UNIVERSITY OF CALIFORNIA SANTA CRUZ OFFICE OF RESEARCH

Three-Dimensional Hierarchical Porous Carbon Foams For Supercapcitors

Tech ID: 33179 / UC Case 2016-533-0

BACKGROUND

Electric double layer capacitors (EDLCs) are promising candidates for use in lightweight power sources because they have high power densities and excellent charge/discharge cycling stabilities. An ideal EDLC electrode should have large surface area, excellent electrical conductivity, and chemical and mechanical stability. To increase the gravimetric capacitance of an EDLC, the electrode must be self-supporting so that current collectors and nonconductive binders are not required. Three-dimensional (3D) self-supporting carbon-based materials such as graphene/carbon aerogels, carbon monoliths, carbon nanotube (CNT) sponges, and carbon nanofiber foams have been extensively studied for use in lightweight EDLCs.

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Still a major challenge for 3D carbon electrodes is the limited ion diffusion rate in their internal structures. During the rapid charging and discharging process, the limited ion diffusion causes undesirable capacitance loss and lowers the rate capability and power density. To address this limitation, the preparation of highly porous 3D structures, providing high numbers of ion diffusion channels, is favorable. The presence of macro- and mesopores facilitates ion diffusion within 3D structures, while the presence of micropores increases the gravimetric capacitance by increasing the ion-accessible surface area. 3D porous carbon materials are expected to have enhanced specific capacitances as well as rate capabilities compared to their 3D non-porous counterparts.

TECHNOLOGY DESCRIPTION

The invention involves a method of fabricating 3D hierarchically porous carbon foam (PCF) derived from K2CO3-embedded chitosan aerogels. Chitosan is the second most abundant natural biopolymer, making it a sustainable precursor for the synthesis of carbonaceous materials. Moreover, on pyrolysis, chitosan forms a graphitic carbonaceous material with excellent electrical conductivity due to its intrinsic N-doping.

Previous studies of chitosan-derived carbonaceous materials have primarily focused on the preparation of carbon powders and pellets. However, carbon powders and pellets may not be the best candidates for EDLC electrodes. The fabrication of a carbon powder electrode requires the addition of non-conductive binders and a conductive substrate as a mechanical support. In contrast, carbon pellets are self-supporting structures, but they are typically assembled with very thick sheets (~2 μm in thickness) that limit the electrode surface area.

In this invention, a glutaraldehyde is used to cross-link chitosan in solution at ambient temperature to form chitosan aerogels. Subsequent pyrolysis of the as-formed aerogel yielded a 3D porous carbon network with interconnected porous thin carbon sheets (~90 nm).

Previously described methods for the production of porous carbon structure can be grouped into two approaches: i) template methods that involve the incorporation and removal of templates such as silica spheres and polystyrene spheres to generate pores, and ii) KOH activation methods, in which carbonized structures are mixed with KOH powder and annealed at high temperatures (>600 ° C) to create pores . Both approaches require at least two steps to obtain the porous carbon structure. In contrast, this method simultaneously carbonizes chitosan and generates meso- and micro-pores, forming the aerogel in one step.

The porous carbon foam structure has a relatively low density of 9.92 mg/cm3 , and the porous structure and thin walls allow rapid ion diffusion and create an ultra-high surface area (1,013 m^2 /g) for charge storage. The self-supporting PCF electrode achieved outstanding electrochemical performance with a gravimetric capacitance of 246.5 F/g (at 0.5 A/g) based on the entire mass of the electrode. Furthermore, a capacitance retention of 67.5% was observed when the current density increased from 0.5 to 100 A/g.

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OTHER INFORMATION

KEYWORDS

capacitor, carbon foam, electric double layer capacitor, electrode, carbon aerogel, porous carbon foam, chitosan, supercapacitor, battery, fuel cell, catalyst, aerogel

CATEGORIZED AS

- **Energy**
  - Storage/Battery

RELATED CASES

2016-533-0

A quasi-solid-state symmetric supercapacitor was assembled using two pieces of PCF, and this delivered an very high power density of 25 kW/kg at an energy density of 2.8 Wh/kg based on the total weight of two electrodes (equivalent to a power density of 6.25 kW/kg and an energy density of 0.68 Wh/kg based on the total mass of device considering a packing factor of 0.4).

Generally, the method of making the carbon foam electrode involves: mixing an SiO2 particle dispersion with a chitosan solution, adding aqueious glutarldehyde, and allowing the mixture to solidify in air to form a hydrogel. The hydrogel is lyophilized and carbonized and the SiO2 dissolved from the hydrogel to form the 3D carbon foam.

APPLICATIONS

Supercapacitors (electric double layer capacitors)

Batteries

Catalysts

Fuel Cells (hydrogen fuel cells)

ADVANTAGES

One-step synthesis

Inexpensive input materials

Extremely high surface area --> capacitance retention of 67.5%

25 kW/kg power density

INTELLECTUAL PROPERTY INFORMATION

Country	Type	Number	Dated	Case
United States Of America	Issued Patent	10,850,983	12/01/2020	2016-533
United States Of America	Issued Patent	10,526,203	01/07/2020	2016-533

RELATED MATERIALS

- Hierarchically porous carbon foams for electric double layer capacitors - 06/07/2016

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Carbon-Doped NiO Catalyst For Hydrogen Evolution Reaction
- Zinc-Iodine Battery with improved Coulombic efficiency
- Z-Scheme Microbial Photoelectrochemical System (Mps) For Wastewater-To-Chemical Fuel Conversion
- Hydrogen-Treated Semiconductor Metal Oxides For Photoelectrochemical (PEC) Water Splitting
- Self-Biased and Sustainable Microbial Electrohydrogenesis Device

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