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Electrosynthesis of SiC derived porous carbon nanospheres for supercapacitors

Kai Zheng [a], Xingli Zou [a,b,*], Xueliang Xie [a], Changyuan Lu [a], Shangshu Li [a], Xionggang Lu [a,*]

[a] State Key Laboratory of Advanced Special Steel & Shanghai Key Laboratory of Advanced Ferrometallurgy & School of Materials Science and Engineering, Shanghai University, Shanghai 200072, PR China
[b] Center for Electrochemistry, Department of Chemistry, The University of Texas at Austin, Austin, TX 78712, USA

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ABSTRACT

Porous silicon carbide derived carbon (SiC-CDC) nanospheres have been successfully synthesized by electrochemical extraction of Si atoms from SiC nanospheres precursor in molten $CaCl_2$. The electrochemical etching process was conducted at 900 °C and 3.2 V. The results show that the obtained product is porous SiC-CDC nanospheres, which contain amorphous carbon and a small amount of ordered graphite phase. The specific surface area of the produced SiC-CDC was determined to be 881 m^2/g. The specific capacitance of the SiC-CDC is 176 F/g and possesses excellent cycling stability (97.8% retention of the initial capacitance after 1000 cycles) at a current density of 1000 mA/g.

1. Introduction

Supercapacitors, commonly called electric double-layer capacitors (EDLCs), which have specific capacitance and long cycle life due to the porous electrode materials with large surface area and high electrical conductivity [1]. Among the various electrode materials of supercapacitors, porous carbon exhibits superior electrochemical performance due to its large surface area and pore sizes [2–4].

Carbide-derived carbons (CDCs) are porous carbon nanomaterials, which were produced by selective extraction of metal or metalloid atoms from carbides. CDCs commonly possess high specific surface area, tunable pore structure and narrow pore size distribution which strengthen the specific capacitance. The controllable structure of CDCs provides good power handling that accelerate fast ion and electron transport, and resulting in a high rate performance [5–7]. Commonly, chlorination process was employed for the production of CDCs. However, the chlorination process involves Cl_2 gas which is hazardous and poisonous [8]. Nowadays, because of the environmental impact of chlorination process, searching for new process for the synthesis of CDCs is thus needed [9].

In this paper, we have successfully produced porous CDC nanospheres from SiC nanospheres by using a simple molten salt electrochemical etching method at 3.2 V and 900 °C. This method is much safer, less expensive and more environmentally friendly to the chlorination process. The microstructure and adsorption capability of the as-prepared SiC-CDC were systemically investigated, and the excellent supercapacitive performance of the obtained SiC-CDC was also confirmed.

2. Experimental procedure

The SiC nanospheres precursor (99.9%, 100–500 nm, Fig. 1a, the inset) was ball milled with 20 wt% binder (polyvinyl butyral PVB) for about 24 h. Approximately 0.5 g of the mixtures powder was pressed under 30 MPa into a pellet (10 mm diameter × 3 mm thickness) and then was sandwiched between two porous nickel foils to form as the anode. A graphite rod (12 mm diameter × 150 mm length) was employed as the cathode. The assembled anode and cathode were placed in an alumina crucible which contained molten $CaCl_2$ as electrolyte to form an electrolytic cell. During the electrochemical etching process, a constant voltage of 3.2 V was applied between the anode and the cathode at 900 °C in an argon atmosphere. After the electrochemical etching process, the etched samples were cooled to room temperature with the furnace in an argon atmosphere, and then the samples were retrieved from the solidified salt by washing with distilled water and dried in air.

* Corresponding authors at: State Key Laboratory of Advanced Special Steel & Shanghai Key Laboratory of Advanced Ferrometallurgy & School of Materials Science and Engineering, Shanghai University, Shanghai 200072, PR China.
E-mail addresses: xzou@utexas.edu (X. Zou), luxg@mail.shu.edu.cn (X. Lu).

