Effect of the supporting substrate on the production yield for geometrically controlled carbon coils

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1. **Abstract:** Carbon coils could be synthesized using C_2H_2/H_2 as source gases and SF_6 as an incorporated additive gas under thermal chemical vapor deposition system. Prior to the carbon coils deposition reaction, two kinds of samples having different combination of Ni catalyst and substrate were employed, namely a commercially-made Al_2O_3 ceramic boat with Ni powders and a commercially-made Al_2O_3 substrate with Ni layer. By using a commercially-made Al_2O_3 ceramic boat, the production yield of carbon coils could be enhanced as much as 10 times higher than that of Al_2O_3 substrate. Furthermore, the dominant formation of the microsized carbon coils could be obtained by using Al_2O_3 ceramic boat.

1. Introduction

Due to their unique geometry and the chirality, carbon coils have been attracted as the high potential materials for nanoengineering [1-4]. Furthermore, carbon coils was supposed to have unique electrical and optical properties that could be used in nanoelectronics [5-8].

For the practical application of carbon coils, however, it is essential to achieve the large quantity production of carbon coils because carbon coils have been usually found as the low-content by products for the synthesis of multiwalled carbon nanotubes in microwave plasma-enhanced chemical vapor deposition (MW-PECVD) or in thermal chemical vapor deposition (TCVD) [9,10]. Recently, catalytic chemical vapor deposition (CCVD) method has been noticed to enhance the production yield of carbon coils because of its relative inexpensive and applicable feature. Besides the system parameters for CCVD such as the reaction temperature and the gas flow rate, the used metal catalyst, the incorporated additives, and the supported substrate are the important factors for the large quantity production of carbon coils. For the metal catalyst, iron family (Fe, Co, Ni), especially Ni, were known as an effective catalyst for the formation of carbon coils [11, 12]. For the incorporated additives, meanwhile, a trace of the sulfur-related species was regarded as the promising additives for the formation of carbon coils [13-15]. Despite many efforts to enhance the production yield of carbon coils, the reports regarding the supporting substrate effect on the formation of carbon coils are few up to the present.

This work presents the enhancement of carbon coils production yield by using Al_2O_3 ceramic boat as a substrate and Ni powders as a catalyst. SF_6 was also added in the source gases to take an advantage for sulfur and fluorine species properties which can enhance the formation of carbon coils [16]. To avoid the highly hazardous problem to the health and environment, the amount of sulfur incorporated chemical species used, namely SF_6 in this work, was minimized by reducing the SF_6 injection time down to 5minutes during the initial reaction stage. By using Ni powders and Al_2O_3 ceramic boat, the geometry control as well as the enhancement of the production yield for microsized carbon coils could be achieved. According to the different supporting substrates and catalysts, the characteristics of the as-grown carbon coils, namely the formation density and the geometry, were examined and discussed.

2. 2. Results and Discussion

Carbon coils syntheses were simultaneously carried out on both Ni powders-boat (Ni powders spreading on Al_2O_3ceramicboat) and Ni layer-substrate (Ni layering on Al_2O_3 substrate). Figure 1 shows the photographs of as-grown carbon coils on the boat (Fig. 1a) and the gathered carbon materials form the boat (Fig. 1b). As a naked eye, a lot of carbon materials seemed to be formed on the boat. The density of the deposited carbon materials were about 0.5g/cm^2 for Ni powders-boat. Microscopically images for the as-grown carbon materials were also investigated using FESEM. Fig.2 shows FESEM image showing the formation of carbon coils on Ni powders-boat. For Ni powders-boat case, the formation of microsized carbon coils with various-sized diameters could be observed as shown in Fig.2b. It is understood that the geometry control to the micro-sized one could be possible merely via Ni powders-boat usage. The cause for this result was understood that the surface roughness of Ni powders-boat may be much higher than that of Ni layer-substrate. Because higher surface roughness seems to provoke the interaction between as-growing carbon elements, they may enhance more active sites for the initiation of microsized carbon coils. Consequently, the higher surface roughness of the boat seems to produce the dominant formation of microsized carbon coils.

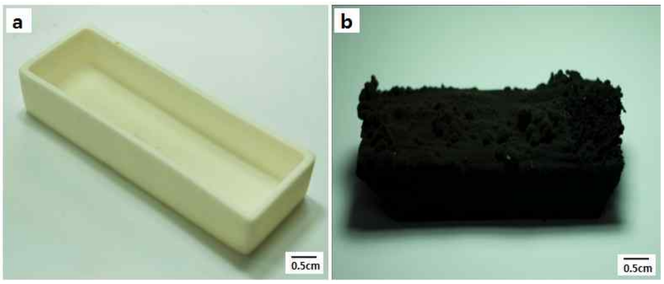

Fig. 1. Photographs of (a) Al_2O_3 ceramic boat and (b) as-grown carbon materials on Al_2O_3 substrate.

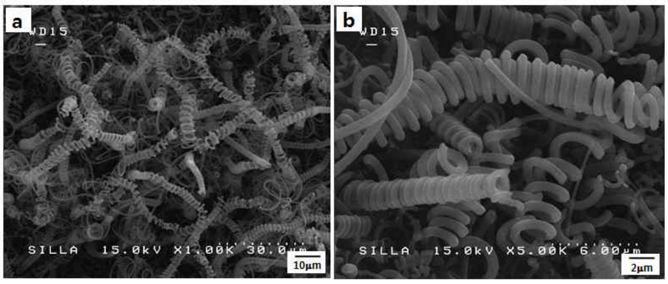

Fig. 2 FESEM image showing (a) the formation of carbon coils on Al_2O_3 ceramic boat and (b) the magnified image of Fig. 2a.

3. Conclusions

Large quantity production of carbon coils could be possible simply by Al_2O_3 ceramic boat usage. Using Al_2O_3 ceramic boat, furthermore, the formation of micro-sized carbon coils could be dominantly achieved. So, the geometry control of carbon coils to the micro-sized one could be possible. The higher surface roughness of the boat seems to be the main cause for the dominant formation of the microsized carbon coils.

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