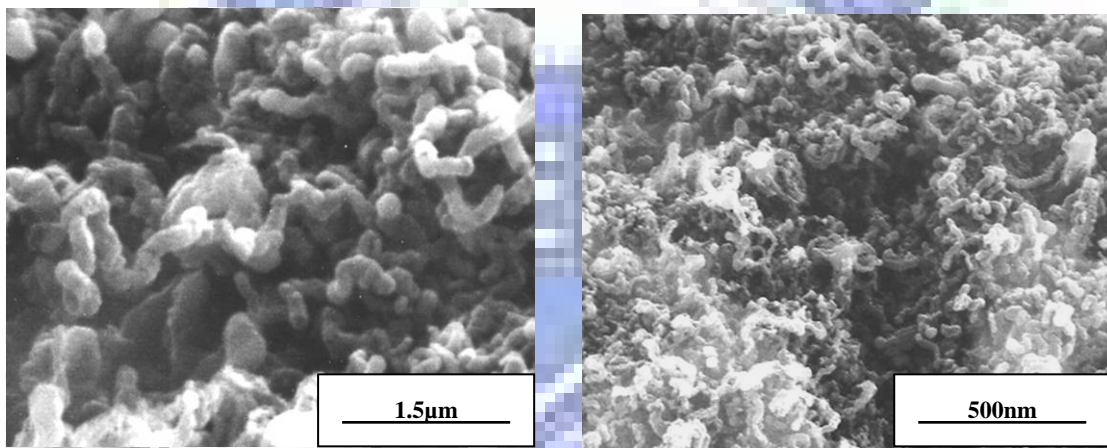
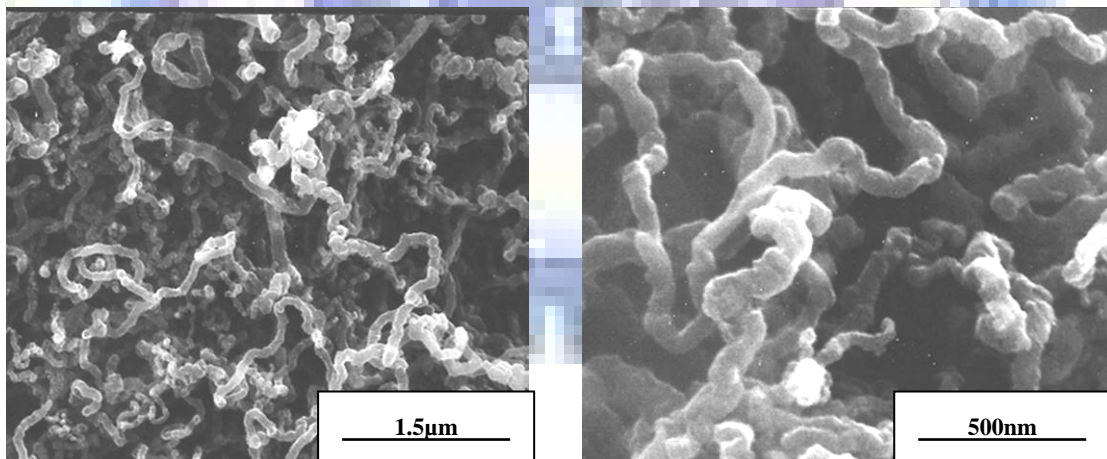


(a) 40/10



(b) 20/10



(c) 10/10

**Fig. 4.6 SEM images of different methane concentration under the growth condition at 200 W and 6 Torr for 30 min, (a)  $H_2/CH_4=40/10$  sccm, (b)  $H_2/CH_4=20/10$  sccm, (c)  $H_2/CH_4=10/10$  sccm.**

|           | 150W       | 200W    |
|-----------|------------|---------|
| D band    | 328869     | 14174   |
| G band    | 141388     | 6363    |
| $I_D/I_G$ | 2.326      | 2.2276  |
| Condition | No Bending | Bending |

Table 4.2 the data of Raman spectra at power of 150 W and 200 W.

