Chapter 10

Conclusion

Owing to both fascinating physical and chemical properties, carbon based nanostructured materials are predicted to be suitable candidates for field emission sources. This dissertation focuses on modification and fabrication of various carbon-based nanostructures as cathode materials to improve the performances of the field emission characteristics. Main results are summarized as follows.

The modification techniques contain bias effect; p-type and/or n-type doping; structure variation and carburization of Si tips in this research. Carburization yields much nano diamond-like carbon and β SiC mounted on the Si tips and enhances the field emission characteristic because of the negativity electron affinity (NEA) and nanosize effect. Applying a bias during deposition not only increase the growth rate of emitters but also cause emitters to exhibit good alignment because of plasma-induced effect. The trimethylphosphite and trimethylborate are used as phosphorus and boron dopants. By adding theses dopants, the electric properties of the materials are enhanced dramatically.

In the fabrication of new material field, the synthesis of new ultra well-aligned carbon nanomaterials and carbon nanoparticles self-embedded on the top of the materials are involved. The carbon nanotips composed of graphite are fabricated in

this research. From the transmission electron microscopy images, it shows that the carbon nanotips are solid materials in comparison with the hollow structures of carbon nanotubes. Besides, these new carbon nanomaterials also possess well-aligned property in the growing direction. Pre-deposition of Pt thin films on the substrate leads to the good electron transport for carbon nanotips instead of catalysts. Furthermore, pre-deposition of Cr thin film will be lifted off with the growing individual carbon nanotips and transformed to nanocrystalline chromium carbides on the top of the carbon nanotips. This self-alignment method could be used in many applications.

It is found that hydrogen plasma cleans the surface of substrates, and activates the as-grown thin metal films into nanoparticles, providing a confined space for the growth of nanoscale materials. With the aid of confined space, it is believed that many kinds of carbon nanoparticles could be fabricated.

As compared to conventional gas mixtures, which is hydrocarbon diluted in hydrogen, new reactive gases of methane-carbon dioxide mixture are used to improve the growth rate, morphology, and characterization of emitters. Due to the more dissociated carbon species in plasma, it is expected to efficiently increase the growth rate of emitters with diverse property. Moreover, by using IC technologies, the novel scheme of gated structure with smaller aperture (the aperture diameter is 4 μm) in

conjunction with metal-insulator-semiconductor (MIS) diode is also presented. This MIS gated structure makes the carbon nanomaterials exhibit low threshold voltage and high current characterization.

Publish Lists

A: International Journal

1. C. L. Tsai, C. F. Chen. Self-embedded of nanocrystalline chromium carbides on well-aligned carbon nanotips. *Applied Physics Letter* V82, 4337 (2003)

2. C. L. Tsai, C. F. Chen, C. L. Lin. Characterization of boron-doped carbon nanotubes arrays. *Diamond and Related Material* V12 1500 (2003).

3. C. L. Tsai, C. F. Chen, Characterization of bias-controlled carbon nanotubes. *Diamond and Related Material* V12, 1615 (2003).

4. C.L. Tsai and .C.F. Chen Special Issue on Field Electron Emission from Carbon Materials: Modification of new carbon based nanomaterials for field emission devices. *IEICE Transactions V. E86-C No. 5 May 2003.*

.5. C. L. Tsai, C. F. Chen, C. L. Lin. Field Emission from Well-aligned Carbon Nanotips Grown in a Gated Device Structure. *Applied Physics Letter* V80,1821 (2002).

6. C. L. Tsai, C. F. Chen, L.K. Wu. Bias effect on the growth of carbon nanotips using microwave plasma chemical vapor deposition. *Applied Physics Letter* V81, 721 (2002).

7. C. L. Tsai, C. F. Chen. C. L. Lin, The Characterization of Phosphorus- Doped and Boron-Doped Diamond-like Carbon Emitter Arrays, *Journal of Applied Physics*

V90, 4847 (2001).

8. C.L. Tsai, C.L. Lin, C.F. Chen. Fabrication and characterization of phosphorus-doped diamond field emitter in triode type field emission arrays. *Diamond and Related Material* V10, 834 (2001).

9. C.L. Tsai, C.L. Lin, C.F. Chen. Study of carbon nanoemitters using CO_2-CH_4 gas mixtures in triode-type field emission arrays. *Diamond and Related Material* V11, 788 (2002).

10. C.L. Tsai, C.L. Lin, C.F. Chen.. Electronic properties of phosphorus-doped triode-type diamond field emitter arrays. *Mat. Chem. Phys.* 72, 210 (2001).

B: International Conference Paper:

1. C. L. Tsai, C. F. Chen. Growth and field emission of boron-doped carbon nanotubes arrays. *The International Conference on Metallurgical Coatings and Thin Films 2003*, San Diego, USA.

2. C. L Tsai, C. L Lin, C. F Chen. Study of Carbon Nano Emitters Using CO_2-CH_4 Gas Mixtures in Triode-type Field Emission Arrays.*13th European Conference on Diamond, Diamond-like Materials, Carbon Nanotubes, Nitrides and Silicon Carbide*, 2002 Granada, Spain.

3. C. L. Tsai, C. F. Chen. Bias effect on the growth of carbon nanotips using microwave plasma chemical vapor deposition. *The International Conference on*

Metallurgical Coatings and Thin Films 2002, San Diego, USA.

4. C. L. Tsai, C. L. Lin, C. F. Chen. Field Emission from Well-aligned Carbon Nanotips Grown in a Gated Device Structure. *11th European Conference on Diamond, Diamond-Like Materials, Carbon Nanotubes, Nitrides & Silicon Carbide*. 2001, Budapest, Hungary.

5. C. L. Tsai, C. L. Lin, C. F. Chen. Fabrication and characterization of phosphorus-doped diamond field emitter in triode type field emission arrays. *The International Conference on Metallurgical Coatings and Thin Films 2001*, San Diego, USA.

C: Honor and Awards:

1 Eligible of Graduate Students Study Abroad Program by National Science Council, R.O.C. Researcher in Univ. of Tokyo, Japan from 2003 to 2004.

2 Winner of the Student Awards of the International Conference on metallurgical Coatings And Thin Films (ICMCTF 2002), San Diego, USA.

3 Winner of the Student Awards of ICMCTF 2003 San Diego, USA.

4 Winner of the Student Awards of ICMCTF 2004 San Diego, USA..

5 Best poster paper on Taiwan Association for Coating and Thin Film Technology 2002.

6 Second Award of the poster paper competition in Taiwan International Diamond and Related Materials Science and Technology Symposium 2000.

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