Journal of Power Sources 360 (2017) 383–390

Contents lists available at ScienceDirect

Journal of Power Sources

journal homepage: www.elsevier.com/locate/jpowsour

Development of 2.8 V Ketjen black supercapacitors with high rate capabilities for AC line filtering

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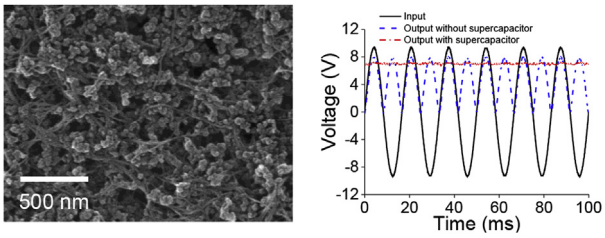
HIGHLIGHTS

- A KB supercapacitor shows excellent performance for AC line filtering.
- High performance is mainly due to open pore structure and graphitic nature of KB.
- The KB supercapacitors are used to successfully convert AC input into DC output.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 January 2017
Received in revised form
24 May 2017
Accepted 10 June 2017
Available online 15 June 2017

Keywords:
Supercapacitor
Mesoporous carbon
Ketjen black
Organic electrolyte
Frequency response

ABSTRACT

Supercapacitors are generally more compact than conventional bulky aluminum electrolytic capacitors (AECs). Replacement of AECs with supercapacitors can lead to miniaturization of electronic devices. However, even state-of-the-art supercapacitors developed in laboratories are superior to or competitive with AECs only in low voltage applications (<~40 V). In order to improve the voltage limits of current supercapacitors, we have incorporated Ketjen black (KB) as an electrode material. Utilizing the open pore structure and the graphitic nature of KB, we demonstrate that the voltage limit can be extended to 53 V. The KB supercapacitor exhibits excellent areal capacitance, cell voltage, and phase angle values of ~574 μF cm^{-2}, 2.8 V, and ~−80°, respectively. In addition, we demonstrate that an AC line filtering circuit with three supercapacitors connected in series can extend the application voltage without significant sacrifice in rate capability (ϕ ~ −77° at 120 Hz). On the other hand, KBs are much less expensive than carbon materials previously demonstrated for AC line filtering and hence are very attractive for practical applications. We believe that this demonstration of high-performance supercapacitors made from low-cost carbon materials is both scientifically interesting and important for practical applications.

1. Introduction

Compact supercapacitors may potentially replace bulky aluminum electrolytic capacitors (AECs) and contribute to miniaturization of electronic devices [1–3]. AECs are often used in an AC line filtering circuit, which is composed of a full wave bridge rectifier, a smoothing capacitor (i.e. an AEC), and a load resistor [4]. The full wave bridge rectifies the 60 Hz AC signal of residential outlet power or line power to pulsating direct current (DC) at 120 Hz. Then, the parallel resistor-capacitor (RC) circuit flattens the pulsating DC to produce the DC voltage that operates various electronic appliances. Because of their low volumetric capacitance, AECs are one of the largest components in this apparatus [5–7]. In contrast, supercapacitors have higher capacitance than AECs by several orders of magnitude [2,8]. This suggests that use of compact supercapacitors can significantly miniaturize AC line filtering

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http://dx.doi.org/10.1016/j.jpowsour.2017.06.032
0378-7753/