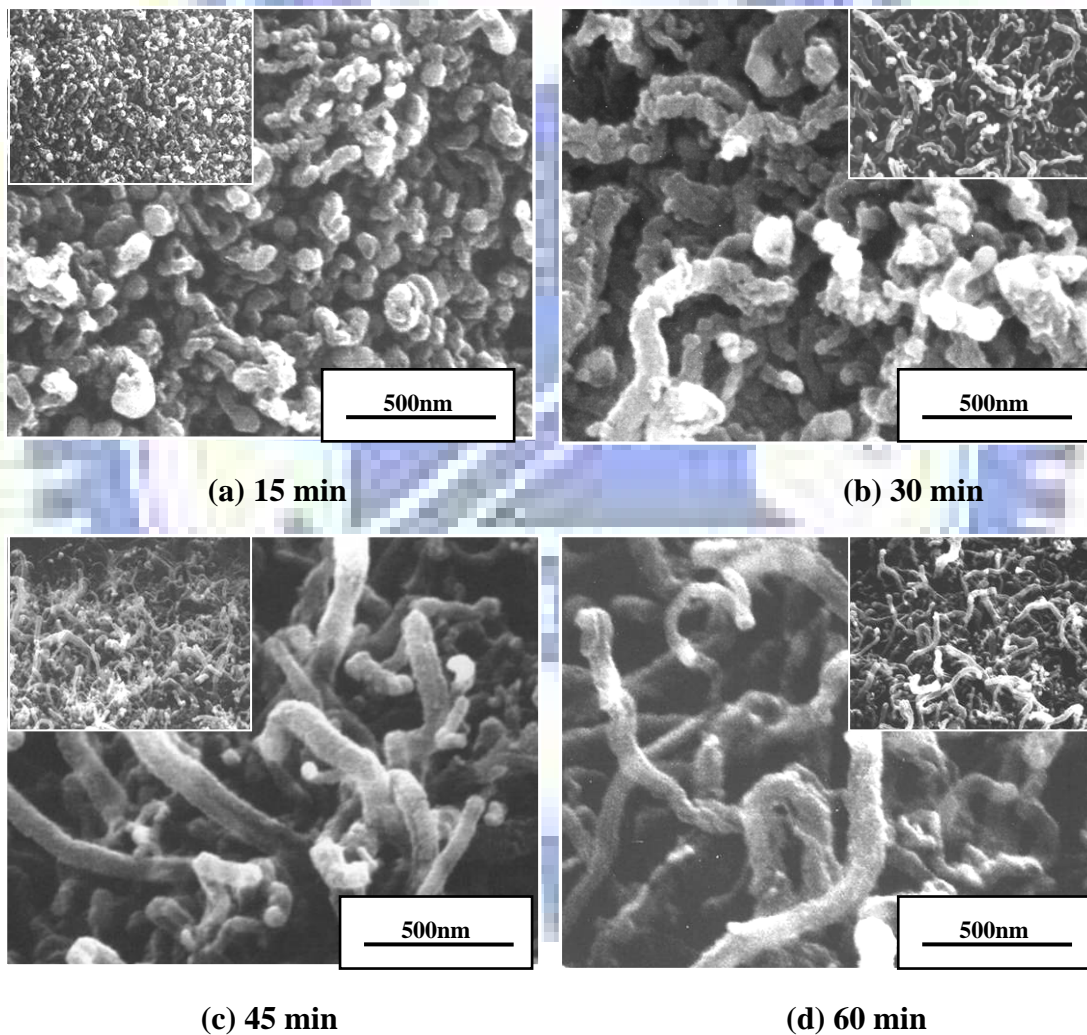
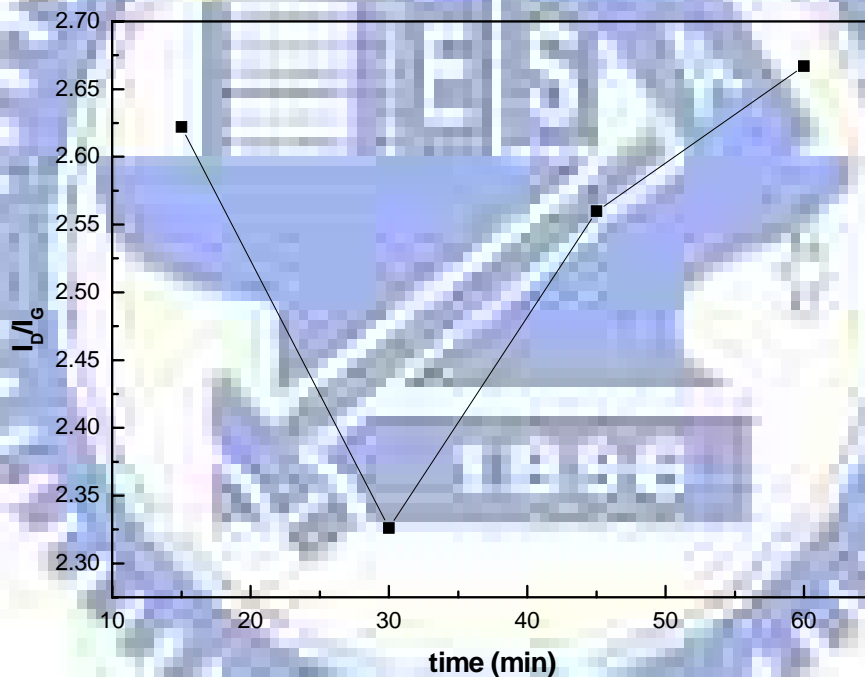


