Thermal Annealing Treatment Effects on the Surface Morphology and Field Emission Properties of Thermal Chemical Vapor...

羅啟榮、李世鴻

E-mail: 9607640@mail.dyu.edu.tw

ABSTRACT

In this work, thermal chemical vapor deposition was utilized to synthesize carbon nanotubes (CNTs). Methane (CH4) was the main source for carbon, and argon (Ar) was used as the carrier gas. CNTs were synthesized from carbon atoms obtained from catalytic thermal decomposition of methane. The synthesized CNTs were subsequently annealed in an argon atmosphere. Scanning electron microscopy (SEM), energy dispersive spectrometer (EDS) and Raman spectroscopy were employed to study the effect of thermal annealing treatment on the properties of CNTs. From experimental data, it is found that the surface morphology, structure, and field emission property of CNTs are strongly dependent on the temperature and duration of thermal treatment employed. Only treatments at the appropriate temperature (200℃) for specific amount of time (10 to 20 minutes) can result in the enhancement of field emission characteristics of CNTs. This enhancement of emitted current is primarily due to the remedy of defects on the surfaces of CNTs and the recrystallization of amorphous carbon originally residing on the surfaces of CNTs. These can result in the exposure of the graphite tip of CNTs and the increase of emitted current as well. Outside of this temperature and duration range, thermal treatments can only deteriorate the structure of CNTs, and hence degrade the field emission characteristics of CNTs.

Keywords : carbon nanotubes (CNTs) ; thermal annealing ; field emission ; thermal chemical vapor deposition (thermal CVD)

Table of Contents

REFERENCES

1. Radushkevich, L. V., & Lukyanovic, V. M. (1952). Zh. Fiz. Khim. 26, 88. 2. Hofer, L. J. E., Sterling, E., & MacCartney, J. T. (1955). J. Phys.