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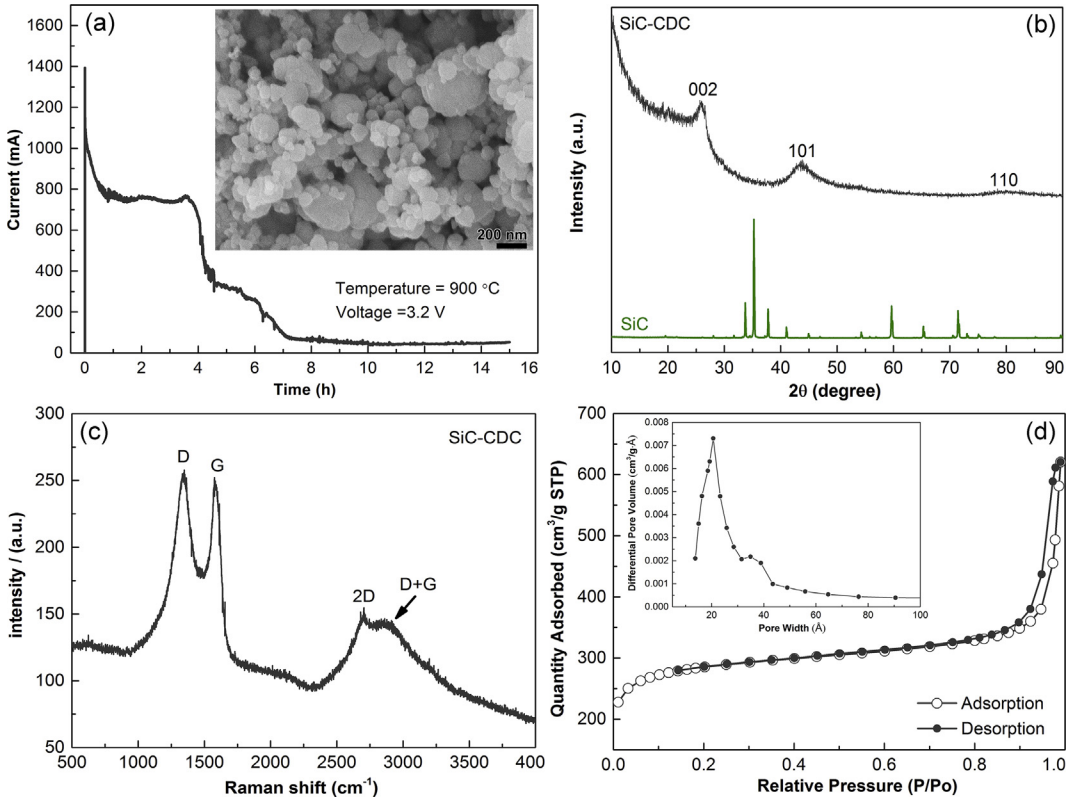

Fig. 1. (a) The current-time curve of the electro-etching process for SiC nanospheres powder precursor, the inserted SEM image is the SiC nanospheres; (b) XRD patterns of the SiC precursor and the obtained SiC-CDC products; (c) Raman spectrum of the SiC-CDC products; (d) N_2 adsorption isotherms and pore size distributions (the inset) of the SiC-CDC products.

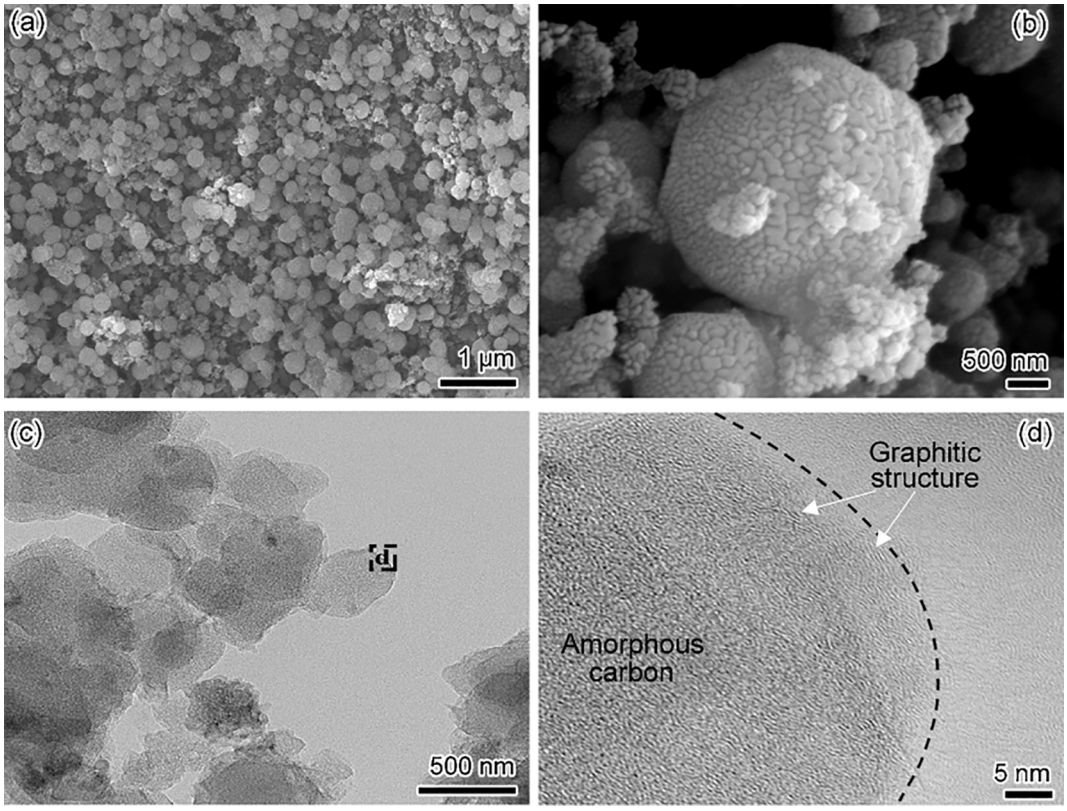

Fig. 2. (a) and (b) SEM images, (c) TEM image and (d) HR-TEM image of the SiC-CDC products.