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## Synthesis of Multi-walled Carbon Nanotubes and Nanofibers on a Catalytic Metal Substrate Using an Ethylene Inverse Diffusion Flame as a Heat Source

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**Key Words:** Flame Synthesis( ), Multi-walled Carbon Nanotubes( ), Carbon Nanofibers( ), Catalytic Metal Substrate( )

### Abstract

Synthesis of carbon nanotubes and nanofibers on a catalytic metal substrate, using an ethylene fueled inverse diffusion flame, was investigated. Multi-walled carbon nanotubes, with diameters of 20 - 60nm, were formed on the substrate coated with nickel-nitrate in the region of 5 - 6mm from the flame center along the radial direction. The gas temperature for this region was ranging from about 1400 to 900K. Nickel particles originated from the coated nickel-nitrate on the substrate were the major catalyst for the formation of the nanomaterials. HR-TEM and Raman spectrum revealed that synthesized carbon nanotubes had multi-walled structures with some defective graphite layers at walls.

1. 가 (doping) , Yuan (graphite layers) , (1,2) 가 가 , Vander Wal (3,4) (fuel riched) TEM 가 Yuan (1,2)

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가

가

2.

( ) ,

Fig. 1

(soot

particles)

가

11mm 94mm

“Santoro”

가

MFC(mass flow

controllers, MKS Co.)

(99 % )

가

0.8 lpm(liters per minute),

5 lpm 30 lpm

가

가 20mm

(blue flame)

(substrate)

0.2mm

가

$Ni(NO_3)_2 \cdot 6H_2O$

(SUS304)

2.5mm

(nickel nitrate, hexahydrate)

, Fig. 1

(deposition)

(flame front)

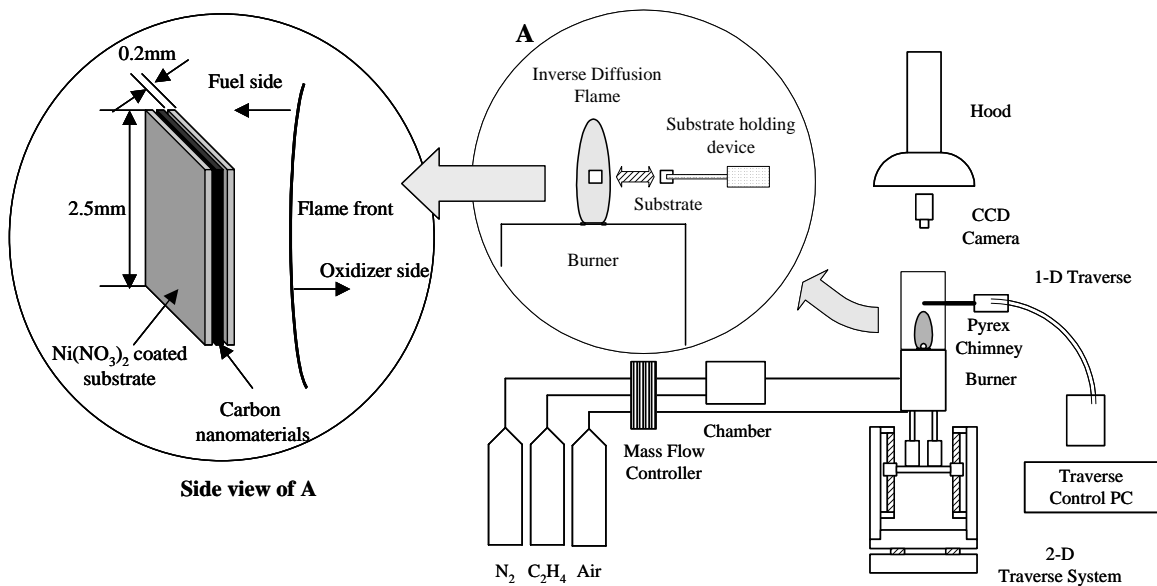
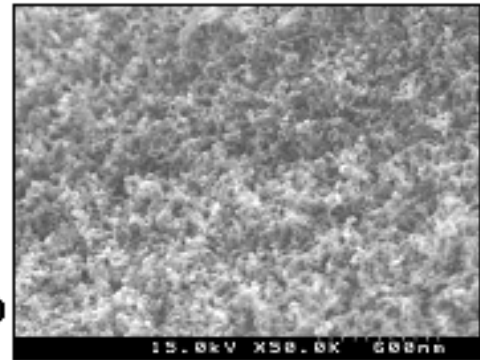


Fig. 1 Schematics of the experimental setup and flame geometry

6.5mm

a)

(tip) 10mm



(a)

