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Hierarchically porous carbon derived from an aqueous curable composition for supercapacitors

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ABSTRACT

Hierarchically porous carbon with micropores, mesopores, macropores and high specific surface area for supercapacitors is fabricated from an aqueous curable composition by curing and subsequent carbonization, followed by KOH activation under N_2 atmosphere. With the manipulation of KOH activation to the peculiar morphology developed during carbonization, the external specific surface area grows from 208 to 1151 $m^2 g^{-1}$, while the specific surface area of micropores stays at around 1100 $m^2 g^{-1}$, leading to the micro/external specific surface area ratio decreases from 5.36 to 0.94. Prepared with KOH/carbon weight ratio at 2.0, the porous carbon with total specific surface area of 1590 $m^2 g^{-1}$ and moderate micro/external specific surface area ratio of about 2.0, exhibits intriguing electrochemical performance in 1 M H_2SO_4 aqueous electrolyte, such as superior specific capacitance (274 F g^{-1} at 0.1 A g^{-1}), excellent rate capability (161 F g^{-1} remained at 20 A g^{-1}) and outstanding cycling stability (no capacitance loss over 5000 cycles). The promising electrochemical performance could be attributed to the synergy of the hierarchically porous morphology and high specific surface area.

1. Introduction

Electric double-layer capacitors, often known together with pseudocapacitors as supercapacitors, have recently attracted significant attention in high power electrochemical technology research owning to their higher power density, higher energy density, excellent pulse charge-discharge characteristics and long cycling stability [1–8]. By investigating the behavior of electric double-layer capacitors, large specific surface area, synergistic effect of micropores/mesopores/macropores, and adequate pore size distribution have been confirmed playing extremely crucial roles for the electrode materials to obtain superior electrochemical performance [1–4,9–18]. Up to now, various porous carbons including carbide-derived carbon [19–23], activated carbon [18,23–24], carbon fiber [25], carbon nanotube [25–28] and graphene [25,29,30], have been considered to be suitable electrode materials for electric double-layer capacitors, on account of their large specific surface area, synergy of hierarchical pores, suitable pore size distribution and good conductivity. Moreover, many methods have been developed to fabricate the porous structure in carbon matrix [18,31–34] Among these methods, KOH activation has been proved to be one of the most common, effective, favorable and of paramount importance one for preparing hierarchically porous carbon with high specific surface area [18,33,34].

However, the practical applications of activated carbon for supercapacitors, whose performance strongly depends on precursor itself and activation methods, are still seriously hindered by the unsatisfactory performance of the electrode material, such as the low specific capacitance and poor rate capability. Given this, searching for new precursors and optimizing activation parameter would be of importance for improving the electric double-layer capacitors' performance.

Poly (arylic acid salt)/Polyol aqueous curable composition, which is used to replace phenol formaldehyde resin in glass wool insulation industry to reduce the allergy, asthma, probable human carcinogen caused by formaldehyde [35–38] has been reported in granted patent [39]. This aqueous curable composition is also environmentally friendly [39] and commercially available in the market. Thus Poly (acrylic acid salt) /Polyol aqueous curable composition might be one of commercialized eco-friendly precursors for porous carbon but hasn't attracted any considerable research heretofore.

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In this work, a bunch of carbons with filled mesopores and macropores are derived from commercialized eco-friendly aqueous curable Poly (acrylic acid salt)/Polyol composition by carbonization. Treated with KOH activation, the hierarchically porous structures with micropores, mesopores and macropores morphology and high specific surface area are developed into the carbon matrix above. Electrochemical studies show that the carbon prepared demonstrates excellent capacitive performance as the active electrode materials for aqueous supercapacitors.

2. Experimental

Poly (acrylic acid salt)/Polyol aqueous curable composition (AQUASET ^{TM} 707) was manufactured by Dow Chemical Company. All other reagents were purchased from Sinopharm Chemical Reagent Co, Ltd. and used as received unless otherwise stated.

