Electronic Supplementary Information for "Improvement of SWCNT transparent conductive film properties via a transition metal doping route"

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1. Experimental set-up for SWCNT-TCF auto spray coating machine

The unique auto spray coating machine was fabricated for transparent conductive film (TCF) based on single-walled carbon nanotubes (SWCNTs). The machine can be automatically operated by the embedded program consisted of coating area, moving speed, strength of spray and bubble size. TCFs were formed on the 10 cm × 10 cm glass substrate coated by thin transparent polymers.

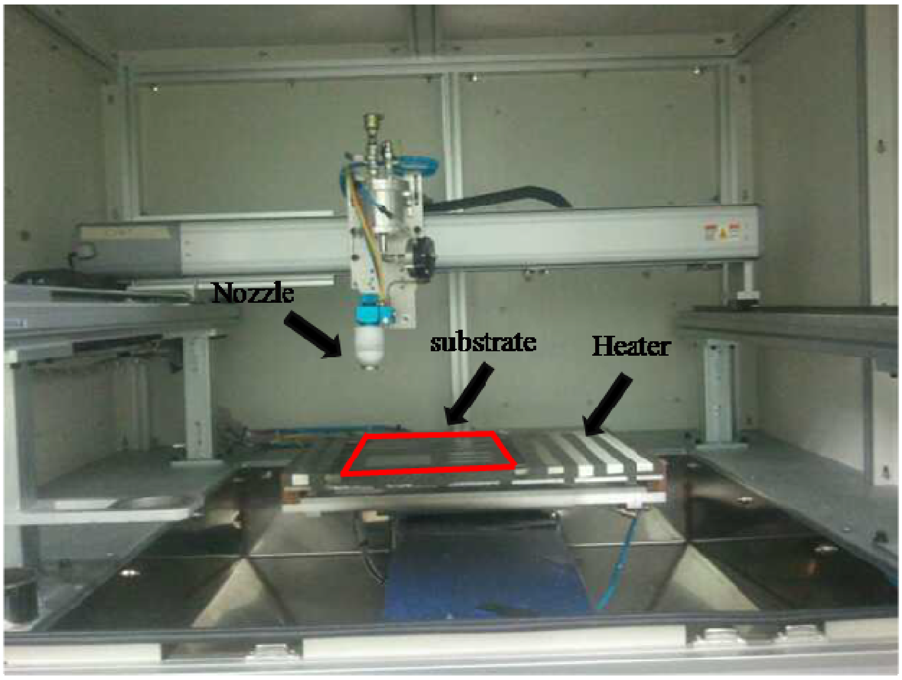

Figure S1. The automatic spray coating machine

2. Properties of SWCNTs synthesized by arc-discharged method

Table S1 shows two kinds of SWCNTs used in our research. When we used highly purified ASP-100F (hereafter hp-SWCNT) SWCNTs, high yield SWCNTs solution could be acquired after ultracentrifugation process. On the other hand, when we used thermally purified SA210 (hereafter tp-SWCNT) SWCNTs, good TCF properties could be acquired. The ratio between metallic and semiconducting SWCNTs was calculated from UV-Vis-NIR spectra. Semiconducting content in the tp-SWCNTs was higher than hp- SWCNTs as shown in Figure S2.

	Purity	Post-Treatment	Producer
ASP-100F	60~70 wt.% (90 vol.%)	Thermal and acid purification	Hanwha nanotech.
SA210	20~30 wt.%	Thermal treatment	Nano Solution

Table S1. Purity and post-treatment methods of two kinds of SWCNTs used in our research.

