

STRUCTURE AND ELECTROCHEMICAL PROPERTIES OF RF CARBON AERIGELS MODIFIED BY GLUCOSE

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Introduction

Carbon aerogels, a kind of new nano-structure porous material, have many special properties such as highly specific surface area (600~1000m²/g), controllable pore size distribution, high porosity and low electrical resistance[1]. It could be used in various application fields such as electrode materials for electric double-layer capacitors, catalyst supports, the microwave absorbents and water desalination [2]. The electrode material for electric double-layer capacitors is an important use for carbon aerogels because its mesoporous properties are suit for the formation of electric double-layer.

Carbon aerogels can be prepared through three steps: synthesis of wet organic aerogels, drying of the wet organic aerogel and carbonization of organic aerogels. Many studies on controlling the structure of carbon aerogels via these steps such as new organic gel system, different kinds and contents of catalyst, different drying environment and various carbonization conditions have been reported [3]. Controlling the structure of organic aerogels is a simple way to vary the pore property of carbon aerogels. A method of using micromolecule as pore former to modify the structure of carbon materials has been reported [4]. The micromolecule was dispersed evenly in the solution and took the place in the synthesis procedure to change the structure of the organic gel. And the micromolecule decomposed totally when it was carbonized. The cavity has been lifted and the structure of carbon aerogels has been changed. In this study, glucose was used as pore former to modify the structure of carbon aerogels that was prepared by resorcinol and formaldehyde [5]. Then the electrochemical characterization of CAs has been studied.

Experimental

2.1 Preparation of carbon aerogels

The synthesis of organic gel is the first procedure. Resorcinol and formaldehyde (1:2 molar ratio) were dissolved in deionized water. Glucose, used to modify the structure of carbon aerogels, was dissolved in the solution. The contents of glucose were 0.5 %, 1.0 %, 1.5 % and 2.0 % (wt %). Sodium carbonate was used as catalyst. The final solid concentration of the RF solution was controlled by deionized water to 25 wt%. The solution was decanted into ampoule bottle and cured in water bath of 85 °C for 3 days. Then the wet gel was soaked in acetone for 3 days and supercritically dried with petroleum

ether. The dried gels were carbonized at 1000 °C for 2 hours in N₂ atmosphere.

2.2 Characterization of carbon aerogel

The surface morphology and microstructures of carbon aerogels powder was observed by scanning electron microscope (SEM, Cambridge S-250MK3). Specific surface areas and pore size distributions of carbon aerogels were obtained from Nitrogen adsorption and desorption isotherms recorded with a gas sorption system (Thermo Sorp Tomatic 1990) at 77 K. The pore size distributions were determined based on the Barrett, Joyner and Halenda (BJH) method. The specific surface area SBET was calculated by Brunauer–Emmett–Teller (BET) method. Mesopore volume was determined by t-plot method and the total pore volume (VTOTAL) was estimated from the amount adsorbed at P/P0 = 0.99.

2.3 Electrochemical measurements

Carbon aerogels were made into powder by precise grinding. The powder was mixed with 5 wt% polytetrafluoroethylene and 10 wt% carbon black, and was then rolled into a thin film. The film was pressed onto a piece of nickel foam (diameter of 1cm) as an electrode. The weight of the carbon on the electrode was around 20 mg. A two electrode system was composed by two electrode separated by a thin polypropylene insulating membrane. 30 wt% KOH solution was filled as electrolyte. The electrochemical characterization was carried out by the typical constant current charge/discharge experiment using Land battery test system (Wuhan Jinnuo Ltd. China). The specific capacitance was calculated from the slope of charge/discharge curve according to the follow formula: [15]

$$C = 2I\Delta t/m\Delta V \quad (1)$$

where C is the specific capacitance, I is the constant current, Δt is the discharge time period, m is the mass of single carbon electrode, and ΔV is the potential differences upon discharge.

Results and Discussion

Fig.1 shows the three-dimensional network structure of RF carbon aerogels. This structure composed of numerous particles with the sizes in nanometers, providing high porosity. This structure is suitable for the adsorption and transmission of ions and the forming of electric double layer. The particles arranging of carbon aerogels modified by glucose are compacter than RF carbon aerogels and the pores among them are smaller. The surface of carbon aerogels is looser than that modified by glucose.

