Supplementary Information

Single-walled carbon nanotubes synthesized by laser ablation from coal for field-effect transistors

Shaochuang Chen[a], Yuguang Chen[a], Haitao Xu[b,c,e], Min Lyu[a], Xinrui Zhang[a], Zhen Han[a], Haoming Liu[a], Yixi Yao[a], Chi Xu[a], Jian Sheng[a], Yifan Xu[a], Lei Gao[e], Ningfei Gao[e], Zeyao Zhang[a,b,c,*], Lian-mao Peng[b] and Yan Li[a,b,d,*]

a. Beijing National Laboratory for Molecular Science, Key Laboratory for the Physics and Chemistry of Nanodevices, State Key Laboratory of Rare Earth Materials Chemistry and Applications, College of Chemistry and Molecular Engineering, Peking University, Beijing 100871, China

b. Institute for Carbon-Based Thin Film Electronics, Peking University, Shanxi, Taiyuan 030012, China

c. Institute of Advanced Functional Materials and Devices, Shanxi University, Taiyuan 030031, China

d. PKU-HKUST ShenZhen-HongKong Institution, Shenzhen 518057, China

e. Beijing Institute of Carbon-based Integrated Circuits, Beijing 100195, China

*: yanli@pku.edu.cn, zeyaozhang@pku.edu.cn.

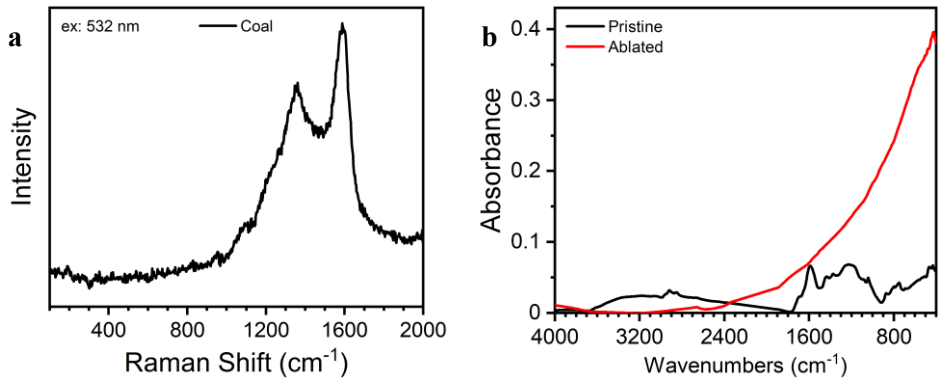

Figure S1. Characterizations of the coal used in the experiment. (a) Raman spectrum of the pristine coal, excitation wavelength: 532 nm. (b) IR spectra of the pristine coal (black) and the coal after ablation (red).

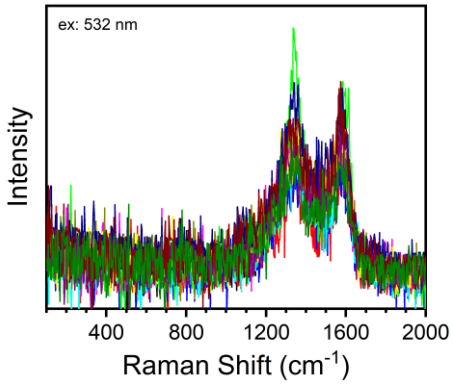

Figure S2. Raman spectra of the product of the ablation of coal without catalyst. Excitation wavelength: 532 nm.

Table S1. Element composition of the pristine coal and graphite. (wt%)

	C	O	H	N	Ca	Fe	S	Si	Al
Coal	72.1	18.6	4.7	0.77	0.48	0.21	0.20	0.19	0.13
Graphite	98.8	0.43	0.40	0	0.01	0	0.05	0.04	0.03

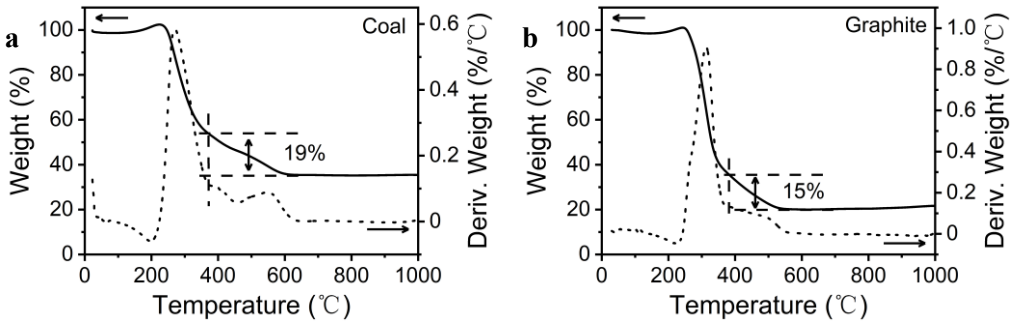

Figure S3. Thermogravimetry analysis of the product by LA from different carbon source. Carbon source: coal (a) and graphite (b).