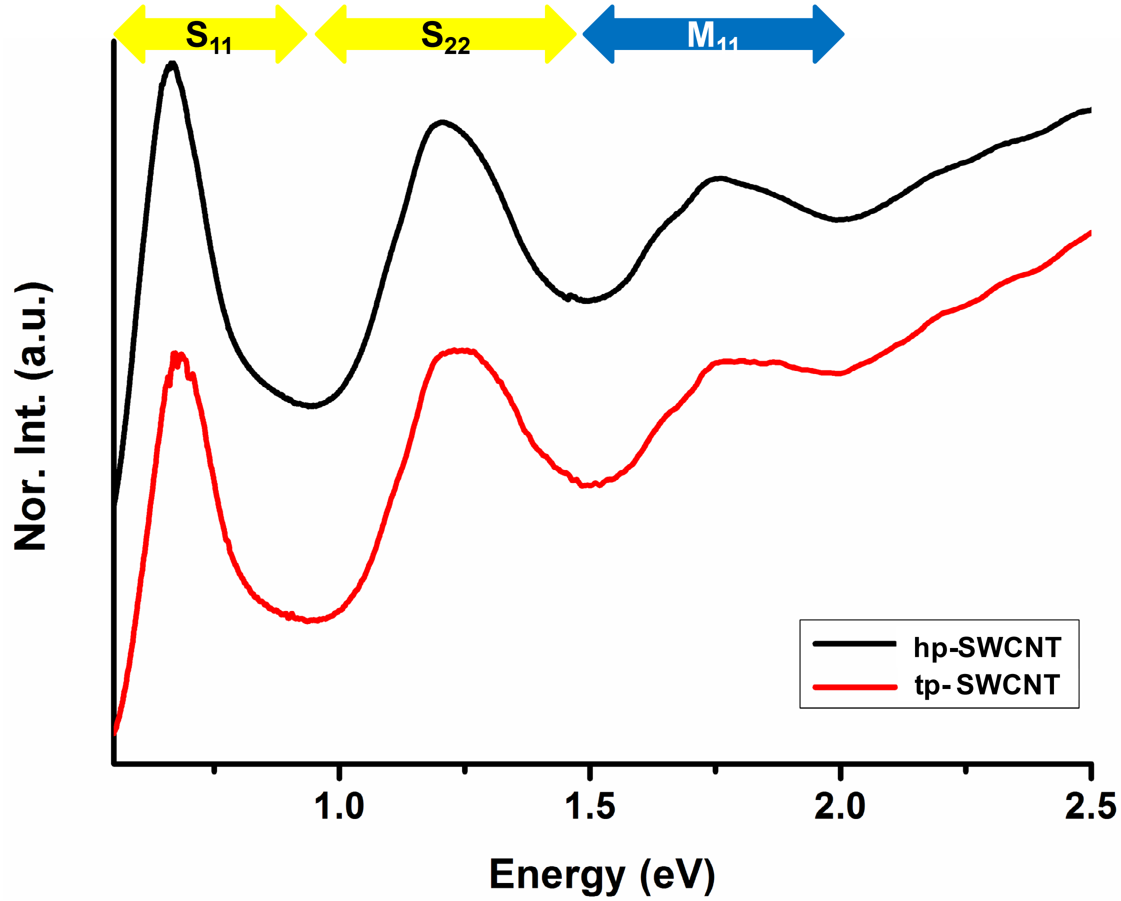

Figure S2. UV-Vis-nIR spectra of hp- and tp-SWCNTs; calculated *(m-)/(s-)* SWCNT ratio was 23.5 %/76.5 % in hp-SWCNTs and 15.3 %/84.7 % in tp-SWCNTs, respectively.

3. HR-TEM studies for metal doped SWCNT

The size of reduced metal particles on the SWCNTs was investigated by using HR-TEM. Increasing the concentration of Ni salt solution, the size of reduced Ni nanoparticles was increased slightly from 3 nm to 7 nm. However, the number of Ni nanoparticles on the SWCNT bundles was increased dramatically as the concentration of doping solution was increased.

In the case of 1mM Ni solution, reduced Ni nanoparticles were rarely observed. However, Ni nanoparticles of about 3 nm diameter were uniformly distributed on the surface of SWCNTs at 5 mM. The size of Ni nanoparticles was increased at 10 mM with smaller number of particles. In the case of 20 mM and 50 mM, the size of Ni nanoparticles was increased to about 7 nm diameters, and clusters of Ni nanoparticles appeared around SWCNT bundles.

