Structure dependence of carbon nanotube on the process parameters using microwave plasma chemical vapor deposition

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Abstract

Vertically aligned carbon nanotubes(CNTs) have been grown on Ni-coated TiN/Si substrate by microwave plasma chemical vapor deposition using H_2/CH_4 *mixture gas. We have investigated the Effect of process parameters on the growth of CNT. During the growth, microwave power, pressure, and growth temperature were varied from 300 W to 700 W, 10 Torr to 30 Torr, and 300 °C to 700 °C. respectively. Then we controlled the size of CNTs. The structure of CNT was sensitively dependent on the process parameters.*

1. Introduction

Carbon nanotubes(CNTs) have received a considerable attention because of the prospect of new fundamental science and many potential applications. CNTs are promising candidates, particularly, for cold cathode field emitter because of their unique electrical properties, high aspect ratios and small radii of curvature at their tips[1-2]. The CNT-based field emission display(FED) has been demonstrated in several occasions[3-6]. For applications such as flat panel displays, vertical alignment, emission properties, low temperature growth, and size control of CNTs are important. They can be controlled by processing parameters such as power density, growth temperature, gas flow rate, the grain size and morphology of catalytic metal. In this work, we have grown CNTs on Ni-coated TiN/Si substrate by microwave plasma chemical vapor deposition(MPCVD) which has been previously reported as a useful tool for the vertical alignment and low temperature growth of CNTs[7].

In this work, we have grown CNTs on Ni-coated TiN/Si substrate by MPCVD. The relationship between process parameters on the growth of CNT was investigated.

2. Experimental

Fig. 1 shows the schematic diagram of the MPCVD system. The growth temperature is detected by two thermometers, that is, pyrometer and thermocouple. A thin TiN layer was used as a buffer layer to improve the adhesion of CNTs to the substrate. The growth morphology, diameter, and length of the grown CNTs were observed by scanning electron microscope(SEM). During the growth, microwave power, pressure, and growth temperature were varied from 300 W to 700 W, 10 Torr to 30 Torr, and 300 ℃ to 700 ℃, respectively. The growth was carried out for 10 min.