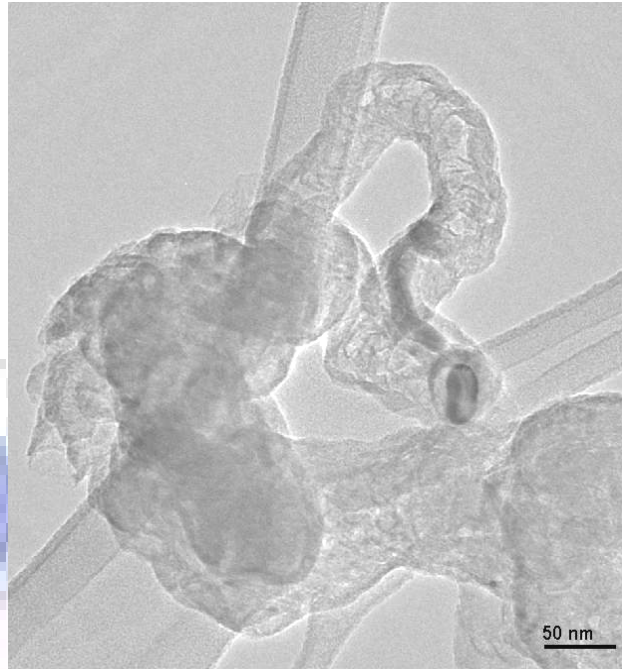
Fig 4.7 SEM images of surface under different the growth condition of  $H_2/CH_4=10/10$  at the power of 150 W and the pressure of 6 Torr: (a) for 15 min, (b) for 30 min, (c) for 45 min, and (d) for 60 min. The insect diagram is the minification.

| <b>150W</b>                 | <b>15min</b> | <b>30min</b> | <b>45min</b> | <b>60min</b> |
|-----------------------------|--------------|--------------|--------------|--------------|
| <b>D band</b>               | 409611       | 328869       | 46056        | 125470       |
| <b>G band</b>               | 156209       | 141388       | 17990        | 47050        |
| <b><math>I_D/I_G</math></b> | <b>2.622</b> | <b>2.326</b> | <b>2.560</b> | <b>2.667</b> |

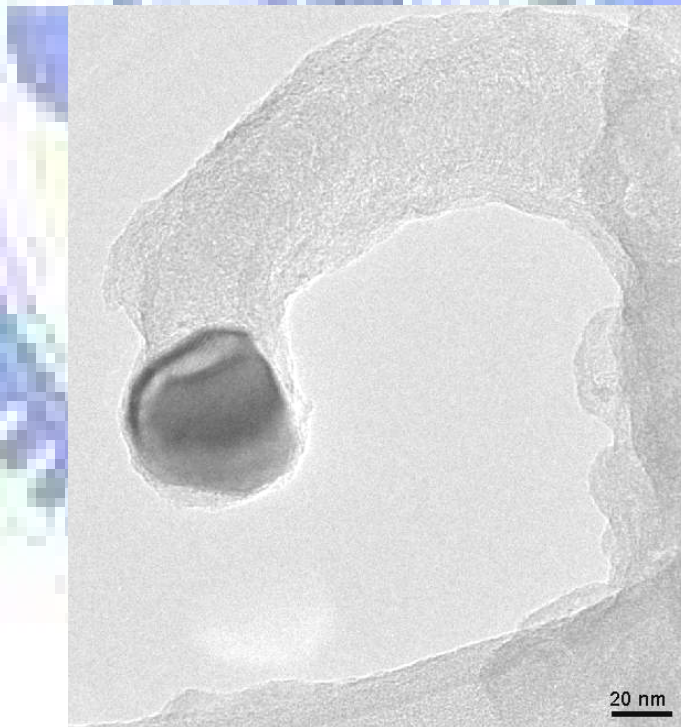
**Table 4.3 Data of Raman spectra at power of 150 W for different growth time.**



