

# Figure Captions

## Chapter 1

Fig. 1-1 The schematic diagram of (a) conventional cathode ray tube (CRT), (b) field emission display (FED)

Fig. 1-2 Energy diagrams of vacuum-metal boundary: (a) without external electric field; and (b) with an external electric field

Fig. 1-3 The SEM micrograph of (a) Spindt type triodes array, (b) Spindt type field emission triode, and the schematic image of (c) Spindt type triode array

Fig. 1-4 The FED products based on Spindt type field emitters, (a) motorola 5.6" color FED, (b) Pixtech 15" color FED, (c) Futaba 7" color FED and (d) Sony/Candescent 13.1" color FED

Fig. 1-5 (a) Si tip formed by isotropic etching and (b) Si tip field emission triodes array formed by CMP

Fig. 1-6 (a) SEM image of CNT cathode from Samsung's FED, (b) a 4.5-inch FED from Samsung, the emitting image of fully sealed SWNT-FED at color mode with red, green, and blue phosphor columns, and (c) a prototype of 5" CNT flat panel display by Samsung

Fig. 1-7 Structures of carbon (a) graphite, (b) diamond, (c) fullerene

Fig. 1-8 TEM images of (a) SWNT, and (b) MWNT

Fig. 1-9 Growth mechanism of CNTs growth (a) catalyst film pre-treatment, (b) carbon source addition, (c) adsorption of carbon atom at the surface of nanoparticles, (d) CNT growth, (e) base growth model, (f) tip growth model

## Chapter 2

Fig. 2-1 Lindemann criterion

Fig. 2-2 The role of catalyst for CNTs growth

Fig. 2-3 Schematic diagram of the CVD reactor with two different temperature zones

Fig. 2-4 Heat of formation of various hydrocarbon gases

Fig. 2-5 Schematic of (a) planar-gate and (b) under-gate CNT-FED structure

Fig. 2-6 FeNi alloy phase diagram

Fig. 2-7 Phase diagrams of (a) NiPd and (b) FeC alloy

Fig. 2-8 Schematic of (a) planar-gate (b) under-gate that we hypothesized

## Chapter 3

Fig. 3-1 Schematic experimental procedures

Fig. 3-2 A (a) photo and (b) schematic picture of thermal CVD

Fig. 3-3 Experimental processes of CNTs grown in diode structure (a) deposit Ti buffer layer on silicon substrate (b) pattern by UV light (c) deposit catalyst metal on Ti buffer layer (d) lift-off photo-resistance (e) pre-treat to form nano-particles (f) grow carbon nanotubes

Fig. 3-4 Fabricated procedures of triode structure (a) wet oxidation (b) deposit poly-Si by LPCVD and dope with  $\text{POCl}_3$  (c) pattern by UV light (d) etching poly-Si and oxide by RIE (e) wet lateral etching (f) deposit Ti buffer layer and catalyst layer (g) lift-off photo-resistance (h) grow carbon nanotubes

Fig. 3-5 Diode structure of CNT-FED on glass substrate

Fig. 3-6 High vacuum measurement system

## Chapter 4

Fig. 4-1 SEM images of (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC nanoparticles after

pretreatment at 700°C in Experiment A

Fig. 4-2 SEM images of (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC nanoparticles after pretreatment at 600°C in Experiment B

Fig. 4-3 SEM images of (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC nanoparticles after pretreatment at 500°C in Experiment C

Fig. 4-4 SEM images of CNTs with (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC as catalyst grown at 700°C in Experiment A, and the inset shows the magnified image

Fig. 4-5 SEM images of CNTs with (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC as catalyst grown at 600°C in Experiment B, and the inset shows the magnified image

Fig. 4-6 SEM images of CNTs with (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC as catalyst grown at 500°C in Experiment C

Fig. 4-7 SEM images of CNTs with (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC as catalyst grown at 500°C in Experiment D, and the inset shows the magnified image

Fig. 4-8 Raman spectrum of CNTs grown at 700°C in Experiment A

Fig. 4-9 Raman spectrum of CNTs grown at 600°C in Experiment B

Fig. 4-10 Raman spectrum of CNTs grown at 500°C in Experiment D

Fig. 4-11 (a) Field emission characteristics and (b) F-N plot of CNTs grown at 700°C in Experiment A

Fig. 4-12 (a) Field emission characteristics and (b) F-N plot of CNTs grown at 600°C in Experiment B

Fig. 4-13 (a) Field emission characteristics and (b) F-N plot of CNTs grown at 500°C in Experiment D

Fig. 4-14 The luminescent images on the ITO anode with phosphor coating on it were observed at applied electric field (a) 4.2, (b) 4.6, (c) 5, (d) 5.4, (e) 5.8, and (f) 6.3 V/ $\mu\text{m}$ , respectively.

Fig. 4-15 SEM images of CNTs with (a) Fe (b) Ni (c) FeNi (d) NiPd (e) FeC as catalyst

grown at 500°C in Experiment E, and the inset shows the magnified image

Fig. 4-16 TEM images of CNTs grown with (a) NiPd (b) FeC as catalyst at 500°C in Experiment E

Fig. 4-17 (a) Field emission characteristics and (b) F-N plot of CNTs grown at 500°C in Experiment E

Fig. 4-18 SEM images of CNTs with (a) Ni (b) NiPd (Pd:21%) (c) NiPd (Pd:60%) (d) NiPd (Pd:84%) (e) NiPd (Pd:92%) as catalyst grown at 500°C in Experiment F, and the inset shows the magnified image

Fig. 4-19 Raman spectrum of CNTs grown at 500°C in Experiment F

Fig. 4-20 (a) Field emission characteristics and (b) F-N plot of CNTs grown at 500°C in Experiment F

Fig. 4-21 SEM images of (a) whole pattern (b) cross-section view in under-gate structure

Fig. 4-22 SEM images of (a) whole pattern (b) cross-section view in planar-gate structure

Fig. 4-23 SEM images of CNTs with (a) FeC (b) NiPd as catalyst grown on glass substrate, and the magnified image is shown in the inset

Fig. 4-24 (a) Field emission characteristics and (b) F-N plot of CNTs grown on glass substrate in Experiment I

Fig. 4-25 (a) Image of CNT film by OM (b) the luminescent image that corresponded with the electron emission from the CNTs was obtained on the anode phosphor substrate