Preparation of Bamboo-based Porous Carbons with Tunable Structure by Growing Carbon Nanofibers

Jiangnan Zhang, Ruitao Lv, Zheng-Hong Huang, Feiyu Kang and Zhengcao Li
Department of Material Science and Engineering, Tsinghua University, Beijing 100084, China

Abstract: The activated bamboo char (ABC) was available commercially and carbon nanofibers (CNF) were grown on its surface by a CVD method. The resultant composites were characterized by nitrogen method at 77K and scanning electron microscopy (SEM). The structure of bamboo-based porous carbon might be tunable by adjusting purposively the growth of CNFs. The CNF/ABC composite would combine the properties both of porous carbon and carbon nanofibers. The promising composites are expected to use as novel absorbent, electrode material and catalyst support.

Key words: Charcoal; Carbon nanofibers; Porous carbon

1. Introduction

The performance of carbon substrates modified with carbon nanofibers (CNFs) as both electrodes and catalyst supports can be remarkably improved by increasing surface areas and/or modifying surface morphologies. Previous work of other groups has reported the growth of CNFs on activated carbon fiber (ACF) （Lim *et al*, 2004; Tzeng *et al*, 2006） and activated carbon (Su *et al*, 2005) by CVD. The CNF/ACF composites can provide a free surface of CNF as well as microporous surface of ACF, which is favourable to the continuous H2SO4 recovery in DeSOx process (Lim *et al*, 2004).

In recent years, bamboo charcoal has attracted much attention in Asia due to its versatile applications. The present study tries to prepare a novel bamboo-based porous carbon with tunable structure by growing carbon nanofibers.

2. Experimental

Ferrocene (0.75 g) was dissolved in 50 ml ethanol, and then 2.00 g of dry activated bamboo char (ABC) available commercially was added to the above solution. After slurry was left overnight, the impregnated ABC was taken out and dried in an oven at 100□.

A prescribed amount of bamboo charcoal in a quartz boat was placed at the center of a quartz reactor heated by a conventional horizontal tube furnace. 0.20 g ferrocene was dissolved in 10 ml xylene to form a solution, and fed into CVD furnace by a syringe pump at a reaction temperature of 1093 K for 30 min. A mixture of Ar and H_2 was flowing through the system at 400 sccm and 60 sccm, respectively.

As-collected black products in the quartz boat were characterized by nitrogen method at 77K using a Micromeritics ASAP2010 system. The structure and morphology of the CNF were observed using scanning electron microscopy (JEOL JSM-6460 LV SEM).

3. Results and discussion

N2 adsorption/desorption isotherms of activated bamboo charcoal (ABC) and CNF/ABC composite were illustrated in Fig 1. ABC exhibits large amounts of adsorption at very low relative pressure resulting from the filling effect of micropores, whereas carbon nanofibers nested on the bamboo charcoal and blocked most of the charcoal's micropores, hence showing little adsorption. Table 1. lists the BET specific surface area, maximum pore volume. The ABC had a high surface area over 1000 m2/g, while CNF/ABC composite just showed a very small value of 5 m2/g. After the CNF growth, the surface area dramatically decreased that was ascribed to the blockage of micropores. This phenomenon similarly occurred in the report (Lim *et al*, 2004): the ACF in their study had a high surface area of 1014 m2/g, while showed a surface area of 150-220 m2/g after CNFs synthesis. Based on above analysis, we reason that the structure of bamboo-based porous carbon might be tunable if we adjust purposively the parameters of CNFs growth, such as deposition time, reaction temperature and amount of catalyst particles.

Table 1. Porosity of bamboo and composite

Sample	Specific surface area(m^2g^{-1})	Pore Volume (mlg^{-1})
ABC	1034	0.358
Composite	5	0.001

