Solid State Science and Technology, Vol. 15, No 1 (2007) 22-29
ISSN 0128-7389

CATALYTIC EFFECT OF FORMATION OF A WEB-LIKE CARBON NANOSTRUCTURES

Noorhana Yahya[1,2], Beh Hoe Guan[1] and Lim Kean Pah[1]

[1]*Department of Physics,*
Faculty of Science,
Universiti Putra Malaysia,
43400 UPM Serdang, Malaysia.

[2]*Advanced Materials Laboratory,*
Institute of Advanced Technology,
Universiti Putra Malaysia
43400 UPM Serdang, Malaysia.

ABSTRACT

Carbon nanotubes have small dimensions, high strength and the remarkable physical and electrical properties. These make them very unique materials with a whole range of promising applications. Carbon nanotubes were formed by laser ablation using a graphite target containing Ni and Co catalysts, each with weight percentage of 10%. The Nd:YAG laser with 532 nm wavelength, 10.54 W power was used to ablate the target to form the carbon nanotubes. The pressure inside the chamber was kept at 4 Torr. Web-liked carbon nanotubes were formed on the substrate after 30 minutes of laser ablation. The SEM images showed that the diameter of the carbon nanotubes formed using Ni and Co catalysts were between 50-150 nm in size.

INTRODUCTION

Carbon nanotubes (CNTs) were first identified in 1991 by Japanese scientist Sumio Iijima [7]. Their discovery have attracted a great deal of interest from the research community [1] since they exhibit unique and useful chemical and physical properties, and many scientific articles and books have been devoted to their synthesis, properties and applications. These properties include remarkable mechanical [10], electrical and thermal properties [11] with extremely small sizes, high conductivity, high mechanical strength and flexibility.

Carbon nanotubes are usually formed by arc discharge [8], Chemical Vapor Deposition [9] or laser ablation using carbon that contains a small quantity of metal catalysts. Laser ablation was considered as one of the most promising techniques due to the relatively clean and ordered CNT growth by this method [15]

So far, there has been much research on this process. Scott et al. reported the growth mechanism for SWNTs using spectral emission and laser-induced fluorescence measurement of plasma plume from a composite carbon target [12]. Yudasaka et al. studied Raman spectra of SWNTs grown by laser ablation at different ambient gas pressures [13]. Recently [14] reported that SWNTs can be produced in nitrogen ambient. In this work, graphite containing nickel (Ni) and cobalt (Co) metal catalyst were in each case used as a target, where the graphite pellet with some metal catalysts absorbs the laser beam, heat up and transforms into molten C. When the particles in the target gain heat from the laser and form a solution with the molten C. Droplets of the molten C containing Ni and Co were expelled from the target and deposited to the substrate. The results of CNTs grown via each of the catalyst compared.

EXPERIMENTAL SETUP

An Nd:YAG laser with a laser wavelength of 532 nm and output power of 10.54 W was used as an evaporation source. Vacuum chamber was used in the process laser ablation for vacuum capability environment for the formation of CNTs. It had cylindrical shape, a diameter of about 15 cm and length of 45 cm (Figure 1).

A stainless steel target holder with the target was placed at the center of the chamber and the target was compressed powder diameter, 12 mm; height, 2.5 mm that was a mixture of graphite, Ni, and Co particles. The weight percentages of C, Co and Ni in the graphite-Co and graphite-Ni target are listed at table 1. Motor was embedded at the target holder to rotate the target during the deposition and the quartz glass was used as a substrate and pasted at the substrate holder by silver paste (Figure 2).

A rotary pump was used to pump out the unwanted particle and an argon gas flowed through the chamber at 250mL/min by using LV 10K fine control needle valve and the pressure inside the chamber was kept at 4 Torr. The whole ablation process in each case was done for 30 min

Table 1: Weight of the graphite/Ni/Co powders used in preparation

Samples	Graphite (g)	Nickel (g)	Cobalt (g)
Graphite-Co	0.45	-	0.05
Graphite-Ni	0.45	0.05	-

