EFFECTS OF SEVERAL FACTORS ON MORPHOLOGY AND MICROSTRUCTURE OF CARBON FILMS FORMED ON STAINLESS STEEL SUBSTRATES BY DC ARC DISCHARGE

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Introduction

The carbon film is one of the important carbon materials, including diamond [1], carbon nanotube [2], grapheme [3] films, etc.. They have attracted much attention due to their excellent electrical, optical and adsorbent properties, and been widely exploited for applications such as sensors, different cells or batteries, electron field emitters, electron devices, nonlinear optical wafer, etc.. Except the traditional methods, such as chemical vapor deposition, arc discharge, laser ablation, magnetron or ion sputtering, electrodeposition, etc., several new methods to prepare the carbon films have been reported recently [4-6]. In this work, we investigate the effects of several factors, such as carbon source, nitrogen temperature, and substrate position, on the morphology and microstructure of carbon films formed on the stainless steel substrates (SSS) by DC arc discharge.

Experimental

The similar DC arc discharge apparatus was described elsewhere [7]. The key differences between ours and those reported in the Ref. [7] are that in our experiment, the nitrogen (purity >99.9 volume %, 50 sccm flow rate) can be firstly heated to 800 ℃ before it flows into the chamber, and the SSS (ca. 10 mm length, 5 mm width and 0.5 mm thickness) is put above or at one side or under the DC arc discharge region (ADR). The distance between the SSS and the centre of the ADR is about 15 mm. The cathode was a pure graphite rod (15 mm diameter, 15 mm length). The anode was a graphite rod (6 mm diameter) in which a hole (ca. 4 mm diameter, 30 mm depth) was drilled and filled with a mixture of Fe_2O_3, Co_2O_3, NiO (the purities of all the three transition metal oxides >99 weight %), and carbon black or graphite powder (both of the purities >99.99 weight %). Each of the Fe, Co, and Ni elements was 1.5 weight % in the mixture. The gap between the graphite electrodes was kept to be constant in the range of 0.5–1 mm by manually advancing the consumed anode. The DC arc discharge voltage and current varied between 30–32 V and 25–30 A, respectively. The DC arc discharge time was 1 min. After the DC arc discharge was finished, the carbon film was formed on the SSS.

The observation of the surface morphology of the carbon film was carried out by scanning electron microscope (SEM, Philips, XL-30).

Results and Discussion

Fig. 1is the SEM images of the carbon films obtained at different temperatures of nitrogen, with the carbon black and graphite as carbon source, respectively. Fig. 1a shows the typical morphology of the quasi-3D netlike structure consisting of the similar-1D species and nanoparticles. By comparing Fig. 1a with Fig. 1c and Fig. 1b with Fig. 1d, respectively, it is known that the quasi-3D netlike structure will be more obvious, when the carbon black is used as the carbon source. By comparing Fig. 1a with Fig. 1b and Fig. 1c with Fig. 1d, respectively, it is known that the quasi-3D netlike structure will be more obvious, when the nitrogen temperature is 800 ℃. As the SSS was put above the ADR, the effect of gravity on the morphology of the film formed was minor.

Fig. 2 is the SEM images of the carbon films obtained when the SSS was put at one side or under the ADR, with the carbon black and graphite as carbon source, respectively. By comparing Fig. 2a and 2b with Fig. 1b, it is known that the quasi-3D netlike structure would be more obvious, when the SSS was put under the ADR. By comparing Fig. 2c and 2d with Fig. 1d, it is known that the quasi-3D netlike structure would be more obvious, when the SSS was put at one side of the ADR. When the nitrogen temperature was room one, the differences among the morphology of the films formed on the SSS put at different positions around the ADR were not so obvious (Figures omitted). The formation mechanism of quasi-3D netlike structure may be explained by the self-assembly of carbon nanoparticles [8].

Conclusions

The carbon film of quasi-3D netlike structure can be prepared on the SSS by DC arc discharge under nitrogen atmosphere, especially at 800 ℃. The carbon source, nitrogen temperature, and SSS position, have the remarkable effects on the morphology and microstructure of carbon films formed.

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References

[1] Shi B, Jin QL, Chen LH, et al., Diam Relat Mater 2009;18(2-3):596-600.
[2] Lu M, Jang MW, Haugstad G, et al.. Appl Phys Lett 2009;94(26): 261903.
[3] Kim KS, Zhao Y, Jang H, et al.. Nature 2009;457(7230):706-710.
[4] Szot K, Lesniewski A, Niedziolka J, et al.. J Electroanal Chem 2008;623(2):170-176.
[5] Svegl IG, Bele M, Ogorevc B. Anal Chim Acta 2008;628(2):173-180.
[6] Hunter CN, Check MH, Bultman JE, et al.. Surf Coat Tech 2008; 203(3-4):300-306.
[7] Cui S, Scharff P, Siegmund C, et al.. Carbon 2004;42(5-6):931-939.
[8] Cole J J, Lin EC, Barry CR, et al.. Appl Phys Lett 2009;95(11): 113101.