**Fig. 4.8  $I_D/I_G$  ratio varies with different growth time of  $H_2/CH_4= 10/10$ .**

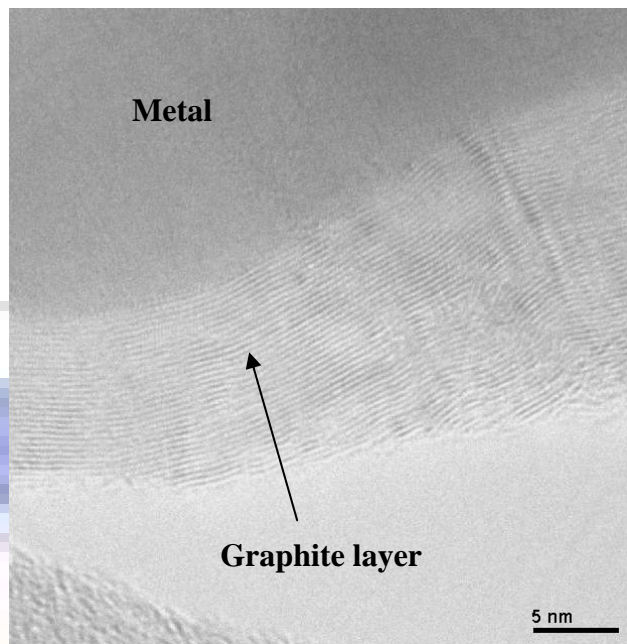


(a)

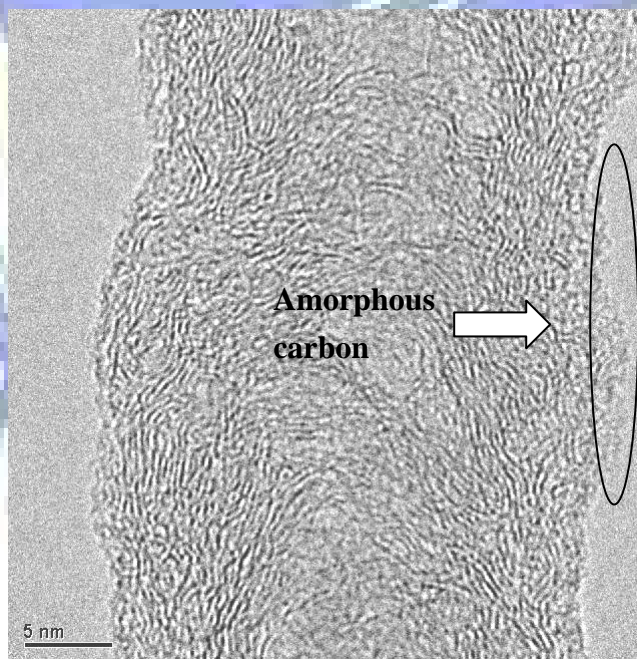


(b)