2.1. Sample preparation

The facile synthesis process was described briefly as follows: 6.0 g AQUASET ^{TM} 707 was placed in an oven at 210 °C for 30 mins, followed by being heated at 500 °C for 2 hrs in a tubular furnace under N_2 atmosphere with a heating rate at 5 °C min^{-1} to accomplish the carbonization process. The yield of the carbonization process was about 21%, and the carbon achieved was named after C-500. The C-500 and KOH were mixed with a desired weight ratio of 1.0, 2.0, and 2.5. Taking the activation with KOH/C-500 weight ratio of 2 for example, 0.3 g of C-500 was immerged with KOH solution (0.6 g KOH in 7.5 ml ethylalcohol), followed by an evaporation of ethylalcohol at 60 °C under magnetic stirring with flowing N_2. The KOH activation process was carried out by heat treatment at 700 °C for 2 hrs in a tubular furnace under N_2 atmosphere with a heating rate of 5 °C min^{-1}. Afterwards, the sample were rinsed with 0.2 M HCl and plenty of distilled water in

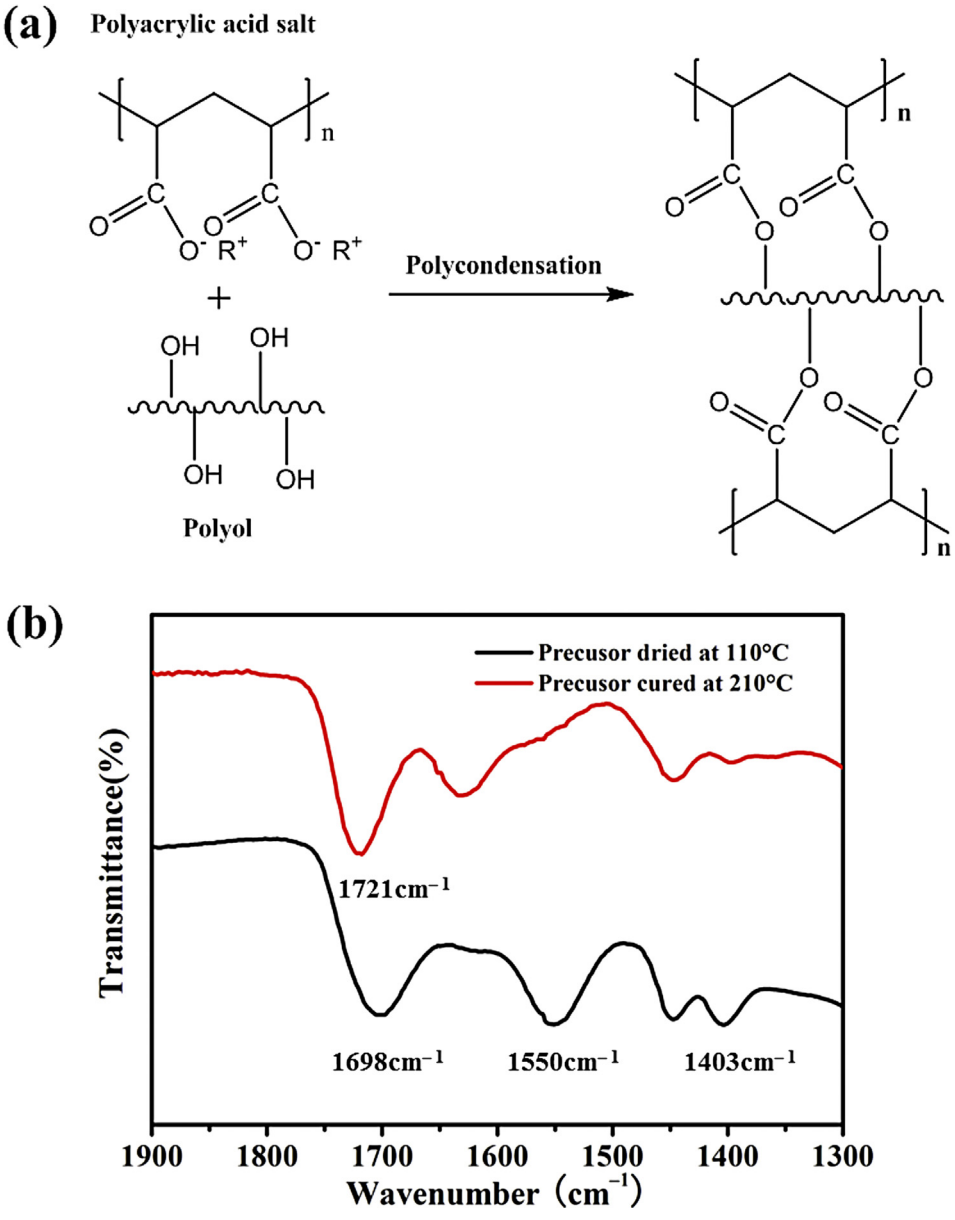

Fig. 1. (a) Synthesis schematic of precursor, (b) FTIR of precursor dried at 110 °C and cured at 210 °C respectively.