Figure 1: Vacuum chamber

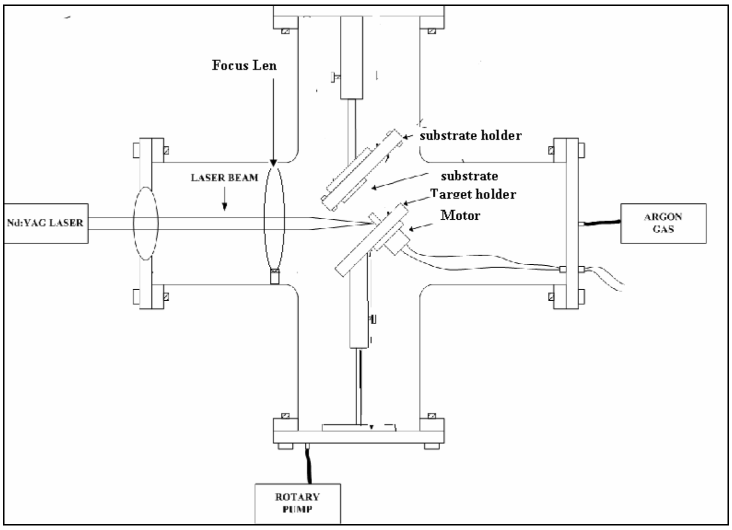

Figure 2: A schematic illustration of pulsed laser deposition system

RESULTS AND DISCUSSION

The spectrum of the deposited sample collected from substrate during the PLAD process by using the graphite-Ni pellet reveals two weak diffraction peaks (Figure 3). The first peak located at 26.48^o corresponds to (002) graphite phase [2] and the second peak located at 44.31^o corresponds to (011) Ni phase. The CNTs peak in the diffraction patterns deposited on the glass substrate is broad as a result of a random orientation of the CNTs and nano-size particles was deposited on the glass substrate. Figure 4 shows

Solid State Science and Technology, Vol. 15, No 1 (2007) 22-29
ISSN 0128-7389

the XRD profile of the CNTs deposited on the glass substrate collected from the PLAD process by using the graphite-Co pellet. The spectrum reveal extremely broad diffraction peak located at 22.52^o corresponds to CNTs phase [3].

Having closer look at Figure 3 and Figure 4 it is obvious that the deposited sample that was filled with Ni catalyst depicted higher counts/s for the CNTs peak. There is no sharp peak correspond to the Co phase. It was reported that the crystallographic orientation of Co on graphite was unstable after ablation process [4], consequently no Co peak was not found at the sample collected after laser ablation.

The deposition of the CNTs with Ni catalyst was more disordered comparing to the deposition of CNTs with Co catalyst. The Ni particles as effective catalyst to enhanced the rapid growth of the tubes during the ablation process. The growth rate is so rapid that it did not have the time to self organize in such a way that the deposition is in disordered manner. The broader CNTs spectrum with higher intensity is a result of the catalytic growth [5].

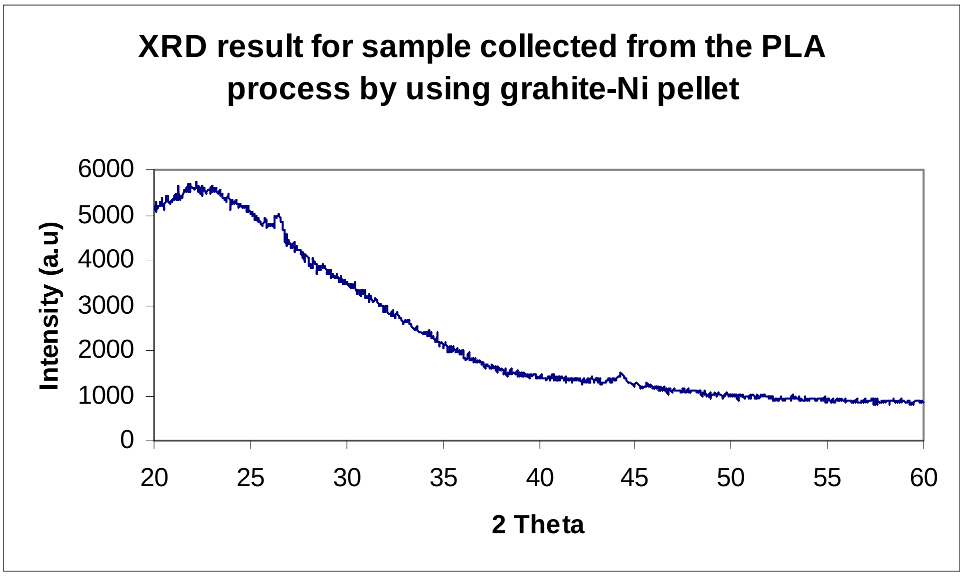

Figure 3: XRD profiles of the CNTs deposited on the glass substrate collected from the PLAD process by using the graphite-Ni pellet.