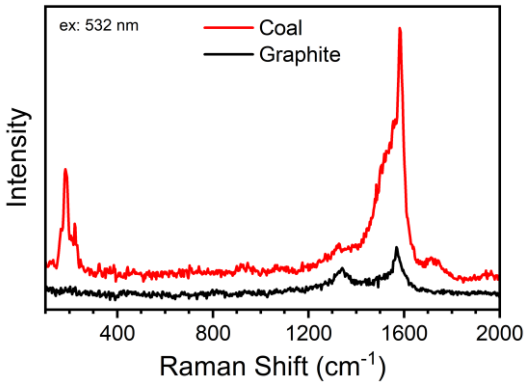

Figure S4. Raman spectra of the product synthesized at 1123 K. Red line: from coal, black line: graphite, excitation wavelength: 532 nm.

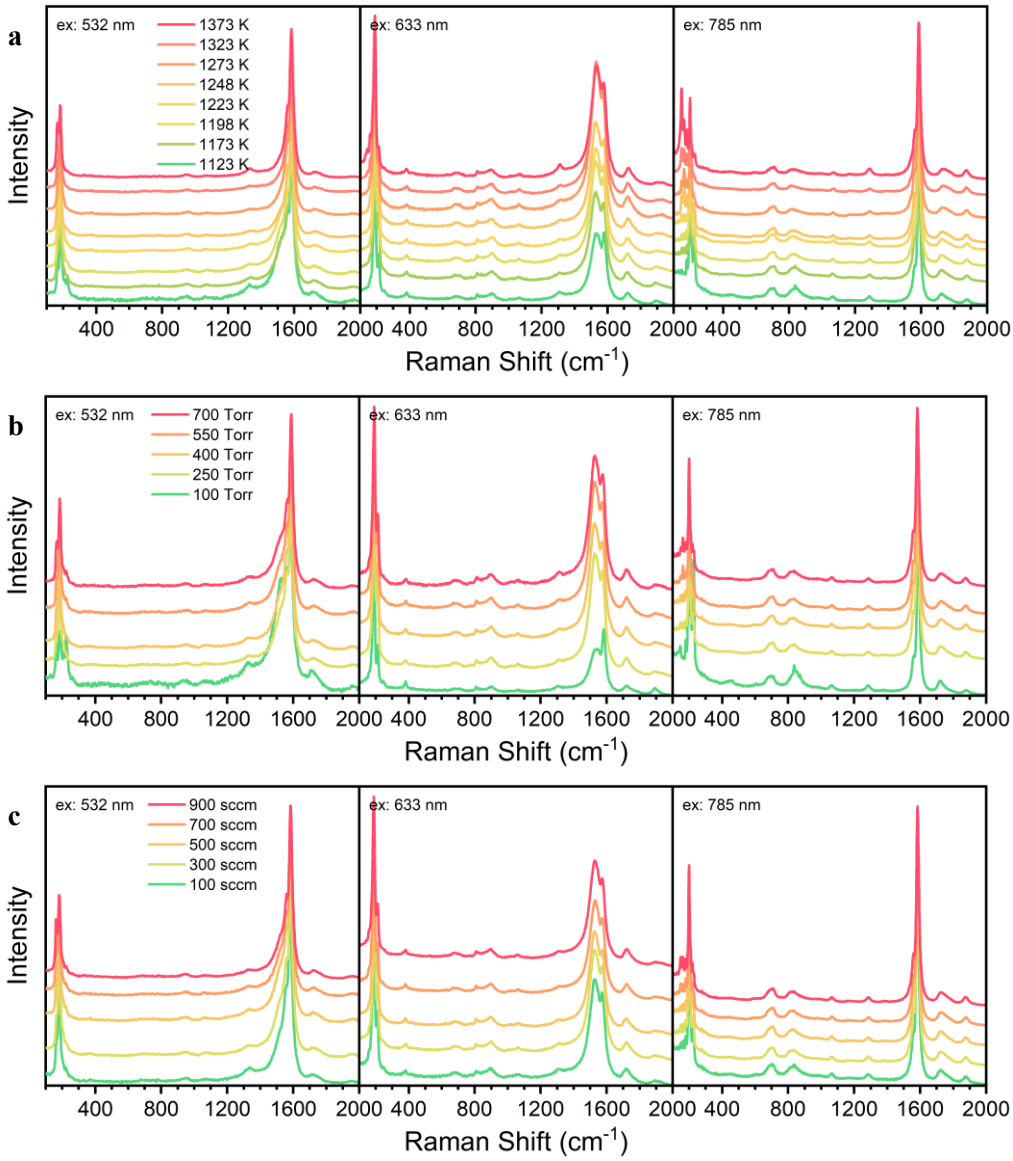

Figure S5. Full Raman spectra of SWCNTs under different conditions. (a) Temperature. (b) Pressure. (c) Ar flow rate. Excitation wavelength: 532 nm (left), 633 nm (middle), and 785 nm (right).

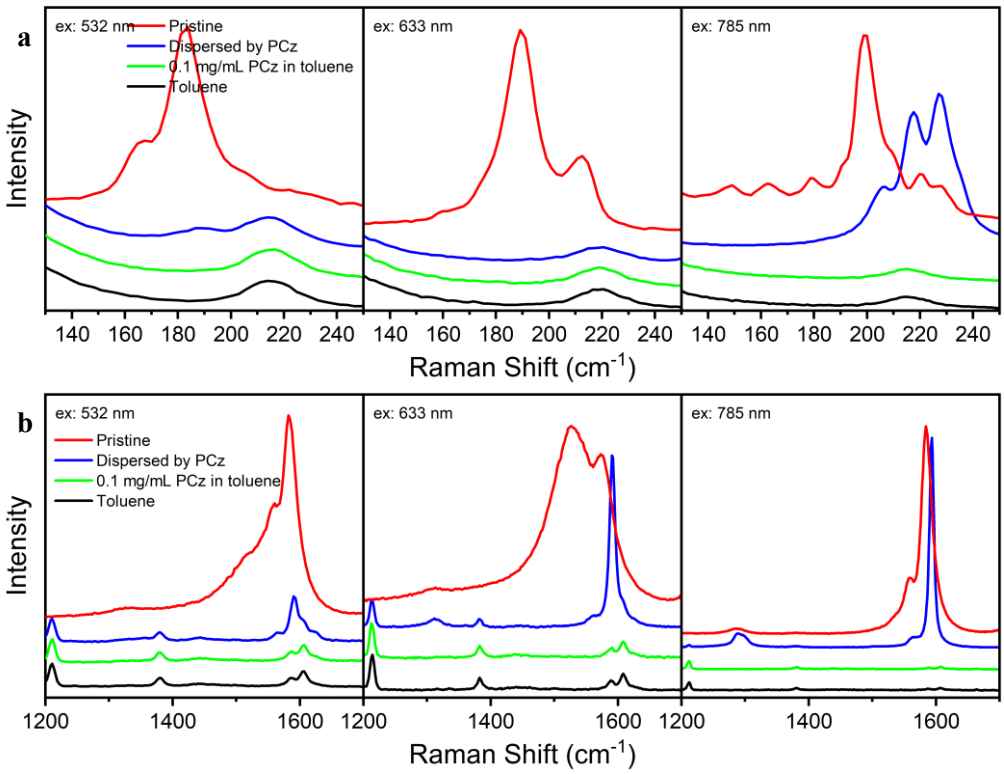

Figure S6. Comparison between the Raman spectra of SWCNT dispersion by PCz in toluene and that of pristine SWCNTs. The region of RBM (a) and the region of D-band and G-band (b) of the Raman spectra of toluene (black line), 0.1 mg/mL PCz in toluene (green line), SWCNT dispersion by PCz in toluene (blue line) and pristine SWCNTs (red line), excitation wavelength: 532 nm (left), 633 nm (middle), and 785 nm (right). The Raman spectra of 0.1 mg/mL PCz in toluene (green line) is almost the same as that of toluene (black line). The concentration of PCz in the dispersion is much lower than 0.1 mg/mL as excess PCz has been removed, which means that the Raman spectra of PCz have almost no influence on the Raman spectra of the dispersion.