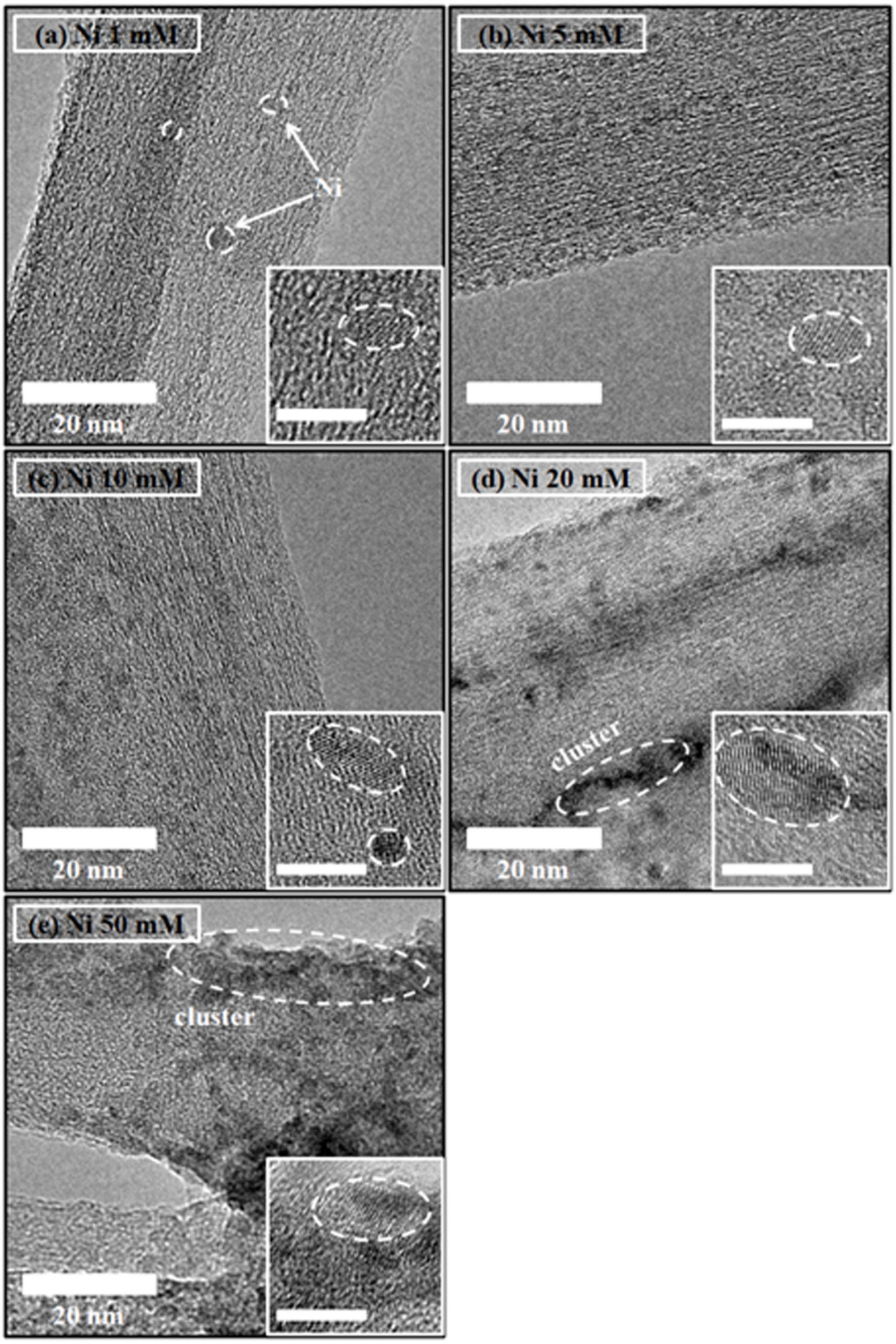

Figure S3. HR-TEM images of reduced Ni nanoparticles on hp-SWCNT bundles (inset scale bar is 5 nm) (a) reduced Ni nanoparticles at 1 mM of Ni solution, (b) at 5 mM of Ni solution, (c) at 10 mM of Ni solution, (d) at 20 mM of Ni solution, and (e) at 50 mM of Ni solution

