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Development of carbon-based composite materials for energy storage.

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Abstract

The following work aims the preparation and characterization of electrodes for supercapacitors employing different carbon materials and their integration functional prototypes. Preparation of electrodes was conducted in two steps; I) formulation and mixing of raw materials and II) coating of the aluminum foil that supports the electrode with the mixture of materials. Different compositions and formulations were carried out to prepare the electrodes. Electrodes were composed by a matrix polymer of PVDF (Polyvinylidene Fluoride) and several carbon material additives (activated carbon, graphite, carbon black, carbon nanotubes and graphene) that ensured a high specific capacity and low electrical resistance. Finally, the build-up of "single-cell" prototypes employing the electrodes was carried out to validate their performance. Galvanostatic charging/discharging cycles, cyclic voltammetry and impedance spectroscopy to characterize the electrodes and prototypes were performed. From these experiments important parameters of a supercapacitor were estimated; equivalent serie resistance (ESR) and specific capacitance (F/g). Results of characterization have shown high capacities and good kinetics in the electrodes developed.

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Keywords: Electrochemical capacitor;Energy storage;Electrode processing;Carbon materials.

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1. Introduction

Supercapacitors are energy storage devices of great interest due to the fact that exhibit extremely high power density, reasonable energy density and fairly long cycle life compared to those of batteries. These unique features make supercapacitors ideal in applications in the field of consumer electronics, heavy electric vehicles and industrial power management [1]. Unlike batteries which store energy through redox processes (faradaic), supercapacitors store and release the energy through the separation of electrostatic charges at the electrochemical interface between a carbon electrode and a liquid electrolyte [2,3]. Owing to the nature of the energy storage mechanism that takes place in supercapacitors their energy density is lower than that of batteries. Hence, huge research is needed to increase the energy density of supercapacitors, so that they may find their way into the market by replacing batteries. High surface area is critical to ensure the excellent performance of a supercapacitor in terms of power density and energy storage capability [4,5]. Moreover, high electrical conductivities of electrode materials are critical to assure quick store and delivery of the electric charges over the charging-discharging processes. Activated carbons are the most widely used electrode materials to store energy owing to their large surface area whereas graphites and carbon blacks are the most common conductive materials due to their low cost and easy processability. During the last year's new carbon-based nanostructured materials such as, graphene and carbon nanotubes (CNTs) have been proposed as candidates for electrode materials due to their great electrical properties. This work aims the preparation of electrodes with different compositions comprising several carbon materials and the later correlation of their electrical properties with their performance in energy storage processes.

2. Experimental

2.1. Chemicals

Electrodes with different compositions of carbon materials were prepared by using PVDF-based polymer "Kynar HSV 900" (ARKEMA) as a binder. Activated carbon "Organosorb 200-C303" was supplied by DESOTEC (1800 m^2/g, 1.57 cm^3/g pore volume) and carbon black "ENSACO 250G" from TIMCAL. Primary synthetic graphite "TIMREX KS5-75TT" from TIMCAL, graphene nanoplatelets "AvanGRP" (AVANZARE) and multiwall carbon nanotubes "Nanocyl NC 7000" (300 m^2/g) were also used as carbon additives. All the carbon materials were degassed and dried overnight prior their use. Tetraethylammonium tetrafluoroborate salt (Et_4NBF_4) from Sigma-Aldrich (Ref. 242144) dissolved in Acetonitrile (Fluka, >99.9%) was used as electrolyte for prototype characterization whereas N-Methyl-2-pyrrolidone (NMP) from Sigma-Aldrich (Ref. 443778) was employed as a solvent in the electrode manufacturing process.

2.2. Preparation of electrodes

Manufacturing of electrodes by a coating-based process was carried out by using the experimental setup showed in Fig. 1. The manufacturing process consisted of 4 steps; i) preparation of a homogeneous slurry or mixture of the carbon materials dispersed in the PVDF previously dissolved in NMP (10%), ii) coating of the aluminum foil with the slurry using a film-coater machine, iii) drying of the electrode to remove the NMP (160ºC) and iv) calendering of the electrode at 70ºC to improve the contact between the carbon material and the aluminum foil.

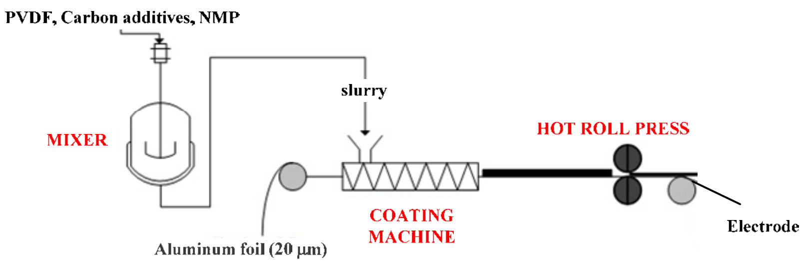

Fig. 1. Scheme of the manufacturing process of electrodes.