Chem., 59, 6210. 3. Kroto, H. W., Heath, J. R., O ' Brian, S. C., Curl, R. F., & Smalley, R. E.(1985). C60: Buckminsterfullerene. Nature, 318 (6042), 162-163. 4. Kratschmer, W., Lamb, L. D., Fostiropoulos, K., & Huffman, D. R. (1990). Solid C60: A new form of carbon. Nature, 347, 354-358. 5. Maiti, Brabec, C. J., Roland, C., & Bernholc, J. (1995). Theory of carbon nanotube growth. Phys. Rev. B, 15; 52(20), 14850-14858. 6. Iijima, S. (1991). Helical microtubules of graphitic carbon. Nature, 354, 7, 56-58. 7. Iijima, S., & Ichihashi, T. (1993). Single-shell carbon nanotubes of 1-nm diameter. Nature, 363, 603-605. 8. Bethune, D. S., Kiang, C. H., deVries, M. S., Gorman, G., Saroy, R., Vazguez, J., & Beyers, R. (1993). Cobalt-catalyzed growth of carbon nanotubes with single-atomic-layer walls. Nature, 363, 605-607. 9. Thess, A., Lee, R., Nikolaev, P., Dai, H., Petit, P., Robert, J., Xu, C., Lee, Y. H., Kim, S. G., Rinzler, A. G., Colbert, D. T., Scuseria, G. E., Tomanek, D., Fischer, J. E., & Smalley, R. E. (1996). Crystalline ropes of metallic carbon nanotubes. Science, 273, 483-487. 10. Peter J. F. Harris, (1999). Carbon nanotubes and related structure. Cambridge University Press, Chapter 4.2: Electronic properties of nanotube. 16 – 54. 11. Charlier, J. C., & Issi, J. P. (1998). Electronic structure and quantum transport in carbon nanotubes. Applied Physics A: Materials Science & Processing, 67, 79-87. 12. Haus, M. D., Dresselhaus, G., Eklund, P., & Saito, R. (1998). Carbon nanotubes. Physics World, 11, 33-38. 13. Mintmire, J. W. & White, C. T. (1998). First-principles band structures of armchair nanotubes. Applied Physics A: Materials Science & Processing, 67, 65-69. 14. Dresselhaus, M. S., Dresselhaus, G., & Saito, R. (1995). Physics of carbon nanotubes. Carbon, 33, 883-891. 15. Dai, H., Rinzer, A. G., Nikolaev, P., Thess, A., Colbert, D. T., & Smalley, R. E. (1996). Single-wall nanotubes produces by mental catalyzed disproportionation of carbon monoxide. Chem. Phys. Lett., 260, 471-475. 16. Lee, Y. H., Kim, S. G., & Tomanek, D. (1997). Catalytic growth of single-wall carbon nanotubes: an Ab initio study. Phys. Rev. Lett., 78, 2393-2396. 17. Saito, Y., Yoshikawa, T., Inagaki, M., Tomita, M., & Hayshi, T. (1993). Growth and structure of graphitic tubules and polyhedral particles in arc-discharge. Chemical Physics Letters, 204, 277-282. 18. Endo, M., & Kroto, H. W. (1992). Formation of carbon nanofibers. Journal of Physical Chemistry, 96, 6491-6944. 19. Baker, R. T. K., & Harries, P. S. (1978). The formation of filamentous carbon. Chemistry and Physics of Carbon, New York: Marcel Deckker, 14, 83-165. 20. Baker, R. T. K., Braker, M. A., Harries, P. S., Feates, F. S., & Waite, R. J. (1972). Nucleation and growth of carbon deposits from nickel catalyzed decomposition of acetylene. Journal of Catalysis, 26, 51-62. 21. Oberlin, A., Ento, M., & Koyama, T. (1976). Filamentous growth of carbon through benzene decomposition. Journal of Crystal Growth, 32, 335-349. 22. Baird, T., & Fryer, J. R. (1974). Carbon formation on iron and. nickel foils by hydrocarbon pyrolysis reactions at 700 ° C. Carbon, 12, 591-602. 23. Oberlin, A., Ento, M., & Koyama, T. (1976). High resolution electron microscope observations of graphitized carbon fibers Carbon. Carbon, 14, 133-157. 24. Journet, C. et al., (1998). Production of carbon nanotubes. Applied Physics, .67, 1-9. 25. Alan, M. et al., (1998). Chemical vapor deposition of methane for single-walled carbon nanotubes. Chem. Phys. Lett., 292, 567-574. 26. Yacaman, M. J., Yoshida, M. M., Rendon, L., & Santiesteban, J. G. (1993). Catalytic growth of carbon. microtubules with fullerene structure. Appl. Phys. Lett., 62, 202-204. 27. Baker, R. T. K., & Chludzinski, J. J. (1980). Filamentous carbon growth on nickel – iron surfaces—effect of various oxide additives. Journal of Catalysis, 64, 464-478. 28. Baker, R. T. K., Harries, P. S., Thomas, R. B., & Waite, R. J. (1973). Formation of filamen-tous carbon from iron and chromium catalyzed decomposition of acetylene. Journal of Catalysis, 30, 86-95. 29. Baker, R. T. K., & Waite, R. J. (1975). Formation of carbonaceous deposit from the platinum-iron catalyzed decomposition. Journal of Catalysis, 37, 101-105. 30. Jung, M., Eun, K. Y., Lee, J. K., Baik, Y. J., Lee, K. R., & Park, J. W. (2001). Growth of carbon nanotubes by chemical vapor deposition. Diamond and Related Materials, 10, 1235-1240. 31. Xie, S., Li, W., Pan, Z., Chang, B., & Sun, L. (2000). Self-assembly of shape-controlled nanocrystals and their in-situ thermodynamic properties. Materials Science and Engineering A, 286, 11-15. 32. Chen, X. H., Feng, S. Q., Ding, Y., Peng, J. C., & Chen, Z. Z. (1999). The formation conditions of carbon nanotubes array based on FeNi alloy island films. Thin Solid Films, 339, 6-9. 33. Lee, C. J., Park, J., Kang, S. Y., & Lee, J. H. (2000). Growth of well-aligned carbon nanotubes on a large area of Co-Ni co-deposited silicon oxide substrate by thermal chemical vapor deposition. Chemical Physics Letters, 323, 554-559. 34. Terrones, M. et al., (1998). Preparation of aligned carbon nanotubes catalysed by laser-etched cobalt thin films. Chemical Physics Letters, 285, 299-305. 35. Liang, Q., Li, Q., Chen, D. L., Zhou, D. R., Zhang, B. L., & Yu, Z. L. (2000). Carbon nanotube prepared in the atmosphere of partial oxidation of methane. Chemical Journal of Chinese Universities-Chineses, 21(4), 623-625. 36. Hernadi, K., Fonseca, A., Nagy, J. B., Siska, A., & Kiricsi, I. (2000). Production of nanotubes by the. catalytic decomposition of different carbon-containing compounds. .Applied Catalysis A: General, 199, 245-255. 37. Li, W. Z., Xie, S. S., Qian, L. X., Chang, B. H., Zou, B. S., Zhou, W. Y., Zhao, R. A., & Wang, G. (1996). Large-scale synthesis of aligned carbon nanotubes. Science, 274, 1701-1703. 38. Pan, Z. W., Xie, S. S., Chang, B. H., Sun, L. F., Zhou, W. Y., & Wang, G. (1999). Direct growth of aligned open carbon nanotubes by chemical vapor deposition. Chemical Physics Letters, 299, 97-102. 39. Li, A. P., Muller, F., Birner, A., Nielsch, K., & Gosele, U. (1998). Hexagonal pore arrays with a 50-420 nm interpore distance formed by self-organization in anodic alumina. J. Appl. Phys., 84, 6023-6026. 40. Masuda, H., Yamada, H., Satoh, M., & Asoh, H. (1997). Highly ordered nanochannel-array architecture in anodic alumina. Appl. Phys. Lett., 71, 2770-2772. 41. Masuda, H., & Satoh, M. (1996). Fabrication of gold nanodot array using anodic porous alumina as an evaporation mask. Jpn. J. Appl. Phys., part 2, 35, 126-129. 42. Nolan, P. E., Schabel, M. J., & Lynch, D. C. (1995). Hydrogen control of carbon deposit morphology. Carbon, 33, 79-85. 43. Pinheiro, P., Schouler, M. C., Gadelle, P., Mermoux, M., & Dooryhee, E. (2000). Effect of hydrogen on the orientation of carbon layers in deposits from the carbon monoxide disproportionation reaction over Co/Al2O3 catalysts. Carbon, 38(10), 1469-1479. 44. Khassin, A. A., Yurieva, T. M., Zaikovskii, V. I., & Parmon, V. N. (1998). Effect of metallic cobalt particles size on occurrence of CO disproportionation. Role of fluidized metallic cobalt-carbon solution in carbon nanotube formation. Reaction Kinetic and Catalysis Letter, 64, 63-71. 45. Tsai, S. H., Chao, C. W., Lee, C. L., & Shin, H. C. (1999). Bias-enhanced nucleation and growth of the aligned carbon nanotubes with open ends under microwave plasma synthesis. Appl. Phys. Lett., 74, 3462-3464. 46. Huang, Z. P., Xu, J. W., Ren, Z. F., Wang, J. H., Siegal, M. P., & Provencio, P. N. (1998). Growth of

