GROWTH OF CARBON MICROCOILS ON CARBON FIBERS BY CATALYTIC CHEMICAL VAPOR DEPOSITION

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Introduction

Carbon microcoils as new carbon materials with special helix structures and unique properties would be well applied as electromagnetic wave absorbers, tunable microdevices and elastic filling in composites, etc[1,2]. Carbon microcoils are usually prepared by catalytic chemical vapor deposition with using metal foams or metal powders (Ni, Co, Fe) as catalysts and substrates [3~6]. Carbon nano fibers grown carbon fibers can be used to improve the interfacial structure of carbon fiber reinforced composites[7,8]. When the carbon microcoils were grown on carbon fibers, it should endow some novel performances to the carbon fibers/carbon microcoils reinfored composites. Therefore, it would be very meaningful to carry out investigation on growth of carbon microcoils on commercial carbon fibers. In the present work, carbon microcoils were grown on PAN-based carbon fibers by Ni-catalyzed pyrolysis of acetylene and their morphologies were examined.

Experimental

PAN-based carbon fibers were used as support for catalysts. Nickel nanoparticles were coated on the carbon fibers by homogeneous precipitation method followed by calcination at 400~420ºC in N_2 atmosphere for 3 hrs and hydrogen reduction at 450~460ºC in a vertical graphite furnace. Then, some of the as-obtained carbon fibers coated with nickel nanoparticles were set on a graphite crucible, which was located at the center part of the iso-thermal zone of the furnace. Commercial acetylene was used as carbon source for growth of carbon microcoils. A gas mixture of acetylene, hydrogen, nitrogen and thiophene in a proper ratio was introduced into the reactor. The used reaction conditions were as follows: reaction temperature 660~690ºC, total gas flow rate 3.0 l/min and reaction time 60min. The as-obtained carbon microcoils grown on carbon fibers were examined by field-emission scanning electron microscope without evaporating conductive layers prior to the investigation.

Results and Discussion

The PAN-based carbon fibers coated with nickel nanoparticles were shown in Fig.1. It was found that carbon fibers were nearly uniformly coated with nickel catalysts as shown in Fig.1a. The nickel catalysts consisted of many smaller nanoparticles. Carbon microcoils grown on the PAN-based carbon fibers were shown in Fig.2. Twisting single-helix microcoils and spring-like double-helix ones grew on the carbon fibers surface. The twisting single-helix microcoils irregularly grew along the surface of carbon fibers (shown by single white arrows in Fig.2a,b) and spring-like double-helix microcoils mostly grew along the radial direction of the carbon fibers (shown by double white arrows in Fig.2a,b). The average coil diameter of the spring-like double-helix coils is about 3-5 μm.

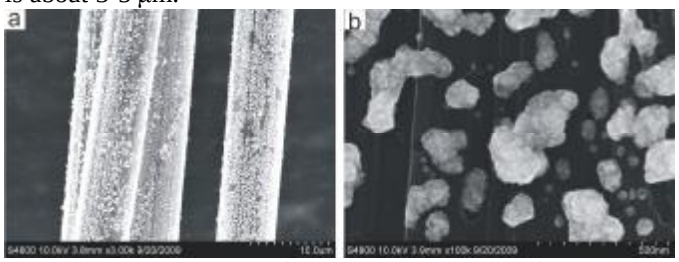

Fig.1 Morphology of Ni catalysts on carbon fibers.
(a) carbon fiber coated with Ni catalysts;
(b) The Ni nano-scale particles on the carbon fiber