가

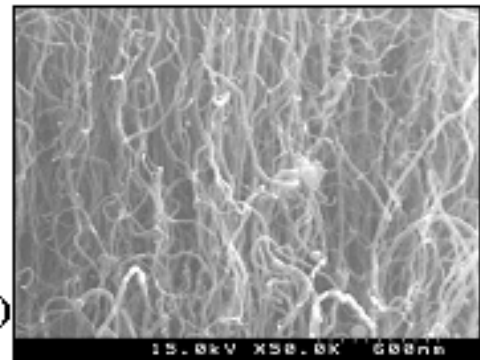
4mm

7mm

0.5mm

120

(6,7)



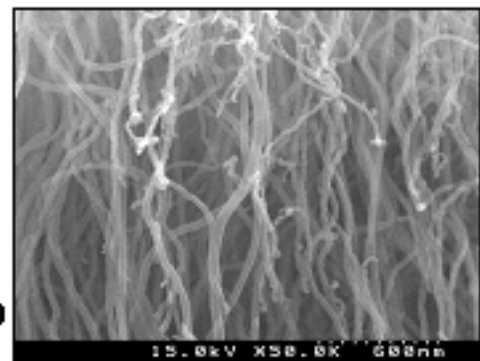
(b)

3.

4.0mm

7.0mm

, Fig. 2



(c)

. Fig. 2 SEM  
6.5, 6.0, 5.5, 5.0mm

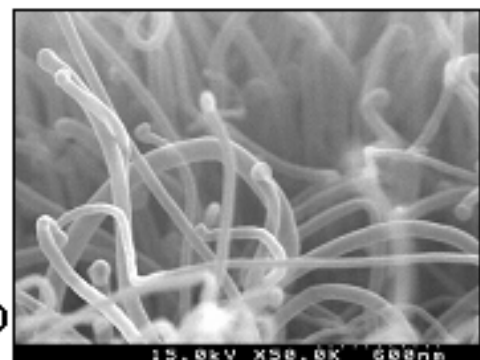
5

SEM  
20 - 60nm 가  
 $\mu m$  10  $\mu m$

가

. SEM

가



(d)

가

5.0mm

d)

가

가

5.5mm

6.0mm

c)

b)

Fig. 2 50K magnified SEM images of nanomaterials formed on a substrate, a) r=6.5, b) r=6.0, c) r=5.5, d) r=5.0mm

layers) 가 (graphite 6.0mm , Fig. 3 TEM 가 , 6.5mm , Fig. 3 TEM hollow) 가 (inside (multi-walled) , 5.0mm , 4.5mm SEM TEM Fig. 4 가 HR(high-resolution)-TEM (tree-branch-shaped) 가 25nm 가 (multi-walled) (tip) 가 EDS (energy dispersive x-ray spectrometer) TEM - EDS (Fe, iron) Fig. 3 HR-TEM 15 - 18 (graphite layers) EDS (nanotube body) 가 (carbon 가 가 clusters) (amorphous) (Fe) EDS 5.0, 5.5,

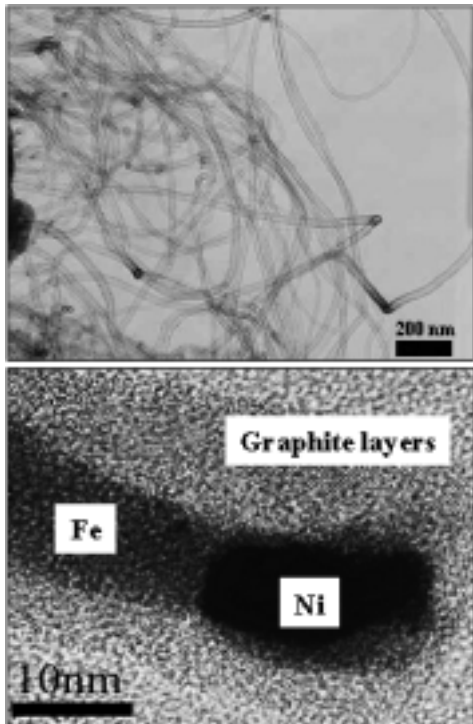


Fig. 3 TEM and HR(high resolution) TEM images of carbon nanotubes formed on a substrate, r=5.5mm

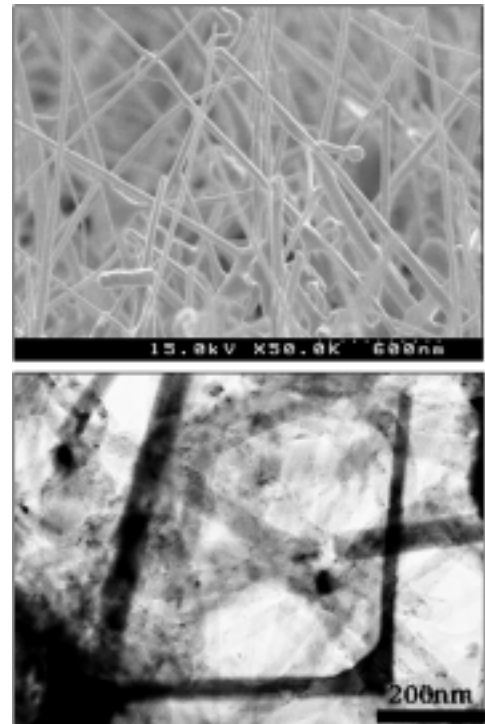


Fig. 4 50K magnified SEM and TEM image of iron(Fe) nanorods formed on a substrate, r=4.5mm