* Corresponding author.
E-mail address: zhhuang@tsinghua.edu.cn

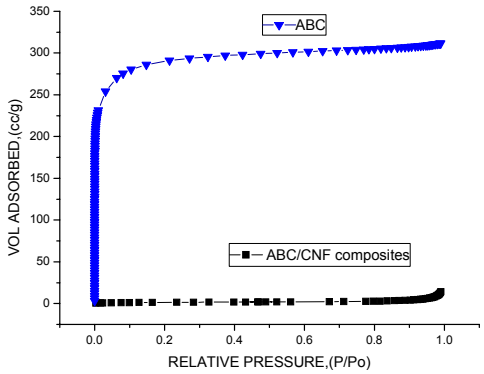

Fig 1. N2 adsorption/desorption isotherms of Bamboo/CNF composites and Bamboo

The micropores with radii of 0.6-2.0 nm in the activated bamboo charcoal appear to provide its most large surface area. The carbon nanofibers deposited on the bamboo charcoal and blocked most of the micropores, indicating that the catalyst particles were selectively nested in the pores of the bamboo charcoal. SEM observation (in Fig 2.) shows that more CNFs grew on the rough surfaces but few on the flatted surfaces. These CNFs were entangled like many nodes, the diameters being estimated from 80 to 200 nm. It was reported （Lim *et al*, 2004; Tzeng *et al*, 2006）that CNFs exhibited fishbone-type fibers or herringbone fibers regardless of what carbon substrate was and what CNF deposition condition was. The CNFs with a fishbone-type exhibit a large portion of open edges on the outer surface, which yields high chemical activity and could be beneficial to the applications in electrochemistry as electrodes for fuel cell or supercapacitor. The SEM image of composite in Fig 2.(a) reveals that the considerable roughness of the outer surface of the CNFs in the pore. Such a morphology is promising for reorganizing pore structure and pore surface of ABC.

4. Conclusions

The carbon nanofibers were grown on activated bamboo charcoal by using chemical vapor deposition with impregnated ferrocene catalyst precursor, leading to a decrease in the porosities of pristine bamboo charcoal. The structure of bamboo-based porous carbon might be tunable by adjusting purposively the growth of CNFs. The CNF/ABC composite would combine the properties both of porous carbon and carbon nanofibers, which is expected to use as novel absorbent, electrode material for supercapacitor.

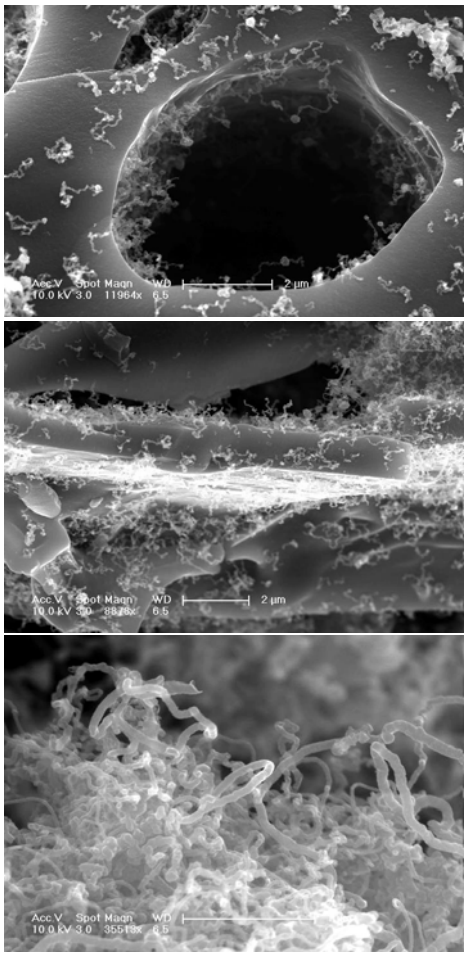

Fig 2. SEM images of CNF/ABC composites

Acknowledgements

The authors truly appreciate the National Natural Science Foundation of China for financial support under the Grant No.550672046.

References

Lim S, Yoon SH, Shimizu Y, Jung H and Mochida I. 2004. Surface Control of Activated Carbon Fiber by Growth of Carbon Nanofiber. Langmuir 20(13): 5559-5563.

Su DS, Chen X, Weinberg G, Klein-Hofmann A, Timpe O, Hamid SBA and Schlogl R. 2005. Hierarchically structured carbon: synthesis of carbon nanofibers nested inside or immobilized onto modified activated carbon. *Angew. Chem. Int. Ed.* 44:5488-5492.

Tzeng SS, Hung KH, Ko TH. 2006. Growth of carbon nanofibers on activated carbon fiber fabrics. Carbon 44:859-865.