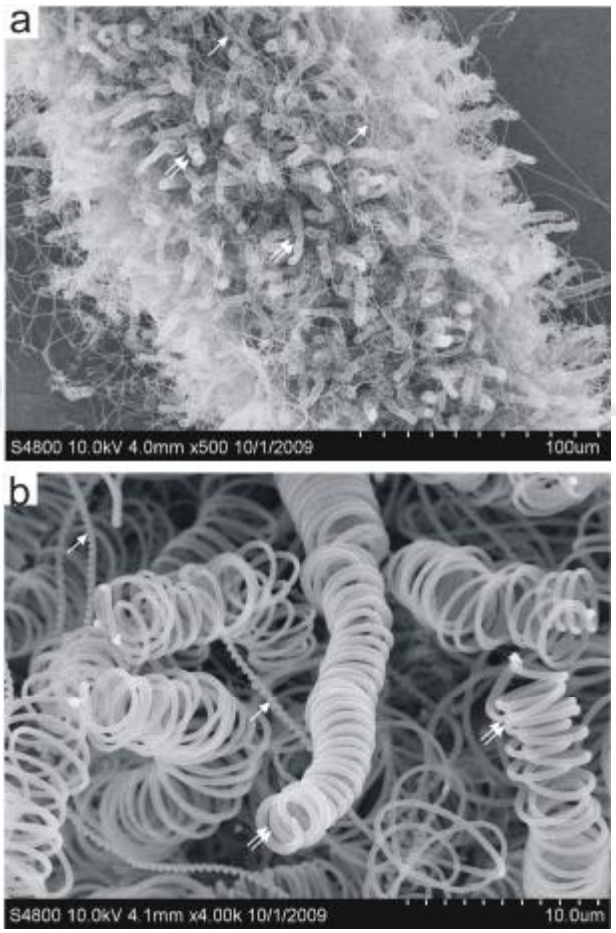

Fig.2 SEM images of carbon microcoils grown on PAN-based carbon fibers. (a) the overall morphology of a carbon fiber with carbon microcoils grown on; (b) magnified view of typical carbon microcils in (a). Noted: the white single arrows shows twisting single-helix coils and the white double ones shows spring-like double-helix microcoils.

