Electrochemical Investigation of Activated Carbon Electrode Supercapacitors

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Abstract—Supercapacitors, also called as ultracapacitors, are electrochemical energy-storage devices that exploit the electrostatic interaction between high-surface-area nanoporous electrodes and electrolyte ions, combining properties of conventional batteries and conventional capacitors. A symmetrical activated carbon (AC) electrode supercapacitor has been fabricated in a simple and inexpensive manner. The AC has been synthesized from Charcoal, has activated in a furnace at high temperatures. The electrode was fabricated by casting slurry made of AC and blended in a polymer solution on the counter electrode (current collector), appeared to have high mechanical strength. The electrochemical performance of the prepared samples was tested in 1 M KCl solution by cyclic voltammetry (CV), galvanostatic charge discharge technique, and impedance spectroscopy. The surface and cross-section of electrode was observed with SEM. Capacitance of fabricated supercapacitor has a favorable capacitance in the range of 65–70 F/g with low resistance. The AC electrode supercapacitor has excellent electro chemical reversibility, good cycle stability with a low fading rate of specific capacitance even after 500 cycles, which is promising for energy storage applications.

Keywords: specific capacitance, cyclic voltammetry, impedance spectroscopy, galvanostatic charge and discharge
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INTRODUCTION

Nowadays, researchers have great interest on renewable energy implementation and integration for improving more affordable and sustainable energy use. While there are different energy storage devices, but electrochemical storage devices are more attractive since high power densities and long life cycle. Thus, one of the current challenges in the field of research is the improvement of electrochemical storage devices with high power, energy density and long cycling life.

Electrochemical supercapacitors can store charges using both double layer and pseudo capacitive mechanism. Double layer supercapacitor working mechanism based on electrostatic forces between electric charges in the electrode and the electrolyte, while pseudocapacitance based on faradaic redox reaction taking place at the surface of electrodes. In this work we are focusing to improve double layer capacitance. The main electrode materials used in electrochemical capacitors are different form carbons. How ever increasing energy density is barrier in commercial application.

The well-known strategies to increase attainable energy density are the use of high surface area carbon, capacitances increases linearly with surface area. The capacitance of an electrode is related to surface area available for the charge formation and inversely related to the distance between the ion and polarized surface. The available surface area is related to wettability of the porosity of electrode, which comes as a result of the combination of, the polarity and size of the molecules of the solvent and the ions that constitute the electrolyte, and the pore size and surface chemistry of electrode. Porous carbon materials are the best suited material for achieving a high capacitance, since they combine high electric conductivity, chemical and physical stability. Many carbons possess naturally occurring surface quinones [1]. However to increase their capacitance, the type and extending of quinone functionalization can be optimized by “activated” carbon, which increases surface area of carbon. Activated carbon represents about half the total material cost of a supercapacitor, this low cost formidable barrier to entry for other carbons. Many other porous carbons have been developed for supercapacitor, but remain prohibitively expensive.

1 The article is published in the original.
Supercapacitor carbons have been the focus of extensive research over the past couple of decades. Carbon—carbon supercapacitors offer higher power, better cycle life, and higher reliability than batteries, but have much lower energy density and higher self-discharge. While the currently available energy density is acceptable for applications such as emergency doors, memory backup, and energy recovery, limited energy density is popularly perceived as the main impediment to supercapacitor market growth. Much research and development has focused on increasing supercapacitor carbon energy density at a premium price. The supercapacitor carbon market, however, is much more sensitive to price than to performance, causing premium supercapacitor carbons to fail in the marketplace.

Supercapacitors are used for applications requiring power for short period of time [2]. Typically an EDLC consists of two porous activated carbon based electrodes electrically isolated by a porous separator [3]. The separator and electrodes are impregnated with an electrolyte, which allows the ionic current to flow between the electrodes while preventing electronic current from discharging the supercapacitor [4]. Compared to batteries, the supercapacitors are characterized by quick charge and discharge regime, high power density and long cycle life.

Many other porous carbons have been developed for supercapacitors. Carbon aerogels, which consist of nanoscale particles made by pyrolyzing polymeric aerogels, and resin derived carbons, which are activated carbons prepared from polymers, have previously been used in supercapacitors. They still attract some attention, but they have been largely supplanted by coconut shell carbon as its cost has decreased. Carbon nanotubes have been extensively studied as supercapacitor materials, but single-walled nanotubes remain prohibitively expensive, while multi-walled nanotubes offer comparable performance to activated carbon at a higher cost. Carbide-derived carbon, which is prepared by etching metal carbides with chlorine gas, has shown roughly double the energy density of activated carbon. However, its processing is expensive and difficult due to the corrosiveness of the reactants involved. Despite the variety of high energy density supercapacitor carbons developed, charcoal activated carbon remains low cost with high performance.

In this study, we fabricated a carbon electrode through a drying process after casting a slurry blended with activated carbon in a polymer solution on the current collector (as aluminum foil). The effect of the polymer binder on the electrochemical properties was investigated for electrodes prepared. The goal of our investigation is to develop electrodes for supercapacitors, namely, activated carbon with low cost and easy method of preparation, and to study their electrochemical behavior.

**FORMULATION OF THE PROBLEM**

**Device Configuration**

EDLC supercapacitor consist of two electrodes separated by an ion permeable membrane (separator), and an electrolyte connecting both electrodes electrically as shown in Fig. 1. By applying a voltage to the supercapacitor, positive or negative layer of ions get deposited in a mirror image on the opposite electrode. Therefore, there is a formation of a layer of ions on both sides of the plate and ions are stored near the surface of carbon. This is called ‘Double layer’ formation. For this reason, the Super capacitor can also be called Double layer capacitor.

In this study, to assemble a supercapacitor cell, two rectangular stripes of AC coated Al were cut out and combined face to face, a separator (Whatman Filter Fig. 1. Schematic of a supercapacitor.