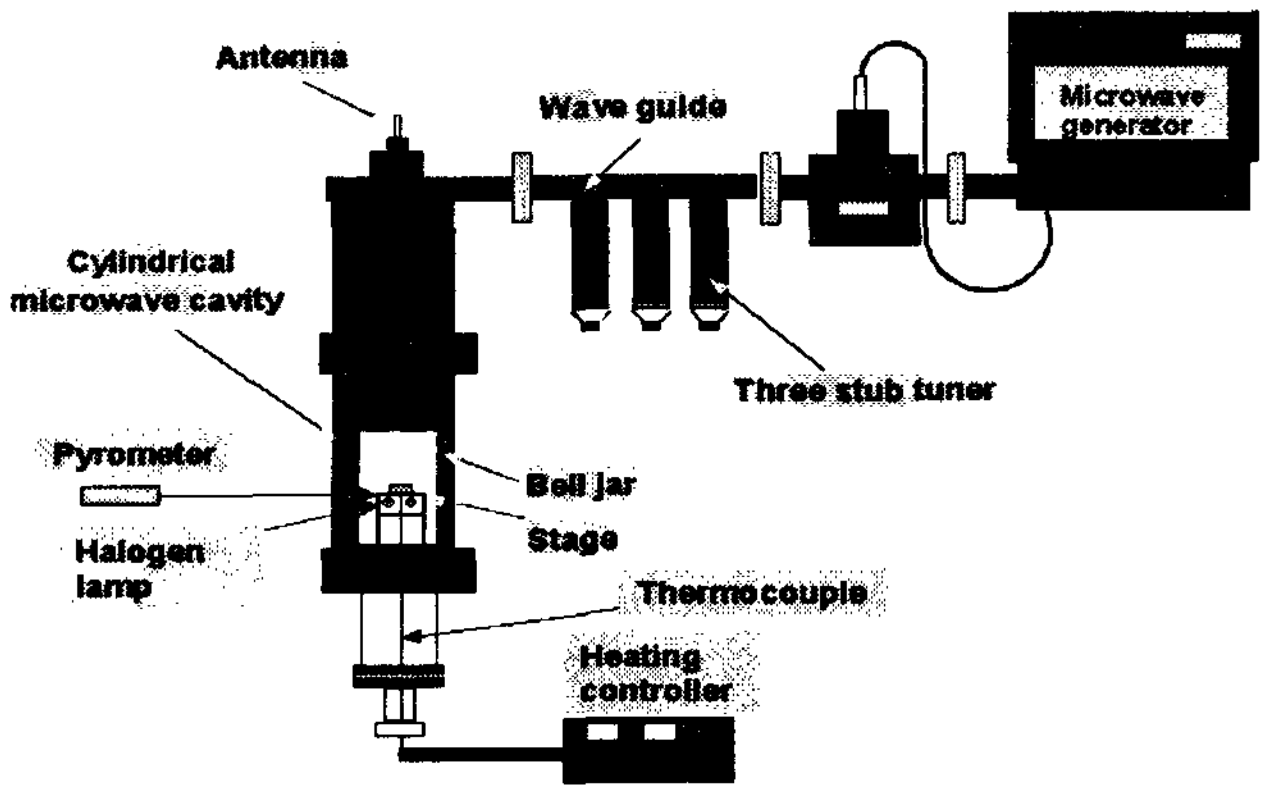

Fig. 1. Schematic diagram of MPCVD system.

3. Results and discussion

Fig. 2 shows the SEM image for CNTs grown at 700 W, 600 ℃, H_2 : CH_4 = 40:10 sccm, 10 Torr, 10 min. The decrease of Ni grain size with increasing microwave power is probably due to the enhanced chemical reaction rate of source gases by increased plasma density as well as due to the enhanced ion bombardment by H_2 plasma. Therefore, we found that the average diameter of CNT decreased from 31.2 nm to 22 nm. Fig. 3 shows the SEM image grown at 400 W, 600 ℃, H_2 : CH_4 = 40:10 sccm, 30 Torr, 10 min. The CNTs were grown sparsely by increasing pressure. We conjecture that the grains of catalytic metal were partly removed by high H_2 plasma etching, because physical impact(ion bombardment) in plasma enhanced chemical vapor deposition(PECVD) is dominant at high pressure, while chemical reaction is dominant at high pressure. Fig. 4 shows the SEM image grown at 400 W, 700 ℃, H_2 : CH_4 = 40:10 sccm, 10 Torr, 10 min. As the temperature increases, the migration rate of Ni particles on TiN/Si substrate also increases, which is due to the enhanced mobility of Ni grains. Therefore, higher substrate temperature results in the larger grain size of Ni. While the initial size of Ni grains was 28 nm, the average diameters of Ni grains after CNTs growth were 36 nm, 41 nm, 45 nm, and 55 nm at the substrate temperatures of 382 ℃, 444 ℃, 500 ℃, and 700 ℃, respectively.