Solid State Science and Technology, Vol. 15, No 1 (2007) 22-29
ISSN 0128-7389

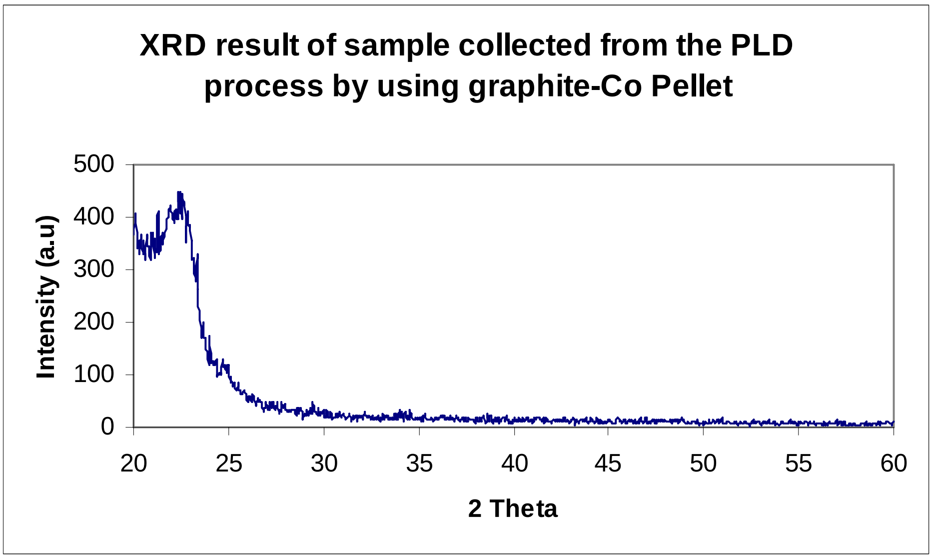

Figure 4: XRD profiles of the CNTs deposited on the glass substrate collected from the PLAD process by using the graphite-Co pellet.

Figure 5 shows a large quantity of web-liked carbon materials are deposited on the surface of substrate collected from the PLAD process by using the graphite-Ni pellet. The diameter of the web liked carbon materials was found between 50nm-100nm.

EDX result of the tube in the web-liked carbon materials (Figure 6) shows the peak of Ni, give us strong evident that Ni catalyst were expelled from the target and effectively works as the catalyst to enhance the growth of the CNTs. It is indicated the Ni decreased the total energy for the graphite to change from the solid phase to gas phase, when the laser irradiated the target surface. On the other hand, Ni in the web-liked carbon materials had diameter size in nm, which indicated the Ni had a small diameter enough to play its role in the growth of CNT in the substrate.

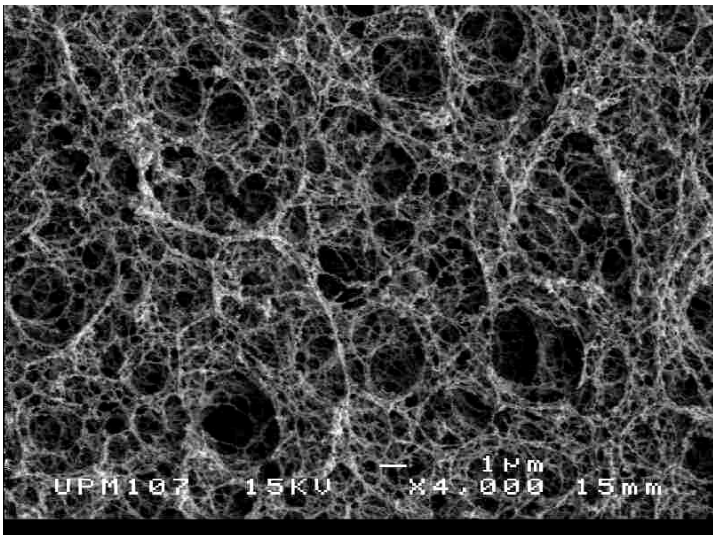

Figure 5: SEM image of sample collected from the PLAD process by using graphite-Ni pellet.

