

Table 4-1 Features of the nanostructures and their properties (for different deposition times)

Specimen designation	The as-deposited nanostructures			Morphology	I_D/I_G	$E_{\text{turn-on}}$ (V/ μm) at 1mA/cm ²	β
	Height (CNCs) +	Base	Number				
	Height (CNFs) (nm)	diameter (nm)	density (G/inch ²)				
A1	---	---	---	Trace deposition (Fig. 4-1(a))	1.91	---	---
A2	109+0	66	44	CNCs (Fig. 4-1(b))	1.77	---	---
A3	178+0	84	34	CNCs (Fig. 4-1(c))	1.85	---	---
A4	341+0	161	28	CNCs (Fig. 4-1(d))	1.77	~0.63	~70205
A5	393+91	174	22	CNFs on CNCs (Fig. 4-1(e))	1.76	~0.39	~70705
A6	894+x	383	8	Dense CNFs on CNCs (Fig. 4-1(f))	2.15	---	---
B1	---	---	---	Trace deposition (Fig. 4-2(a))	1.76	---	---
B2	50+0	49	69	CNCs (Fig. 4-2(b))	1.88	---	---
B3	193+0	121	33	CNCs (Fig. 4-2(c))	1.86	---	---
B4	400+0	160	29	CNCs (Fig. 4-2(d))	1.72	~0.53	~75595
B5	637+147	287	18	Trace CNFs on CNCs (Fig. 4-2(e))	1.65	~0.24	~21389
B6	1061+x	295	x	Dense CNFs on CNCs (Fig. 4-2(f))	1.81	---	---
C1	---	---	---	Trace deposition (Fig. 4-3(a))	1.82	---	---
C2	83+0	42	92.5	CNCs (Fig. 4-3(b))	1.93	---	---
C3	144+45	73	75	CNFs on CNCs (Fig. 4-3(c))	1.65	~0.56	~20095
C4	547+200	157	38	CNFs on CNCs (Fig. 4-3(d))	1.59	~0.18	~75605
C5	843+303	268	22	CNFs on CNCs (Fig. 4-3(e))	1.38	~0.39	~30423
C6	1400+x	406	x	Trace CNFs on damaged CNCs (Fig. 4-3(f))	2.10	---	---

---: No values could be observed. ; x: The values could not be estimated.

Table 4-2 Features of the carbon nanostructures and their properties (for different working pressures)

Specimen designation	The as-deposited carbon nanostructures			Morphology	I _D /I _G
	Height (CNCs) + Height (CNFs) (nm)	Base diameter (nm)	Number density (G/inch ²)		
A7	816+116	153	24	CNFs on CNCs (Fig.4-10 (a) 、(b))	1.75
A8	369+143	103	28	CNFs on CNCs (Fig.4-10 (c) 、(d))	1.69
A9	0 +78	41	x	Short CNFs no CNCs (Fig.4-10 (e) 、(f))	1.73
B7	350+166	121	42.5	CNFs on CNCs (Fig.4-11 (a) 、(b))	1.61
B8	166+181	94	47.5	CNFs on CNCs (Fig.4-11 (c) 、(d))	1.68
B9	0+134	59	30	Short CNFs no CNCs (Fig.4-11 (e) 、(f))	1.75
C7	516+290	147	33	CNFs on CNCs (Fig.4-12 (a) 、(b))	1.39
C8	334+1197	109	47	CNFs on CNCs (Fig.4-12 (c) 、(d))	1.46
C9	---	---	---	Catalyst-embedded carbon film (Fig.4-12 (e) 、(f))	1.58

---: No values could be observed.

x: The values could not be estimated.

Table 4-3 Features of the carbon nanostructures and their properties (for different H₂/CH₄ flow ratios)