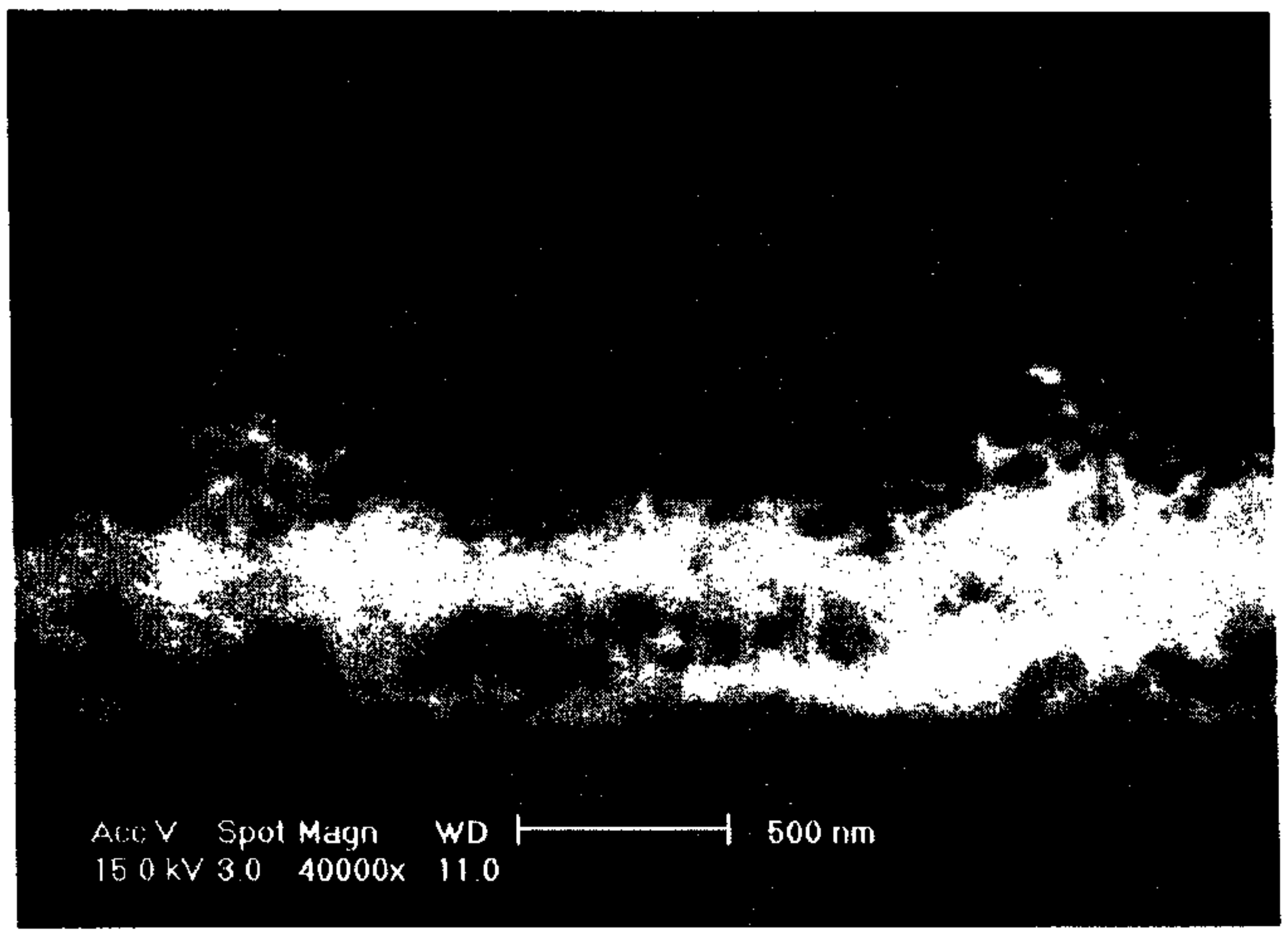

Fig. 2 SEM image of CNTs grown at 700 W, 600 ℃, H_2 : CH_4 = 40:10 sccm, 10 Torr, 10 min.