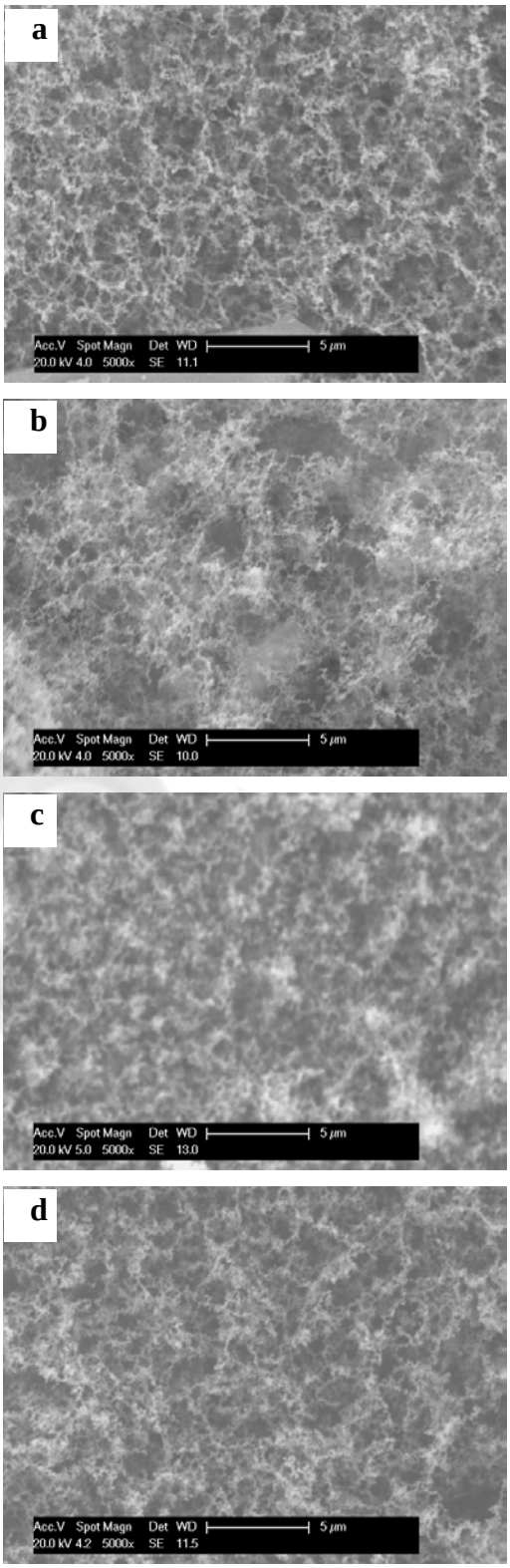

Fig. 1 SEM images of the carbon films obtained at (a) and (c) room temperature, (b) and (d) 800 ℃of nitrogen, with the carbon black ((a) and (b)) and graphite ((c) and (d)) as carbon source, respectively. The SSS was put above the ADR.

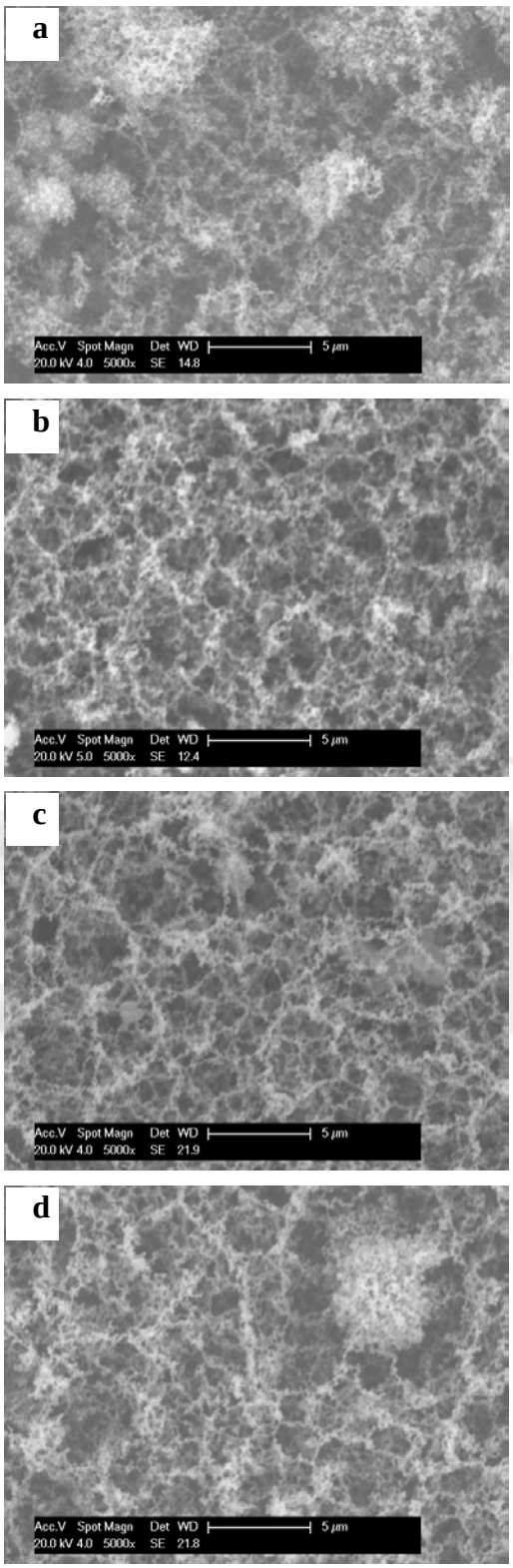

Fig. 2 SEM images of the carbon films obtained when the SSS was put at one side ((a) and (c)) of or under ((b) and (d)) the ADR, with the carbon black ((a) and (b)) and graphite ((c) and (d)) as carbon source, respectively. The nitrogen temperature was 800 ℃.