The as-deposited carbon nanostructures		
Specimen designation	Morphology	I_D/I_G
E1	CNCs (Fig. 4-13 (a))	1.88
E2	Carbon film on CNCs (Fig. 4-13 (b))	1.78
E3	Carbon film on CNCs and trace CNTs growth (Fig. 4-13 (c))	1.65
E4	Tubule-like CNTs and catalyst-embedded carbon film (Fig. 4-13 (d))	1.52
E5	CNTs and catalyst-embedded carbon film (Fig. 4-13 (e))	0.66
E6	CNTs and catalyst-embedded carbon film (Fig. 4-13 (f))	1.43
E7	CNTs and fewer catalyst-embedded carbon film (Fig. 4-13 (g))	1.26
E8	Spaghetti-like CNTs (Fig. 4-13 (h))	1.06
F1	CNCs (Fig. 4-14 (a))	1.99
F2	Carbon film on CNCs (Fig. 4-14 (b))	1.76
F3	Carbon film on CNCs and trace CNTs growth (Fig. 4-14 (c))	1.20
F4	Tubule-like CNTs and catalyst-embedded carbon film (Fig. 4-14 (d))	1.06
F5	CNTs and catalyst-embedded carbon film (Fig. 4-14 (e))	0.79
F6	CNTs and catalyst-embedded carbon film (Fig. 4-14 (f))	1.24
F7	CNTs and fewer catalyst-embedded carbon film (Fig. 4-14 (g))	1.21
F8	Spaghetti-like CNTs (Fig. 4-14 (h))	1.31
G1	CNCs (Fig. 4-15 (a))	2.03
G2	Carbon film on CNCs (Fig. 4-15 (b))	1.89
G3	Carbon film on shorter CNCs (Fig. 4-15 (c))	1.68
G4	Carbon film on catalysts (Fig. 4-15 (d))	1.49
G5	CNTs and catalyst-embedded carbon film (Fig. 4-15 (e))	0.91
G6	CNTs and catalyst-embedded carbon film (Fig. 4-15 (f))	1.19
G7	CNTs and catalyst-embedded carbon film (Fig. 4-15 (g))	1.20
G8	Spaghetti-like CNTs (Fig. 4-15 (h))	1.32

Table 4-4 Features of the carbon nanostructures and their properties (for $H_2/CH_4 = 0/1$ (sccm/sccm))

Specimen designation	The as-deposited carbon nanostructures		$E_{turn-on}$ (V/ μm) at 1 mA/cm ²	β
	Morphology	I_D/I_G		
H1	Carbon film (Fig. 4-16 (a))	2.03	---	---
H2	Carbon film and trace CNTs (Fig. 4-16 (b))	2.00	---	---
H3	Fewer carbon film and short CNTs (Fig. 4-16 (c))	1.83	---	---
H4	Catalyst-embedded carbon film and CNTs (Fig. 4-16 (s))	1.72	---	---
H5	Bamboo-like CNTs (Fig. 4-16 (e))	1.01	---	---
H6	Catalyst-embedded carbon film and CNTs (Fig. 4-16 (f))	1.78	---	---
H7	Catalyst-embedded carbon film (Fig. 4-16 (g))	2.55	---	---
I1	Carbon film (Fig. 4-17 (a))	2.07	---	---
I2	Catalyst-embedded carbon film (Fig. 4-17 (b))	1.72	---	---
I3	Catalyst-embedded carbon film and CNTs (Fig. 4-17 (c))	1.77	---	---
I4	Short CNTs (Fig. 4-17 (d))	1.73	~7.76	---
I5	Bamboo-like CNTs (Fig. 4-17 (e))	1.66	~5.00	~912
I6	Well-aligned CNTs (Fig. 4-17 (f))	1.66	~5.61	~841
I7	Catalyst -embedded carbon film and spaghetti-like CNTs (Fig. 4-17 (g))	1.81	~9.98	---
J1	Carbon film (Fig. 4-18 (a))	2.02	---	---
J2	Carbon film and trace CNTs growth (Fig. 4-18 (b))	1.89	---	---
J3	Carbon film and CNTs (Fig. 4-18 (c))	1.81	---	---
J4	Catalyst-embedded carbon film and CNTs (Fig. 4-18 (d))	1.76	---	---
J5	Catalyst-embedded carbon film and bamboo-like CNTs (Fig. 4-18 (e))	1.69	---	---
J6	Catalyst-embedded carbon film and CNTs (Fig. 4-18 (f))	1.79	---	---
J7	Catalyst-embedded carbon film (Fig. 4-18 (g))	1.83	---	---

---: No values could be observed.

Table 4-5 Features of the nanostructures and their properties (for H₂/CH₄ =100/0 (sccm/sccm))

Specimen designation	The as-deposited nanostructures		Morphology
	Length (nm)	Number density (G/inch ²)	
K1	---	---	Catalysts particles (Fig. 4-19 (a))
K2	---	---	Catalysts particles (Fig. 4-19 (b))
K3	---	---	Catalysts particles (Fig. 4-19 (c))
K4	42	30.4	Si nanostructures with ~42 nm height (Fig. 4-19 (d))
K5	178	11.6	Si nanostructures with ~178 nm height (Fig. 4-19 (e))
K6	254	6.0	Si nanostructures with ~254 nm height (Fig. 4-19 (f))
L1	---	---	Catalyst film (Fig. 4-20 (a))
L2	---	---	Catalysts particles (Fig. 4-20 (b))
L3	72	---	Si nanostructures with ~72 nm height (Fig. 4-20 (c))
L4	100	37.0	Si nanostructures with ~100 nm height (Fig. 4-20 (d))
L5	158	10.2	Si nanostructures with ~158 nm height (Fig. 4-20 (e))
L6	162	8	Si nanostructures with ~162 nm height (Fig. 4-20 (f))
M1	---	---	Catalysts particles with ~30nm diameter (Fig. 4-21 (a))
M2	---	---	Catalysts particles with ~42nm diameter (Fig. 4-21 (b))
M3	---	---	Catalysts particles with ~44nm diameter (Fig. 4-21 (c))
M4	90	29.8	Si nanostructures with ~90 nm height (Fig. 4-21 (d))
M5	114	6.4	Si nanostructures with ~114 nm height (Fig. 4-21 (e))
M6	182	x	Si nanostructures with ~183 nm height (Fig. 4-21 (f))

---: No values could be observed.

x: The values could not be estimated.