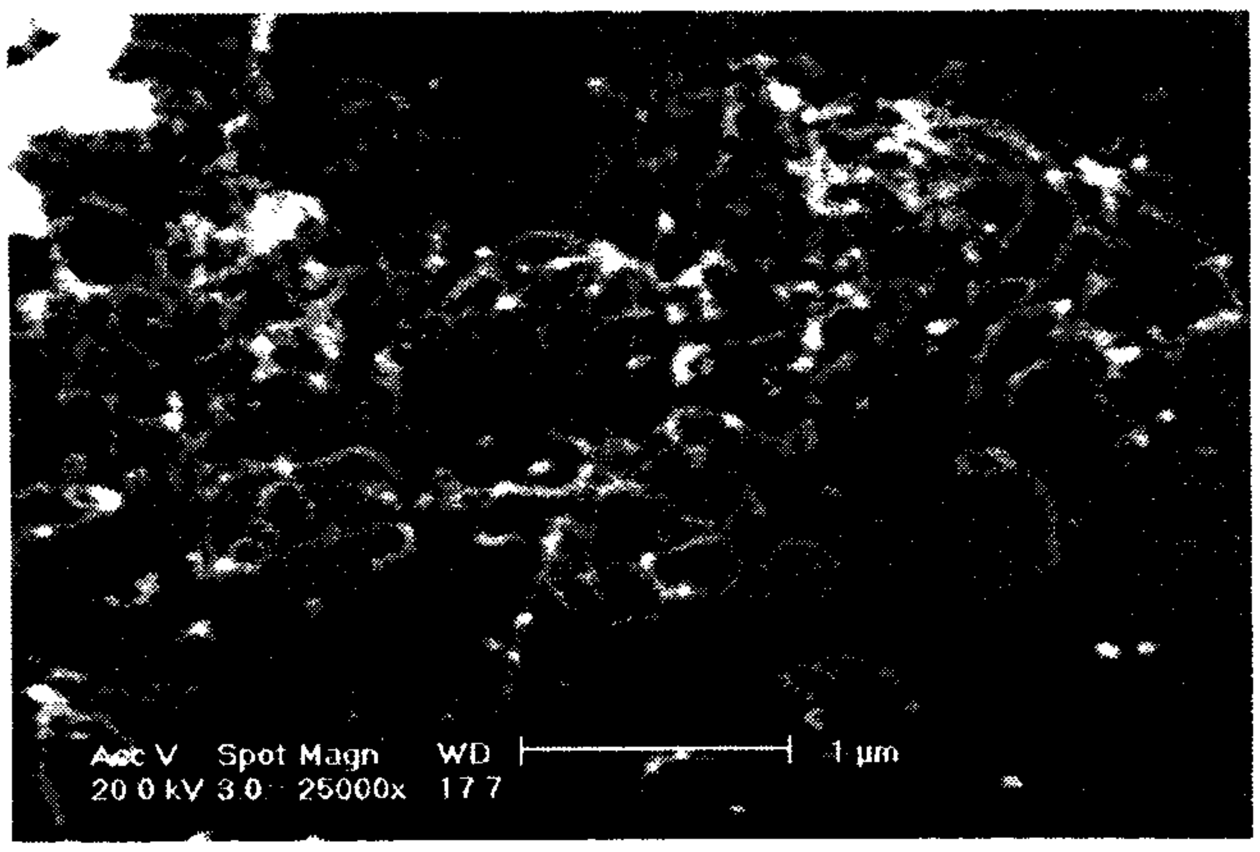

Fig. 3 SEM image of CNTs grown at 400 W, 600 ℃, H_2 : CH_4 = 40:10 sccm, 30 Torr, 10 min.

