Investigations of activated carbon from different natural sources for preparation of binder-free Few-walled CNTs/activated carbon electrodes

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Energy storage has become one of the main drivers of technological progress, as industrial and transportation activities are now heavily reliant on the combustion of fossil fuels [1]. The search for environmentally friendly, commercially available, and energy-efficient systems is the objective of numerous research efforts. Batteries, fuel cells, and electrochemical capacitors (ECs) are the most common electrical energy storage devices, each working on different principles [2]. The main principle of batteries and fuel cells is based on converting electrical energy into chemical energy through redox reactions in the anode and cathode materials [3]. ECs are power devices that can be fully charged or discharged in seconds, also known as supercapacitors, ultracapacitors, or "double-layer capacitors". Electric energy is stored through ion adsorption or fast redox reactions on the surface of the active material, which has an unlimited service life in charge/discharge cycles [4,5].

The active material is used in powdered form to create a porous structure with a high specific surface area that is available for electrochemical reactions. Polymer materials are added to the active material to form a usable electrode. Due to the insulating nature of the polymer materials, various forms of conductive carbon materials are added to increase the conductivity of the electrode. The mass fraction of the polymer binder is 10-20 wt.%, and the conductive additive is 5-15 wt.% of the total electrode mass. However, even with the addition of conductive agents, the electrode efficiency is still relatively low (usually about 1 ohm/cm or less). The low conductivity of the electrode necessitates the use of a metal with high conductivity, called a current collector. During charging, electrons quickly spread throughout the two-dimensional surface of the electrode to the current collector, and they only need to pass through the thickness of the electrode to reach all of the active material. The current collector also functions as a substrate and mechanical support for the electrode material. Although some electrode compositions can form a separate film or sheet, the substrate usually plays a crucial role in maintaining the structural integrity of the electrode throughout the production and service life of the device. Traditionally, the electrode consists of 80% active material by mass, while the other 20 wt.% is made up of inactive elements (binder and conductive additive). Therefore, to increase the specific energy of batteries and electrochemical capacitors, it is important not only to use active materials that can store more energy but also to minimize the inactive weight required to create the final device.

This study presents the results of producing activated carbons (AC) through thermal treatment of plant-based raw materials of various origins, including rice husk, apricot stones, walnut shells, beet pulp, and sunflower seeds, which were used to manufacture composite electrodes. The investigation of different sources of AC enabled the selection of the best raw material. The carbonization and thermal decomposition behavior of the raw materials were investigated using differential scanning calorimetry, while the AC samples were characterized using nitrogen adsorption, BET analysis, SEM, EDAX analysis, TEM, and Raman spectroscopy. A methodology for obtaining a flexible, ultra-light hybrid electrode with high specific capacitance based on AC and carbon nanotubes (CNTs) is also proposed. The AC electrodes showed a high specific capacitance of approximately 172 and 119 F/g at scan rates of 5 and 100 mV/s, respectively. The use of domestically produced AC with a surface area of 2000-3000 m2/g resulted in electrode materials with higher specific capacitance compared to electrodes produced using traditional methods. The AC/CNT electrodes also exhibited low resistance. These findings demonstrate the potential of AC electrodes as a promising alternative for use in high-performance energy storage devices. In the authors' opinion, this study highlights the importance of investigating different sources of raw materials, such as rice husk, apricot stones, walnut shells, sugar beet pulp, and sunflower seeds, to identify the most suitable precursor for the production of high-performance AC electrodes.

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