highly-oriented carbon nanotubes by plasma-enhanced hot filament chemical vapor deposition. Appl. Phys. Lett., 73, 3845-3847. 47. Ren, Z. F., Huang, Z. P., Wang, D. Z., Wen, J. G., Xu, J. W., Wang, J. H., Calvet, L. E., Chen, J., Klemic, J. F., & Reed, M. A. (1999). Growth of a single freestanding multiwall carbon nanotube on each nanonickel dot. Appl. Phys. Lett., 75, 1086-1088. 48. Fan, S., Chapline, M. G., Franklin, N. R., Tombler, T. W., Cassell, A. M., & Dai, H. (1999). Self-oriented regular arrays of carbon nanotubes and their field emission properties. Science, 283, 512-514. 49. Kwon, Y. K., Lee, Y. H., Kim, S. G., Jund, P., Tomanek, D., & Smalley, R. E. (1997). Morphology and stability of growing multiwall carbon nanotubes. Phys. Rev. Lett., 79, 2065-2068. 50. Oh, D. H., & Lee, Y. H. (1998). Stability and cap formation mechanism of single-walled carbon nanotubes. Phys. Rev. B, 58, 7407-7411. 51. Kuznetsov, V. L., Usoltseva, A. N., Chuvilin, A. L., Obraztsova, E. D. & Bonard, J. M. (2001). Thermodynamic analysis of nucleation of carbon deposits on metal particles and its implications for the growth of carbon nanotubes. Phys. Rev. B, 64, 235401-1. 52. Jo, S. H., Tu, Y., Huang, Z. P., Carnahan, D. L., Wang, D. Z., & Ren, Z. F. (2003). Effect of length and spacing of vertically aligned carbon nanotubes on field emission properties. Appl. Phys. Lett., 82, 3520-3522. 53. Wang, Z. L., R. P. Gao, W. A. deHeer, P. Poncharal, (2002). In situ imaging of field emission from individual carbon nanotubes and their structural damage. Appl. Phys. Lett., 80, 856-858. 54. Bonard, J. M., Dean, K. A., Coll, B. F., & Klinke, C. (2002). Field emission of individual carbon nanotubes in the scanning electron microscope. Phys. Rev. Lett., 89(19), 4, 1976021-24.