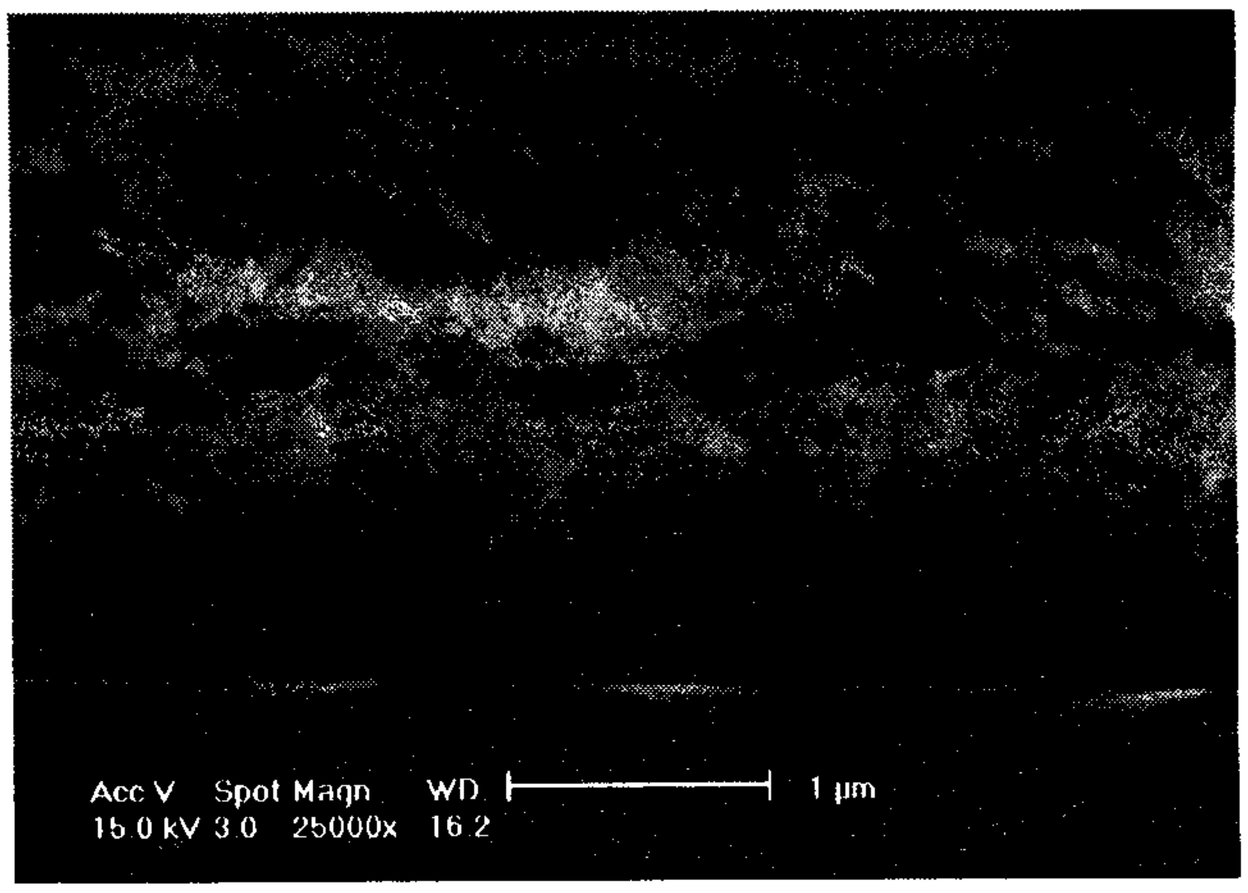

Fig. 4 SEM image of CNTs grown at 400 W, 700 ℃, H_2 : CH_4 = 40:10 sccm, 10 Torr, 10 min.

Fig.5 shows the trend of CNT diameter as a function of the growth temperature. As confirmed from the figure, CNT diameter is closely related to Ni grain's size and thus growth temperature should be optimized to obtain CNTs suitable for field emission.

4. Conclusion

In conclusion, the process parameters which affect the growing behavior for CNTs were briefly discussed. Vertically aligned CNTs generate high electron field emission under high aspect ratio and density, and thus CNT with very small diameter is more favorable. In future, the electron emission behavior will be investigated according to the variation of these factors.