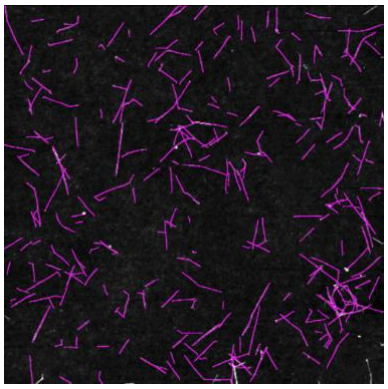

Figure S7. AFM image of the sparse SWCNT film on the Si substrate used for the measurement of length, size: 3 μm.

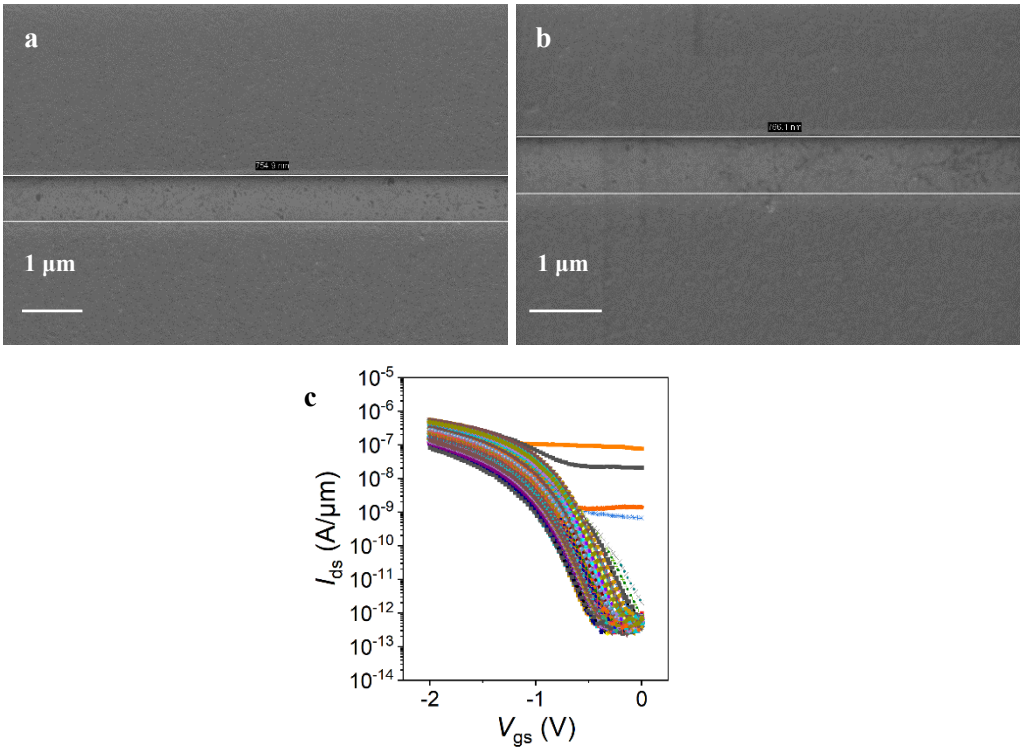

Figure S8. Characterizations of the FETs fabricated by SWCNTs synthesized from coal. SEM images (a, b) of the channel of FETs, scale bar: 1 μm. Transfer characteristic curves (c) of all 222 FETs.

PHASE_6.4: mixed solution of PEG (6 kDa), DX (70 kDa) and H_2O with weight ratio of 8:14:78.
ET_A: top phase extracted from 960 μL PHASE_6.4 and 480 μL H_2O.
ET_B: ET(0.4% SDS), top phase extracted from 960 μL PHASE_6.4, 29 μL 20% SDS and 451 μL H_2O.
ET_C: ET(0.6% SDS), top phase extracted from 960 μL PHASE_6.4, 43 μL 20% SDS and 437 μL H_2O.
ET_D: ET(0.8% SDS), top phase extracted from 960 μL PHASE_6.4, 58 μL 20% SDS and 422 μL H_2O.
ET_E: ET(0.8% SC), top phase extracted from 960 μL PHASE_6.4, 58 μL 20% SC and 422 μL H_2O.
ET_F: ET(0.8% SC + 0.4% SDS), top phase extracted from 960 μL PHASE_6.4, 58 μL 20% SC, 29 μL 20% SDS and 394 μL H_2O.
EB_A to EB_F are the bottom phase corresponding to ET_A to ET_F respectively.