Fig.2 shows the pore size distributions (PSDs) of carbon aerogels. It exhibited that the pore sizes of the RF carbon aerogels and the sample modified by glucose cover the range of 20-40 nm, but the PSDs of glucose modified sample is narrower and smaller, around 8-10 nm. The pore textural parameters, S_{BET} , V_{total} , V_{mes} and D are listed in Table 1. The specific surface area of glucose modified by glucose of 1 wt% increased from 403.6 m²/g to 684.3 m²/g, but decreased to

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625.8 m²/g with the increase of the glucose content to 2 wt%. The possible reason is that glucose takes some places in the procedure of the synthesis of organic gel and decomposed when carbonized so that the structure of the network become compact and the PSDs become narrow.

The charge–discharge curves of carbon aerogels modified by glucose with different contents were measured in 30 % KOH aqueous solution. Fig.3 shows the specific capacitance of the carbon aerogels modified by glucose with different contents. The specific capacitances of carbon aerogels electrodes increased from 70.2 F/g to 115.2 F/g in the glucose content range from 0 to 1.0 wt%. When the glucose content is more than 1.0 wt%, the specific capacitances decreased with the increase of the glucose content. So, the glucose content of 1.0 wt% is the better addition to modify the structure of carbon aerogels.

Table 1. Porous textural parameters of carbon aerogels.

Sample	S _{BET} (m ² .g ⁻¹)	V _{total} (cm ³ .g ⁻¹)	V _{mes} (cm ³ .g ⁻¹)	D (nm)
CA-0	403.6	2.23	2.07	20.5
GCA-1	684.3	1.78	1.72	10.41
GCA-2	625.8	1.93	1.56	12.34

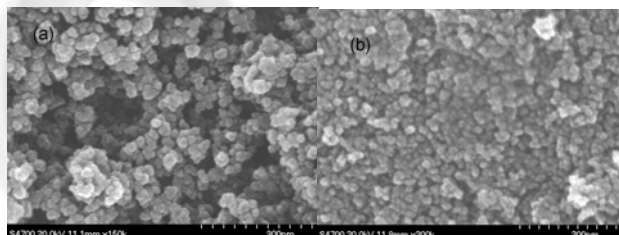


Fig. 1 SEM micrograph of the carbon aerogels. (a) RF carbon aerogels. (b) RF carbon aerogels modified by Glucose 1wt%.

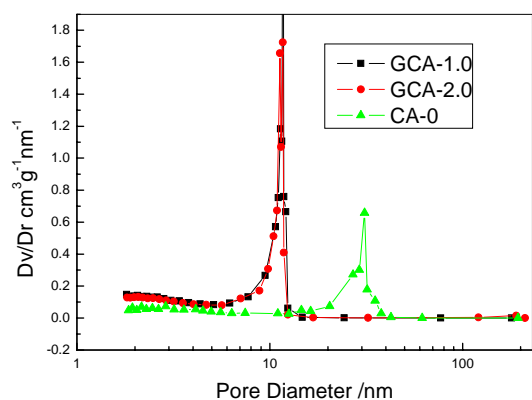


Fig. 2 Pore size distribution of carbon aerogels (CA-0 is RF carbon aerogels, GCA-1 and GCA-2 are carbon aerogels modified by glucose).

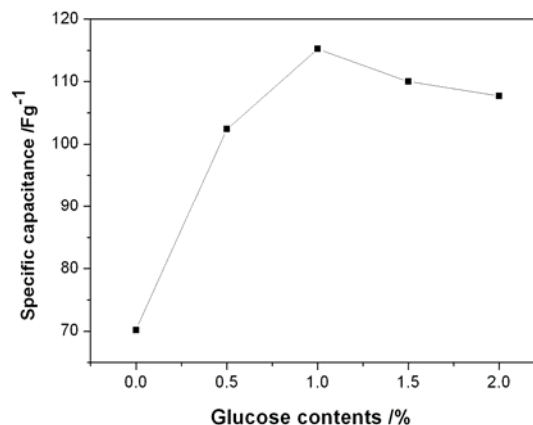


Fig. 3 Specific capacitance of the carbon aerogels modified by glucose with different contents

Conclusions

The structure of organic aerogels synthesized by resorcinol and formaldehyde can be modified by glucose, and the glucose was decomposed in the procedure of carbonization. The specific surface area of sample modified by glucose increased from 403.6 m²/g to 684.3 m²/g when the content of glucose was 1 wt%, and the average pore size decreased from 20.50 nm to 10.41 nm. The specific capacitances of carbon aerogels electrodes increased from 70.2 F/g to 115.2 F/g at the current of 1 mA. When the contents of glucose exceed 1 wt%, the specific surface area and specific capacitances decreased..

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