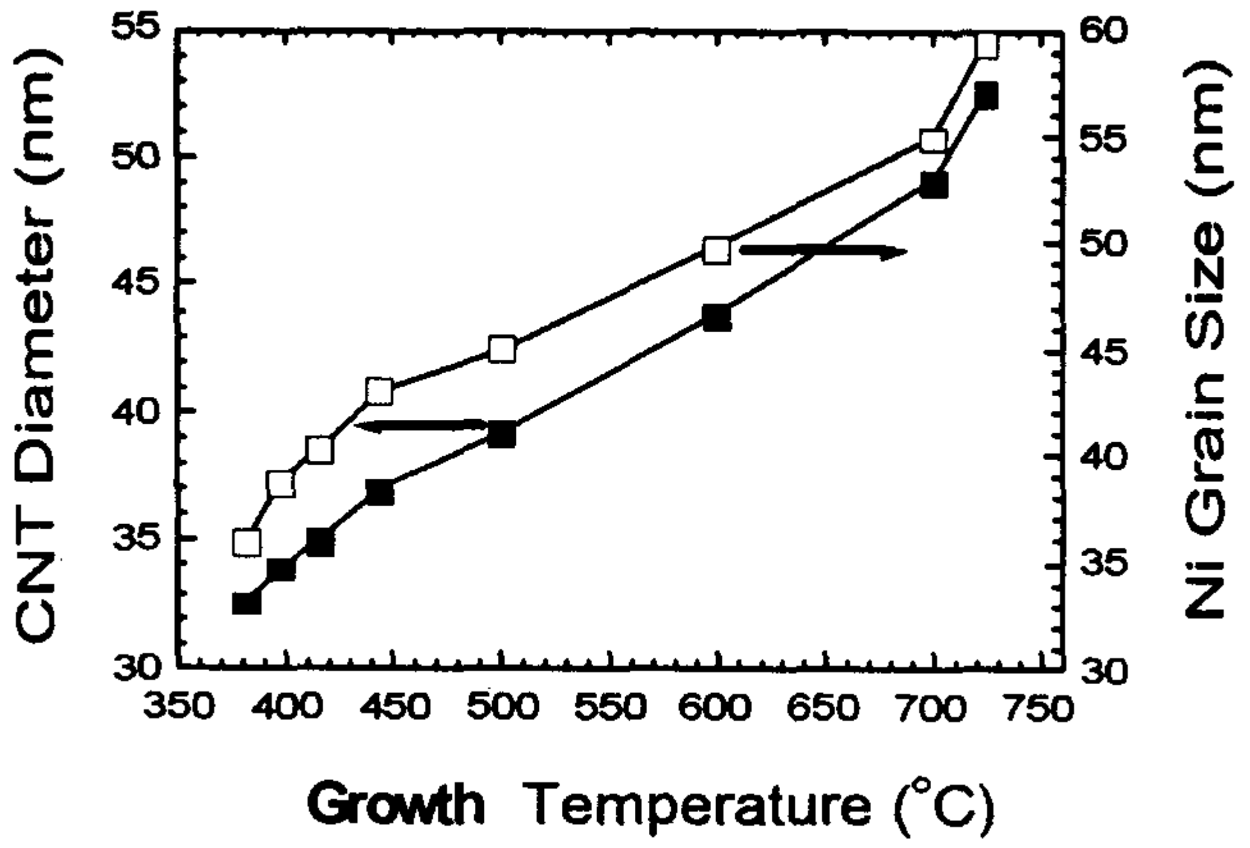

Fig. 5. Temperature dependence of CNT diameter.

5. References

[1] S. Fan, M.G. Chapline, N.R. Franklin, T.W. Tombler, A.M. Cassell, H. Dai, Science 283 (1999) 512.

[2] W. Zhu, C. Bower, O. Zhou, G. Kochanski, S.Jin, Appl. Phys. Lett. 75 (1999) 873.

[3] A.G. Rinzler, J.H. Hafner, P. Nikolaev, L. Lou, S.G. Kim, Tomanek, P. Nordlander, D.T. Colbert, R.E. Smalley, Science 269(1995) 1550.

[4] W.A. de Heer, A. Chatelain, D. Ugrate, Science 270(1995) 1179.

[5] P.G. Collins, A. Zettl, Phys. Rev. B 55(1997) 9391.

[6] Y. Saito, K. Hamaguchi, K. Hata, K. Uchida, Y. Tasaka, F. Ikazaki, M. yumura, A. Kasuya, Y. Nisshina, Nature 389(1997) 554.

[7] Y.C. Choi et al., Met., Vol. 108, (2000) 159.