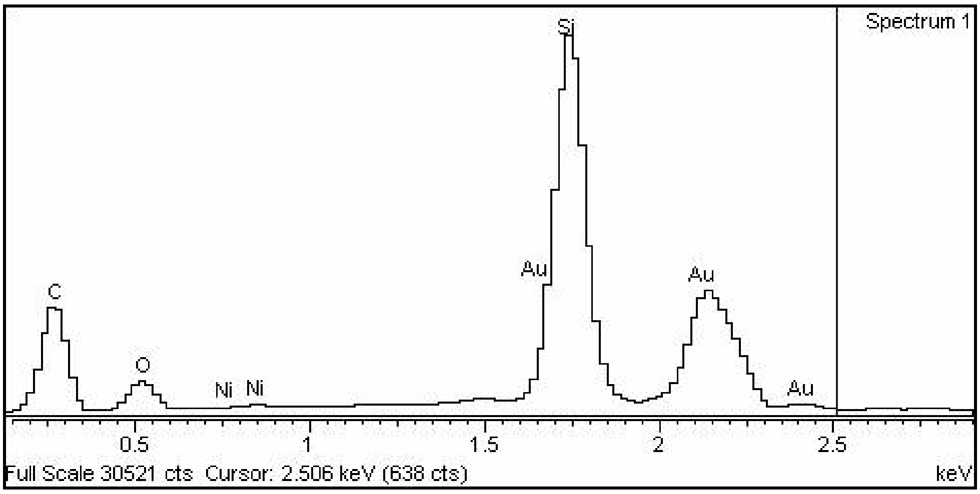

Figure 6: EDX profile for the sample collected from the PLAD process by using graphite-Ni pellet.

The surface morphology for the deposited sample collected from the PLAD process by using graphite-Co pellet is shown in Figure 7. Large quantities of web-liked materials on the surface of substrate are observed. The microstructure of the sample exhibits a very small size of diameter of the web-liked material, ranging from 50nm-150nm. We speculate multi wall carbon nanotubes were formed.

The EDX profiles (Figure 8) gives us strong evident that Co catalyst were expelled from the target and effectively works as the catalyst to enhance the growth of the CNTs. Higher weight % of the Co concentrated in the deposited sample and a small yield of

Solid State Science and Technology, Vol. 15, No 1 (2007) 22-29
ISSN 0128-7389

CNTs compared with the Ni (0.08 wt%) with the higher yield of CNTs indicated that the Co was not an effective catalyst for the growth of CNTs. It was reported that the low dissolution rate of Co in C and the poor activity of Co as a graphitization catalyst compare with the Ni, account for the extremely small yield of CNTs [6].

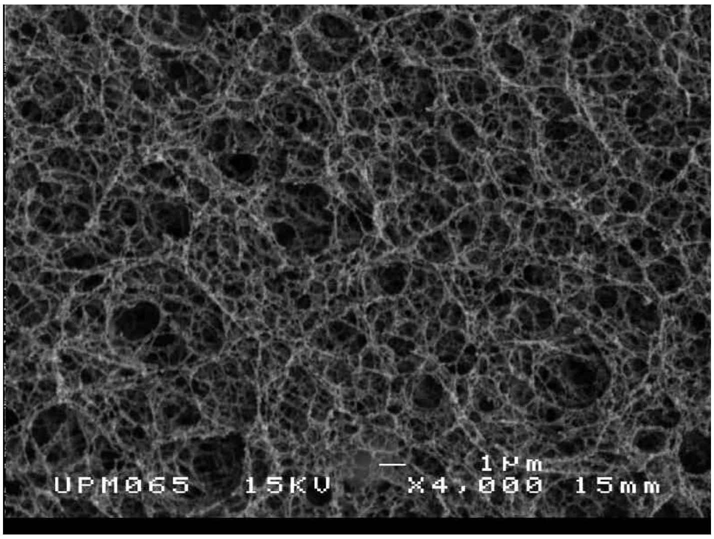

Figure 7: SEM image of sample collected from the PLAD process by using graphite-Co pellet.