가 가 가 3mm  
 가 (visual flame front) 가  
 3.5mm 4.0mm 4.5mm 4.0mm 7.0mm 1000  
 가 가 가  
 , 1400K 900K , 900K  
 가 700K (Fe)  
 (iron nanorods),  
 Fig. 5 SEM TEM 가 , Fig. 3 HR-TEM  
 R- (Pt - Pt/13%Rd) (substrate)  
 FT-Raman  
 (rapid insertion measurement technique) (inVia Raman Microscopy, Renishaw  
 .(8,9) (flame Inc.) 10 $\mu$ m  
 front) 3.5 - 4.0mm  
 1650K 가 514.5nm  
 2300K Fig. 6 FT-Raman  
 Tangential  
 C-C stretching 1,595cm<sup>-1</sup>  
 G(graphite) peak  
 1,355cm<sup>-1</sup>  
 D(defect) peak  
 (graphite layers)  
 (interface) (defects) (carbon  
 가 1,400K 900K clusters)

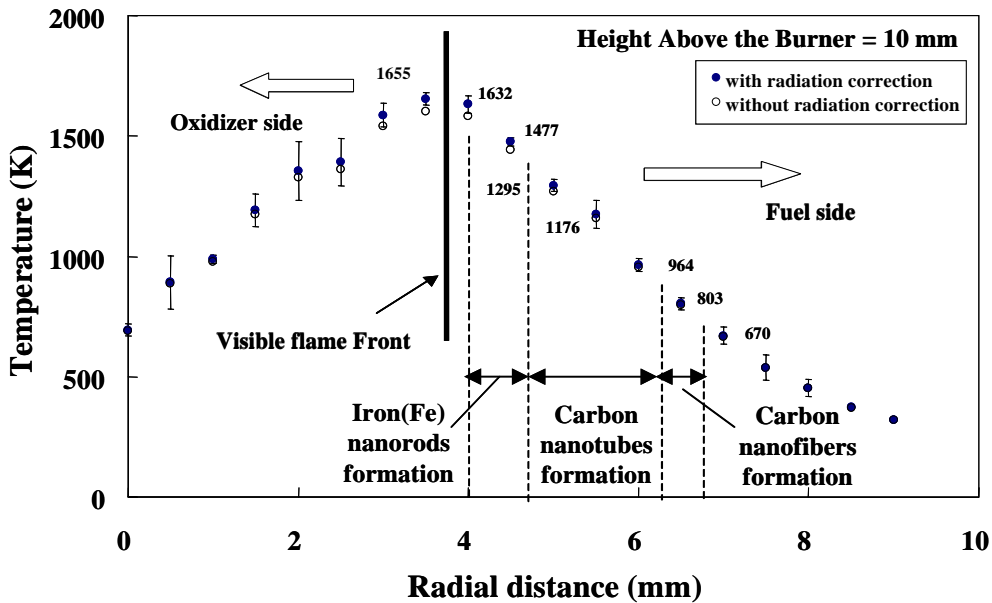


Fig. 5 Temperature distributions showing three formation regions

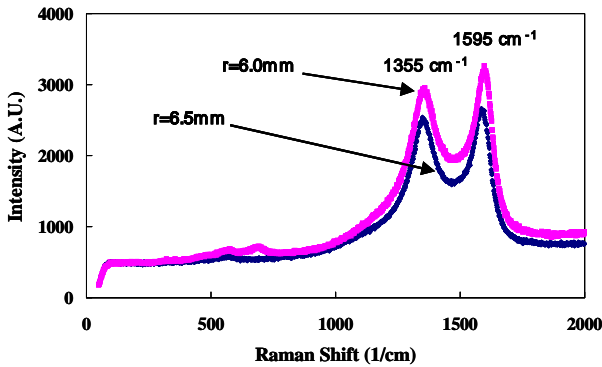


Fig. 6 FT-Raman spectrum of carbon nanotubes formed on a substrate

4.

(SUS304)

1400K 900K

, Fe- (nanorods) 가  
10nm  
80nm  
SEM TEM  
20 - 60nm 가

( : 2003-41-D00358)

(KIST)

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