**Fig. 4.9 TEM image of carbon nanotubes.(a) herringbone-like structure,(b) carbon nanofiber-like structure.**

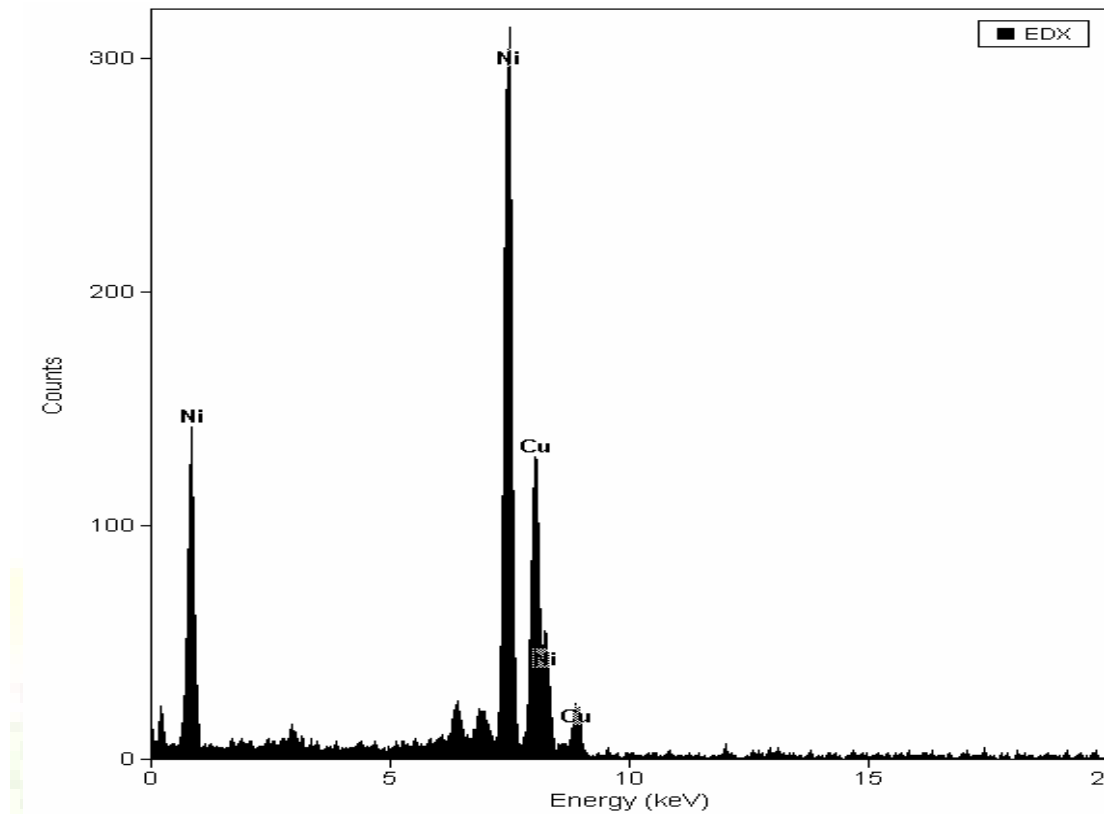


(a) at the tip

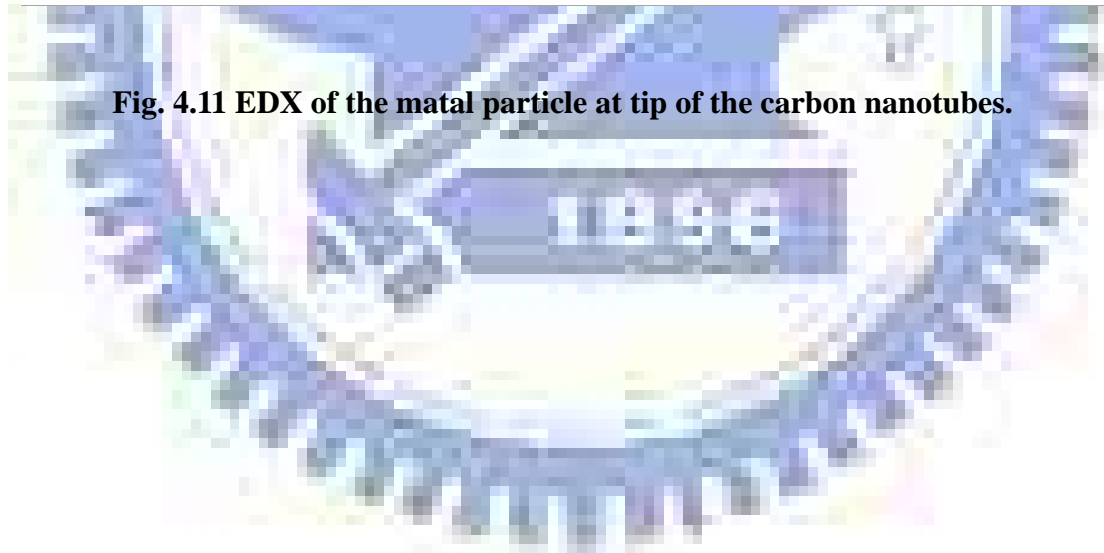


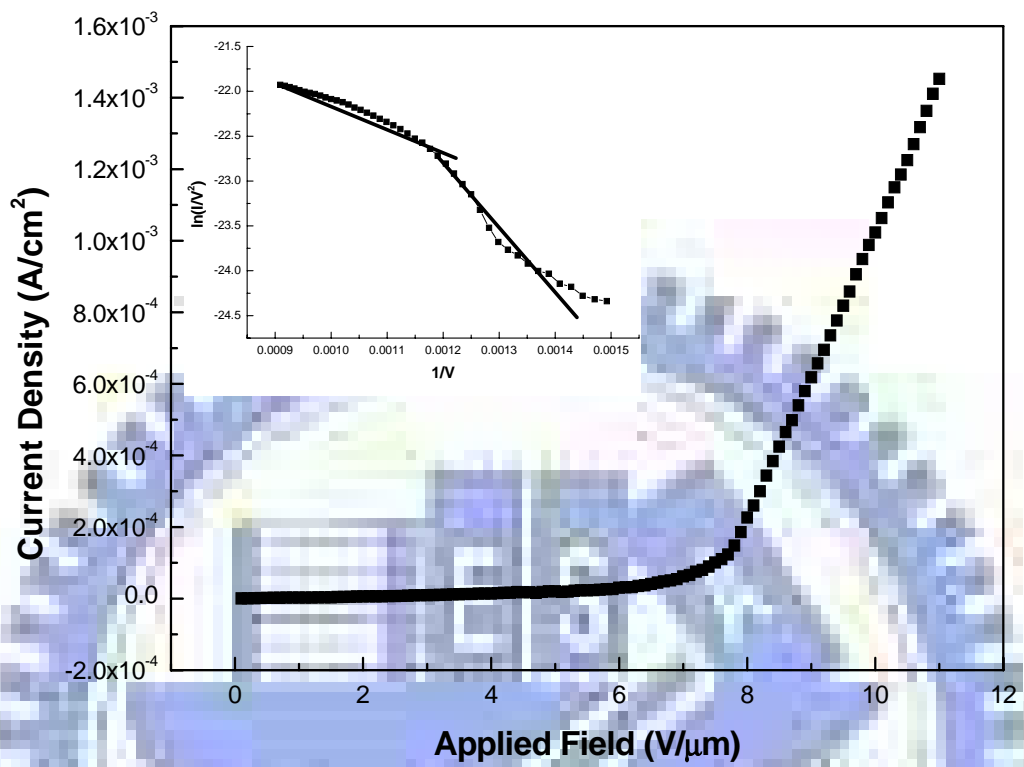
(b) at the body

**Fig. 4.10 HRTEM images of carbon nanotubes.**



**Fig. 4.11 EDX of the metal particle at tip of the carbon nanotubes.**





**Fig. 4.12** Field electron emission properties of CNTs by solution deposition method on diode structure.

## 4.2 Sol-Gel Method

### 4.2.1 Pretreatment Time of Hydrogen Plasma

Fig. 4.13 shows SEM images of as-deposited samples with catalysts synthesized by sol-gel method. The thickness of the specimen with Ag cathode and Ni catalysts was about 5.5  $\mu\text{m}$ . We can see many holes on the surface of the sample and only some catalysts presented on the holes or near the holes. Prior to the deposition of carbon nanotubes, the catalytic seeds were formed by  $\text{H}_2$  plasma treatment under the power of 150 W and the work pressure of 6 Torr.

Fig. 4.14 represented the SEM pictures of the surface morphology of the catalytic layer treated by microwave hydrogen plasma for 5 min, 15 min, 30 min and 45 min. The layer was transformed into catalytic and the size of particles increased with the increase of treatment time. The reason was that the catalysts embedded in the surfactant were present after hydrogen plasma bombarded the surface of the specimen. For compared with the specimens synthesized by solution deposition method, we fixed the condition of hydrogen treatment of specimens with catalysts synthesized by sol-gel method. The condition of hydrogen treatment was the growth time of 5 min under 150 W and 6 Torr.