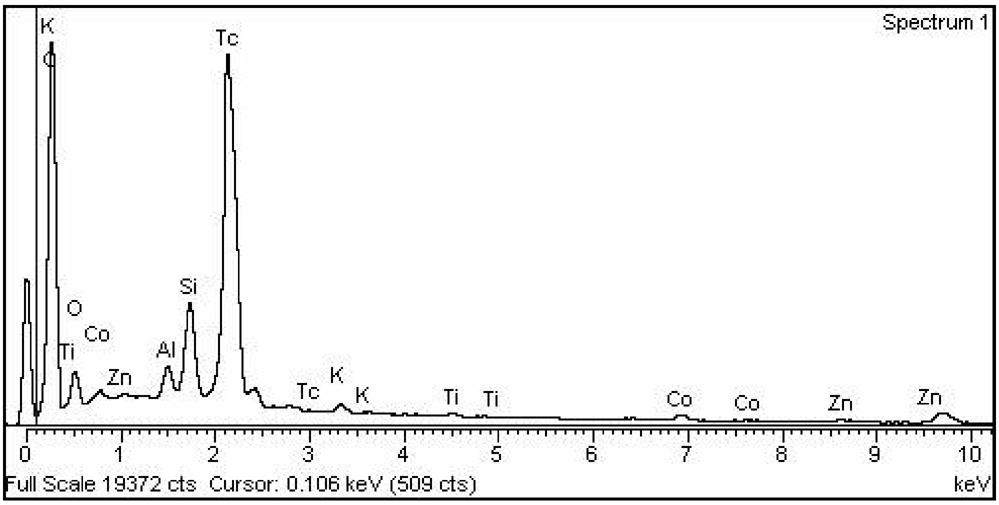

Figure 8: EDX profile for the sample collected from the PLAD process by using graphite-Co pellet.

Solid State Science and Technology, Vol. 15, No 1 (2007) 22-29
ISSN 0128-7389

CONCLUSION

We have formed the carbon nanostructures possibly carbon naotubes by using Co and Ni catalysts via pulsed laser ablation technique. The higher yield was found by using the Ni catalyst compared to Co catalyst with the same weight percentage, thus is concluded that cobalt as a catalyst is less effective than nickel for the growth of CNTs.

ACKNOWLEDGEMENT

The financial support of the Ministry of Science, Technology and Innovation of Malaysia under IRPA grant, vot 09-02-04-0855-EA001 is greatly acknowledged.

REFERENCES

[1]. Yudasaka, M. Komatsu, T. Ichihashi and T. Iijima, S (1997; *Chemical Physics Letter.* **278**,102.
[2]. Ju, Y., Li, F.Y and Wei, R. Z (2005); *J. Serb. Chem. Soc.* **70 (2)**, 277.
[3]. Cao A., Xu A., Ji L., Wu D and Wei B (2001).*Chemical Physics Letter*, **344**,13.
[4]. Yudasaka, M. Kasuya, Y. Kokai, F. Takahashi, K. Takizawa, M. Bandow, S. Iijima, S (2002); *Applied Physics A.* **74**, 377.
[5]. Park, J.B. Choi, G.S. Cho, Y.S. Hong, S.Y. Kim, D. Choi, S.Y. Lee, J.H and Cho, K.I (2002); *Crystal Growth*. **244**, 211.
[6]. Yudasaka, M. Yamada, R. Sensui,N. Wilkins, T. Ichihashi, T and Iijima, S (1999); *Physical Chemistry B.* **103**,6224.
[7]. S. Iijima, *Nature* **354** (1991), p. 56.
[8]. T.W. Ebbesen and P.M. Ajayan, *Nature* **358** (1992), p. 220
[9]. S. Amelinckx, X.B. Zhang, D. Bernaerts, X.F. Zhang, V. Joanov and J.B. Nagy, *Science* **265** (1994), p. 635
[10]. E.W. Wong, P.E. Sheehan and C.M. Lieber, *Science* **277** (1997), p. 1971
[11]. M. Ouyang, J.-L. Huang and C.M. Lieber, *Acc. Chem. Res.* **35** (2002), p. 1018
[12]. C.D. Scott, S. Arepalli, P. Nikolaev and R.E. Smalley. *Appl. Phys. A* **72** (2001), pp. 573–580
[13]. M. Yudasaka, T. Komatsu, T. Ichihashi, Y. Achiba and S. Iijima. *J. Phys. Chem. B* **102** (1998), p. 4892
[14]. D. Nishide, H. Kataura, S. Suzuki, K. Tsukagoshi, Y. Aoyagi and Y. Achiba. *Chem. Phys. Lett.* **372** (2003), pp. 45–50
[15]. Y. Suda, K. Utaka, M.A. Bratescu, Y. Sakai, J. Tsujina and K. Suzuki, *Appl. Phys. A* **79** (2004), pp. 1331–1333