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Growth of carbon nanostructures upon stainless steel and brass by thermal chemical vapor deposition method

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ABSTRACT

The lack of complete understanding of the substrate effects on carbon nanotubes (CNTs) growth poses a lot of technical challenges. Here, we report tbe direct growth of nanostructures such as the CNTs on stainless steel 304 and brass substrates using thermal chemical vapor deposition (TCVD) process with C_2H_2 gas as carbon source and hydrogen as supporting gas mixed in Ar gas flow. We used an especial etching of substrates. The catalysts consist of a thin layer of Cu deposited on substrates. Morphology and structural information about prepared CNTs were provided by scanning electron microscopy (SEM). Results showed that some nanostructures such as single and multi walled carbon nanotubes (SWCNTs and MWCNTs), bundle (70-80 nm), nano wire (80-100 nm) and amorphous carbon were formed on stainless steel 304 as substrate. Moreover, different kind of carbon nanotubes such as MWCNTs (30-50 nm), nano crystalline diamond (10-30 nm), amorphous carbon, roped (70-80 nm) structures with different sizes grew on the brass substrate as well. In conclusion, we suggest that stainless steel 304 and brass can be replaced with Si/SiO_2 as substrate in practical applications.

Keywords: Multi walled carbon nanotube; Thermal chemical vapor deposition; Stainless steel 304; Brass

INTRODUCTION

High yield CNTs synthesis is desired for many composite materials and mechanical applications due to their high strength and light weight [1-3], that also have very promising applications in electronics, such as super-capacitor electrodes [2, 4].

Various methods have been used to grow both SWCNTs and MWCNTs, in clouding arc-discharge [5, 6], laser vaporization [7], and CVD [8]. The CVD method has many advantages over other methods, since the CNTs can be synthesized with bigh purity and yield, selective growth and well-alignment [9, 10].

TCVD is preferred due to its simplicity and low cost production of nanomaterials for future industrial applications [11]. However, most of these studies are based on an empirical optimization of growth conditions and a systematic investigation is still needed for a better understanding about the effect of different experimental parameters (e.g. substrate, catalyst and gas composition) on the extended of growing [12]. Among the growth methods, TCVD allows the production of CNTs film vertically aligned on predeposited catalyst pads on large scale and good uniformity. In general the synthesis of aligned CNTs via TCVD is based on the decomposition of hydrocarbon gas molecules (CH_4, C_2H_2, CF_4, ...), at relatively low temperatures (500-1000 °C), on the surfaces catalyzed by transition metals, like Fe, Ni, Co and Cu followed by bulk or surface diffusion of carbon on the catalyst particles [13, 14]. Many researchers have also found that the substrate could affect the growth of CNTs in TCVD process [15-18].

In the present study, we try to grow the carbon nanostructures such as MWCNTs, nanofibers, nano

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crystalline diamond on the stainless steel 304 and brass as substrates by TCVD method.

EXPERIMENTAL

Substrate preparation

Stainless steel 304 and brass plates were prepared into 20 × 25 mm^2 rectangular pieces and used as substrates for growing CNTs. Polishing of substrates was done mechanically with sandpaper in order to remove contaminants and stains of the surface.

By emission spectroscopy (ARL 3460/451) image, the elementary analysis of stainless steel 304 as Fe alloy and brass as Cu alloy can be achieved. The results are shown in Table 1.

Table 1. Elementary analysis of Stainless Steel 304 and Brass by emission spectroscopy method

Stainless Steel 304		Brass	
Component	Percentage	Component	Percentage
C	0.014	Pb	0.018
P	0.027	Fe	0.029
Mn	1.394	Ni	0.058
Ni	7.951	Al	0.001
Cr	18.174	P	0.002
Mo	0.235	Si	0.001
Sn	0.011	Zn	32.378
Co	0.163	Sn	0.001
Al	0.011	Mn	0.003
B	0.000	Bi	0.001
Si	0.491	As	0.002
S	0.007	Cu	67.51
Nb	0.005		
Fe	71.10		
V	0.069		
Cu	0.278		
W	0.067		
Ti	0.006		

Substrate activation

All of prepared substrates were cleaned under ultrasonic irradiation in three-consecutive steps by deionized water, ethanol and acetone for 10 minutes that followed by rinsing with deionized water.

Substrate etching

Prepared stainless steel 304 were etched by fresh etchant of 15 ml HNO_3 (64%), 15 ml HCl (37%) and 7 ml CH_3OH (99%). It was immersed in the etchant up to 40 seconds. The etchant of 50 ml H_2O and 50 ml HNO_3 (64%) was used for etching of the brass samples up to 5 seconds. HNO_3, HCl and CH_3OH were purchased from Merck's company and use without further purification.

Substrate Sputtering

A thin film of Cu as catalyst was deposited on the prepared stainless steel 304 and brass as substrates. All deposition was performed by a DC magnetron sputtering system under 4×10^{-2} Torr pressure at room temperature for 15 second.