Table S2. Detailed separation process of SWCNTs synthesized at 1373 K in DOC-SDS system.

Step	Blank phase (μL)	20% SDS (μL)	5% DOC (μL)	Operation
1	400 μL PHASE_6.4 + 12 μL 20% SDS + 188 μL dispersion			Vortex，centrifuge then extract 1T
2	300 (ET_B)			Vortex，centrifuge then extract 2T
3	300 (ET_B)			Vortex，centrifuge then extract 3T
4	300 (ET_B)		2.6	Vortex，centrifuge then extract 4T
5	300 (ET_B)	1.5	6	Vortex，centrifuge then extract 5T
6	300 (ET_B)	2.26	6	Vortex，centrifuge then extract 6T
7	300 (ET_C)		6	Vortex，centrifuge then extract 7T
8	300 (ET_C)	0.75	6	Vortex，centrifuge then extract 8T
9	300 (ET_C)	2.4	6	Vortex，centrifuge then extract 9T
10	300 (ET_C)	3.3	6	Vortex，centrifuge then extract 10T
11	300 (ET_C) + 150 (ET_A) + 150 (EB_A)	5.24	6	Vortex，centrifuge then extract 11T
12	450 (ET_C)		2.98	Vortex，centrifuge then extract 12T, left 12B

Table S3. Detailed separation process of SWCNTs synthesized at 1198 K in DOC-SDS system.

Step	Blank phase (μL)	20% SDS (μL)	5% DOC (μL)	Operation
1	400 μL PHASE_6.4 + 12 μL 20% SDS + 120 μL dispersion + 68 μL H_2O			Vortex，centrifuge then extract 1T
2	300 (ET_B)			Vortex，centrifuge then extract 2T
3	300 (ET_B)			Vortex，centrifuge then extract 3T
4	300 (ET_C)		6	Vortex，centrifuge then extract 4T
5	300 (ET_C)	1.5	6	Vortex，centrifuge then extract 5T
6	300 (ET_C)	3	6	Vortex，centrifuge then extract 6T
7	300 (ET_C)		3.6	Vortex，centrifuge then extract 7T
8	300 (ET_D)		4.8	Vortex，centrifuge then extract 8T
9	300 (ET_D)		2.4	Vortex，centrifuge then extract 9T
10	300 (ET_D)		2.4	Vortex，centrifuge then extract 10T, left 10B

Table S4. Detailed separation process of SWCNTs synthesized at 1373 K in SC-SDS system.

Step	Blank phase (μL)	20% SDS (μL)	10 mM NaClO (μL)	Operation
1	400 μL PHASE_6.4 + 60 μL dispersion + 140 μL H_2O			Vortex，centrifuge then extract 1T
2	300 (ET_E)			Vortex，centrifuge then extract 2T
3	300 (ET_E)			Vortex，centrifuge then extract 3T
4	300 (ET_E)			Vortex，centrifuge then extract 4T
5	300 (ET_F)			Vortex，centrifuge then extract 5T
6	300 (ET_F)	9	1.2	Vortex，centrifuge then extract 6B
7	300 (EB_F)	3	1.8	Vortex，centrifuge then extract 6TT, left 6TB

The absorption spectrum of 6TT is shown as S1 in Fig. 3b.

Table S5. Detailed separation process of SWCNTs synthesized at 1198 K in SC-SDS system.

Step	Blank phase (μL)	20% SDS (μL)	10 mM NaClO (μL)	Operation
1	400 μL PHASE_6.4 + 120 μL dispersion + 80 μL H_2O			Vortex，centrifuge then extract 1T
2	300 (ET_A)			Vortex，centrifuge then extract 2T
3	300 (ET_E)			Vortex，centrifuge then extract 3T
4	300 (ET_E)			Vortex，centrifuge then extract 4T
5	300 (ET_E)			Vortex，centrifuge then extract 5T
6	300 (ET_F)			Vortex，centrifuge then extract 6T
7	300 (ET_F)	9	2.4	Vortex，centrifuge then extract 7B
8	300 (EB_F)	3	4.8	Vortex，centrifuge then extract 7TT, left 7TB

The absorption spectrum of 7TT is shown as S2 in Fig. 3d.