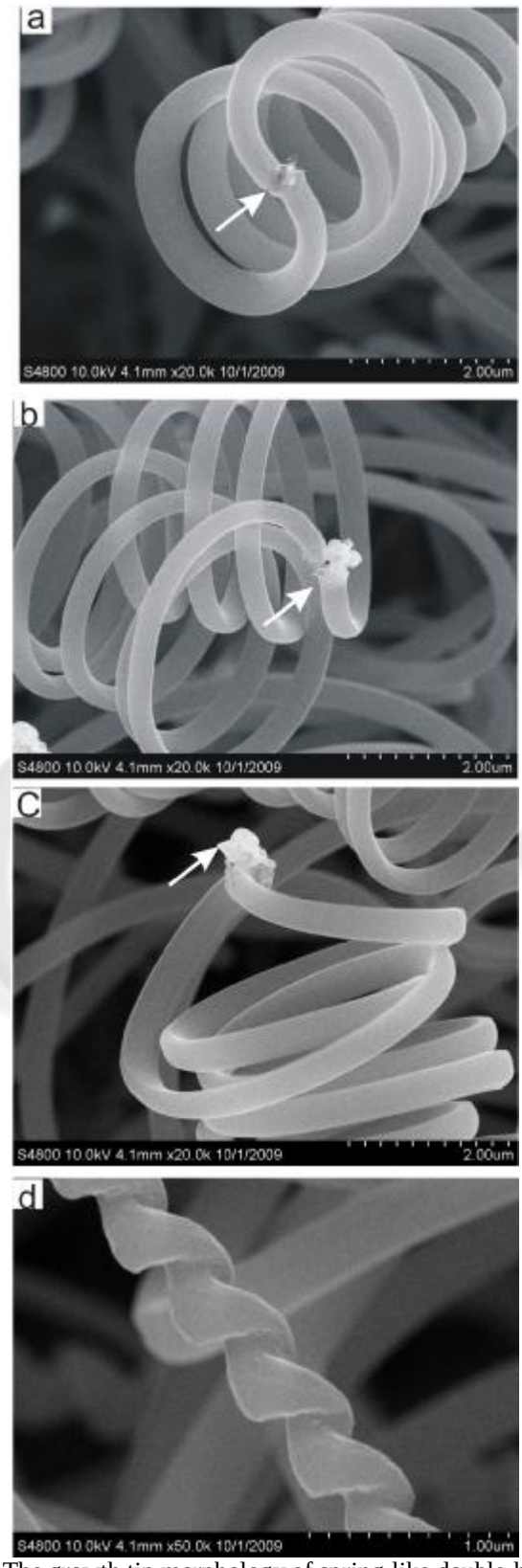

Fig.3 The growth tip morphology of spring-like double-helix microcoils (a,b and c) and morphology of twisting single-helix micocoils (d). The white arrows in (a), (b) and (c) indicate the nickel catalysts at the growth tip.

Fig.3 shows the growth tip morphology of spring-like double-helix microcoils (Fig.3a,b and c) and morphology of a typical twisting single-helix micocoils (Fig.3d). The morphologies of the growth tip of spring-like double-helix microcoils was different with the spiral degree and integrity of the two component fibers. The catalysts at the growth tip were in the shapes of polyhedral, which leads to catalytic anisotropy and forcing the coiling of the grown carbon fibers (as shown in Fig.3a,b and c). The average diameter of the component fibers of the spring-like double-helix microcoils is about 200 nm. The average diamter of the twisting single-helix microcoils is about 300nm and its coil pitch is about 600nm(Fig.3d).

Conclusions

Carbon microcoils were sucessfully grown on PAN-based carbon fibers by catalytic chemical vapor deposition with nickel nanoparticles as catalysts. Twisting single-helix carbon microcoils and spring-like double-helix carbon microcoils could be grown at the same time under the present parameters of catalytic chemical vapor deposition processing. The twisting single-helix microcoils irregularly grew along the surface of carbon fibers and spring-like double-helix microcoils mostly grew along the radial direction of the carbon fibers.

Acknowledgment The authors gratefully acknowledge the financial support of the present work by the "973" Project (2006CB600905), the Open Project Program of Low Dimensional Materials & Application Technology (Xiangtan University), Ministry of Education, China (No.KF0601) and the Open Project of the Key Laboratory of Nondestructive Test (Ministry of Education) (No. ZD200729010).

References

[1] Xiuqin Chen, T Saito, M.Kusunoki and S.Motojima. Three-dimensional vapor growth mechanism of carbon microcoils. J Mater Res 1999; 14(11):4329-4336.

[2]Yunfang Liu and Zengmin Shen. Preparation of carbon microcoils and nanocoils using activated carbon nanotubes as catalyst support. Carbon 2005;43:1574-1577.

[3] K Mukhopadhyay, K Ram, D Lal, G Narayan Mathur and KU Bhasker Rao. Double helical carbon microcoiled fibers synthesis by CCVD method. Carbon 2005;43:2400-2402.

[4] Yong Chen, Chang Liu, Jin-hong Du and Hui-ming Cheng. Preparation of carbon microcoils by catalytic deposition of acetylene using nickel foam as both catalyst and substrate. Carbon 2005;43:1874-1878.

[5] Motojima S, Asakura S, Hirata M, Iwanaga H. Effect of metal impurities on the growth of micro-coiled carbon fibers by pyrolysis of acetylene. Mater Sci Eng B 1995;34:9 – 11.

[6] Yang S, Chen X and Motojima S. Morphology of the growth tip of carbon microcoils/nanocoils. Diamond & Related Materials 2004; (13): 2152– 2155.

[7] Hammel E, Tang X, Trampert M, Schmitt T,.Mauthner K, Eder A, Potschke P. Carbon nanofibers for composite applications. Carbon,2004; (42):1153-1158.

[8] Dongbo Zhu, Tengfei Chen, Lei Liu and Kechao Zhou. Preparation and microstructural investigation on carbon fibers/carbon nanofibers reinforced carbon composites by chemical vapor infiltration. Carbon 2010 confernce , USA, Clemson University. I.D.460.