hollow. CNB has a higher specific capacitance than AcB at a high scan rate. In order to increase the specific capacitance of EDLC, CNB was oxidized at 625 °C in the air. By oxidization, the outer shell of CNB forms wrinkle. We call this material oxidized CNB (Ox-CNB). AcB, CNB, and Ox-CNB were used for the EDLC electrodes and were compared with commercially available activated carbon (AC). Cyclic voltammetry and electrochemical impedance spectroscopy of the EDLC electrodes were measured by an electrochemical measurement system. The specific capacitance of Ox-CNB (29 F/g) was larger than that of AC (16 F/g) at a scan rate of 500 mV/s. Furthermore, Ox-CNB had a high conductivity as a result of impedance measurement. Ox-CNB is an excellent electrode material of EDLC when using at a high charge/discharge rate.

1. Introduction

The reduction of CO_2 emissions from cars has recently become an important issue, and the development of rechargeable batteries and fuel cells for powering hybrid electric vehicles (HEVs) or electric vehicles (EVs) is now in progress [1]. The Li-ion battery has a high energy density and therefore is widely used [2,3]. However, it is beset with problems, such as deterioration of a battery when using in large-current as a regeneration brake system or fast charge as acceleration of a vehicle [4]. The hybridization of electrochemical capacitors and rechargeable batteries has been proposed and discussed by several authors in order to reduce the deterioration of rechargeable batteries [5,6]. In this research, we study electric double layer capacitors (EDLCs) which have an advantage in quick charge/discharge like the rapid acceleration/deceleration of a vehicle. EDLCs perform charge and discharge by the electric double layer which arises in the interface of an electrode and electrolyte. Furthermore, any metal materials are not used for the electrode. EDLCs do not use redox reactions. Therefore, EDLCs have advantages that provide higher specific power and perform longer cycle life compared with rechargeable batteries [7–9]. Because the discharge amount of EDLCs depends on the electron transport between electrodes, the conductivity of an electrode is strongly related to the charge and discharge capability of EDLCs. Additionally, the amount of electric charge stored is proportional to the number of adsorbed ions. Simply, the specific surface area of electrode materials is large, so the specific capacitance of the EDLC is large [10]. Activated carbon (AC) is commonly used for the EDLC electrode because of its large specific surface area [11–15]. AC is a main material which is used for all of commercially available EDLC electrodes. These EDLCs can be used in HEVs and EVs. However, the specific capacitance of AC is decreased in rapid charge/discharge use because its conductivity is low. Therefore, researches study carbon nanomaterials including carbon nanotube and graphene which can be replaced with AC [16,17]. In our previous study, we improved both of the specific capacitance and conductivity of EDLCs by using a mixture of arc black (AcB) and carbon nanoballoon (CNB) [18]. AcB was synthesized by arc discharge [19]. CNB was produced by heating AcB at

* Corresponding author. Department of Electrical and Electronic Information Engineering Toyohashi University of Technology 1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi 441-8580, Japan Tel.: +81 0 532 44 6726; fax: +81 0 532 44 6757.
E-mail address: suda@ee.tut.ac.jp (Y. Suda).

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