Table 4-6 Features of the nanostructures and their properties (for Specimens A5, B5, and C5 after different H-plasma post-treatment times)

Specimen designation	Post-treatment condition	The post-treated nanostructures		I_D/I_G	$E_{turn-on}$ (V/ μm) at 1 mA/cm ²	β
		Length (CNCs + CNFs) (nm)	Morphology			
		A5	Post1			
A5	Post2	358+x	Trace CNFs on CNCs (Fig. 4-25 (b))	2.28	~0.59	~19603
A5	Post3	313+0	Damaged CNCs, no CNFs (Fig. 4-25 (c))	2.14	---	---
A5	Post4	285+0	Damaged CNCs, no CNFs (Fig. 4-25 (d))	1.94	---	---
A5	Post5	757+0	Damaged CNCs, CNFs (Fig. 4-25 (e))	1.95	---	---
A5	Post6	892+0	Damaged CNCs,CNFs (Fig. 4-25(f))	1.96	---	---
B5	Post1	697+0	CNCs (Fig. 4-26 (a))	1.79	---	---
B5	Post2	571+0	CNCs (Fig. 4-26 (b))	1.87	~0.40	~18395
B5	Post3	429+0	Damaged CNCs (Fig. 4-26 (c))	2.28	---	---
B5	Post4	256+0	Damaged CNCs (Fig. 4-26 (d))	2.08	---	---
B5	Post5	519+0	Damaged CNCs (Fig. 4-26 (e))	2.10	---	---
B5	Post6	x	Damaged CNCs (Fig. 4-26 (f))	2.21	---	---
C5	Post1	827+162	CNFs on CNCs (Fig. 4-27 (a))	2.21	---	---
C5	Post2	766+79	Damaged CNFs on CNCs (Fig. 4-27 (b))	2.44	~0.81	~10061
C5	Post3	678+0	Trace CNFs on damaged CNCs (Fig. 4-27 (c))	2.23	---	---
C5	Post4	537+0	Damaged CNCs, no CNFs (Fig. 4-27 (d))	2.21	---	---
C5	Post5	962+0	Damaged CNCs, no CNFs (Fig. 4-27 (e))	2.22	---	---
C5	Post6	1617+0	Damaged CNCs, no CNFs (Fig. 4-27 (f))	2.33	---	---

---: No values could be observed.

x: The values could not be estimated.

Table 4-7 Features of the nanostructures and their properties (for Specimens H4, I4, and J4 after different H-plasma post-treatment times)

Specimen designation	Post-treatment condition	Morphology	I_D/I_G
H4	Post1	CNTs-embedded carbon film (Fig. 4-29(a))	1.39
H4	Post2	CNTs-embedded carbon film (Fig. 4-29(b))	1.48
H4	Post3	Short CNTs (Fig. 4-29(c))	1.17
H4	Post4	Damaged CNTs and Si nanocones (Fig. 4-29(d))	1.43
H4	Post5	Damaged CNTs and Si nanocones (Fig. 4-29(a))	1.52
H4	Post6	Damaged CNTs and Si nanocones (Fig. 4-29(f))	2.12
I4	Post1	CNTs-embedded carbon film (Fig. 4-30(a))	1.61
I4	Post2	Shorter CNTs (Fig. 4-30(b))	1.50
I4	Post3	Short CNTs (Fig. 4-30(c))	1.08
I4	Post4	Damaged CNTs and Si nanocones (Fig. 4-30(d))	1.35
I4	Post5	Damaged CNTs and Si nanocones (Fig. 4-30(e))	1.83
I4	Post6	Damaged CNTs and Si nanocones (Fig. 4-30(f))	2.09
J4	Post1	CNTs-embedded carbon film (Fig. 4-31(a))	1.54
J4	Post2	CNTs-embedded carbon film (Fig. 4-31(b))	1.47
J4	Post3	Damaged CNTs and Si nanocones (Fig. 4-31(c))	1.40
J4	Post4	Damaged CNTs and Si nanocones (Fig. 4-31(d))	1.42
J4	Post5	Damaged CNTs and Si nanocones (Fig. 4-31(e))	2.06
J4	Post6	Damaged CNTs and Si nanocones (Fig. 4-31(f))	2.27