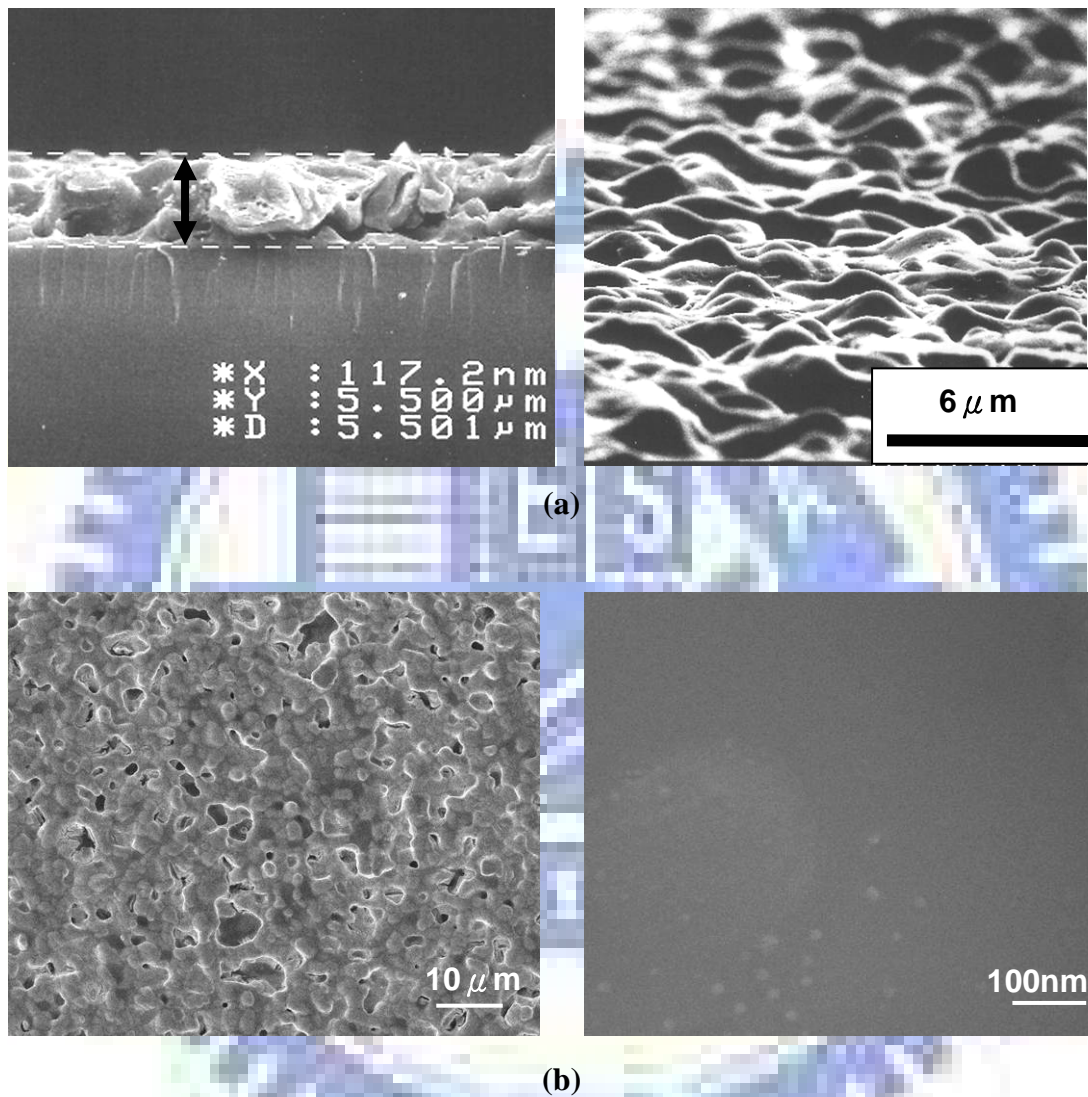
### 4.2.2 Effect of Methane Concentration

Fig. 4.15 presents the SEM images of various  $\text{H}_2/\text{CH}_4$  ratio for 30 min under fixing the methane flow rate, the hydrogen flow rate was changed from 40 sccm to 10 sccm. As the concentration of carbon source increases, the diameter and the length also increase in our experiments. The graphitized carbon nanotubes were uniformly grown on a large area with high density.

In fig. 4.16 it showed the Raman data. The  $I_D/I_G$  ratio decreased with increasing methane concentration. This result was the same with section 4.1.2. It implied the



amorphous carbonaceous adhered to wall and defective structure in multiwall layer decreased.



**Fig. 4.13 SEM images of the as-deposited specimens with catalyst synthesized by screen printing method. (a) cross-section view; (b) top view.**