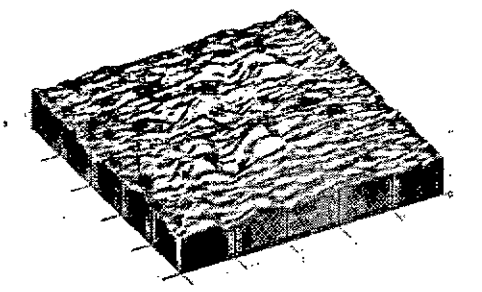
TCVD method

After Cu deposition, the samples were placed on a ceramic boat and loaded into a quartz tube of 100 mm inner diameter with heating furnace at atmospheric pressure. Temperature of the samples was ramped up to 150 °C for 15 min with a flow of Argon gas (80 sccm) for 10 min, then from 150 °C to 350 °C with mixed flow Argon gas (80 sccm) and H_2 (20 sccm) for 20 min. After stabilizing the temperature at 350 °C for 30 min, then, the furnace temperature was reramped to 550 °C with a flow of Argon gas (80 sccm) and H_2 (20 sccm) for 30 min. After stabilizing the temperature at 550 °C, C_2H_2 gas (20 sccm) was introduced into the quartz tube for 45 min for CNTs growth. Finally, Argon gas (80 sccm) was introduced to cool the samples to the room temperature.

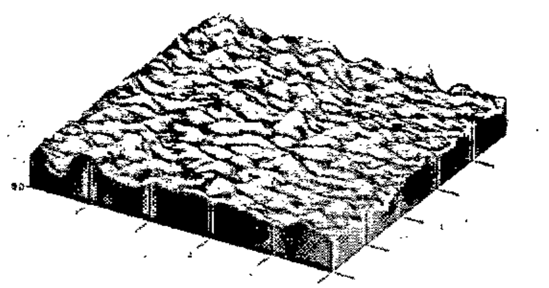
The morphology and structure of the as-prepared samples were examined by SEM (Philips XL30).

RESULTS AND DISCUSSIONS

Fig. 1 The AFM images show 3D projection of two substrates surfaces after sputtered nano thin layer of Cu on stainless steel 304 (Fig. 1a) with 19.6Å roughness and brass alloy (Fig. 1b) with 6.27Å roughness.

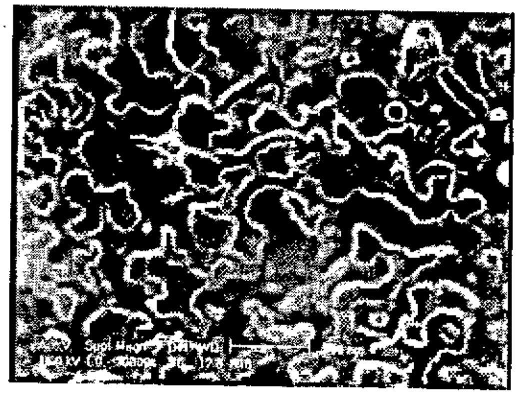


a



b

Fig. 1. 3D projections of stainless steel 304/Cu (a) and brass/Cu substrate (b) after sputtering.



a

b

Fig. 2. SEM images of grew carbon nanostructures: (a) on the stainless steel 304/Cu, (b) on the brass/Cu substrate.

Fig. 2 represents the SEM photographs of carbon nanostructures grew on the stainless steel 304 and brass substrates. Fig. 2 (a) shows some nanostructures such as MWCNTs, SWCNTs, bundle, nano wire and amorphous carbon that formed on stainless steel 304 as substrate. The diameters of MWCNTs are about 30-50 nm and SWCNTs are about10-20 nm. Fig. 2 (b) reveals that different kind of CNTs such as MWCNTs (30-50 nm), nano crystalline diamond (10-30 nm), amorphous carbon, roped (70-80 nm) structures with different sizes have grown on brass substrate. Alternatively we an conclude that the yield and length of nanotubes in surface of the brass substrate are more than those in surface of the stainless steel 304 substrate. However, the variety of nanostructures appeared in the surface of stainless steel is more than those of brass substrate.

It seems, the above different behavior comes from may be due to the kind of the substrates (stainless steel 304 and/or brass), and also, from etching effect and interaction between substrate and catalyst (Cu). Ward et al. Indicated that the ideal substrate for SWNT growth is a spun-on alumina film, while, single crystal substrates promoted the growth of mixed SWNTs and MWNTs [19]. On the other hand, some previous reports have been shown that etching time and species have important roles in some growth characteristics of CNTs such as density (yield) and diameters [20, 21].

CONCLUSION

Carbon nanostructures were synthesized from acetylene and hydrogen directly on the prepared stainless steel 304 and brass substrates by TCVD method. It was found that pretreatment of the substrate surface is very important for successful nanostructures synthesis. We observed different kind of morphologies and nanostructures, with different yield and length of CNTs using SEM. SEM observations conformed that there are a very kind of nanostructures on to these substrates but not the same. In addition CNTs yields and lengths respect to two these substrates. It seems that the stainless steel 304 substrate is better than the brass substrate for growing the nanostructures. Never the less, we suggest that Si/SiO_2 can be replaced with stainless steel 304 and brass as substrate in practical applications.

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