4. Properties of SWCNT-TCF doped with Au, Pd, Ir, Ni and Co

Doping effects on the SWCNT network were also studied by using palladium and cobalt. The properties of SWCNT networks were also affected by Palladium (Pd) and Cobalt (Co). Transmittance line and conductivity line of hp_TCF doped with Pd and Co was similar to Ir and Ni doping line. Also tp_TCF properties were similar to Ir and Ni doped TCF properties. In order to estimate the influence on the TCF properties by metal reduction, 3 cases of starting TCF sample was prepared.

(a) Gold doped SWCNT TCF

hp-SWCNT	**Au doping**					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	96.43	1278.84	85.10	261.2	76.66	137.08
10 mM	93.93	349	83.81	91.9	73.59	49

(b) Pd doped SWCNT TCF

hp-SWCNT	**Pd doping**					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	96.43	1278.84	85.10	261.2	76.66	137.08
1 mM	95.48	729	85.73	193	76.76	98.8
5 mM	95.63	750	85.34	174.5	75.84	92.5
10 mM	95.07	698	84.94	166.5	76	99.1
20 mM	95.45	733	83.22	160.5	76	99.5
50 mM	94.84	785	82.12	136.5	74.42	85.9

(c) Ir doped SWCNT TCF

hp-SWCNT	**Ir doping**					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	96.43	1278.84	85.10	261.2	76.66	137.08
1 mM	95.24	665	84.85	181.5	74.7	86.6
5 mM	94.97	563	83.85	155	74.41	84.5
10 mM	94.2	489	83.1	117.3	73.26	64.2
20 mM	94.62	544	84.36	137.5	75.11	78.5
50 mM	94.26	621	83.09	133.3	74.06	73.3

(d) Ni doped SWCNT TCF

hp-SWCNT	Ni doping					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	96.43	1278.84	85.10	261.2	76.66	137.08
1 mM	94.88	747	85.11	178	74.38	90.4
5 mM	94.87	747	84.66	149	74.4	75
10 mM	94.7	726	83.81	146.6	75.24	89.7
20 mM	94.22	712	83.64	174.5	74.15	85.9
50 mM	92.76	834	82.25	182.5	74.06	99.1

(e) Co doped SWCNT TCF

hp-SWCNT	Co doping					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	96.43	1278.84	85.10	261.2	76.66	137.08
1 mM	95.27	698	85.24	216	75.52	105.4
5 mM	95.57	688	85.82	195.1	75.3	86.2
10 mM	94.7	593	84.51	158.1	75.6	82.7
20 mM	94.92	740	83.24	153.6	74.94	84.1
50 mM	93.94	719	82.92	152.5	73.9	87.9

(f) Gold doped SWCNT TCF

tp-SWCNT	**Au doping**					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	98.20	1805.67	94.10	767.33	83.29	277.67
10 mM	96.73	687	93.08	270	81.09	70.5

(g) Pd doped SWCNT TCF

tp-SWCNT	**Pd doping**					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	98.20	1805.67	94.10	767.33	83.29	277.67
1 mM	98.21	1344	93.67	399	82.72	139.3
5 mM	98.07	1201	94.02	363	82.49	129
10 mM	98	1417	93.36	384	83.17	129.1
20 mM	97.67	1295	93.05	415	82.15	126.7
50 mM	97.06	1455	92.27	383	81.54	116.6

(h) Ir doped SWCNT TCF

tp-SWCNT	**Ir doping**					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	98.20	1805.67	94.10	767.33	83.29	277.67
1 mM	98.08	1162	93.62	385	83.22	142.4
5 mM	98.05	1117	92.91	328	82.44	123.5
10 mM	97.26	1110	92.3	295	81.75	101.2
20 mM	97.57	1173	92.39	326	83	124.9
50 mM	96.56	1138	92.2	372	80.62	111.7

(i) Ni doped SWCNT TCF

tp-SWCNT	Ni doping					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	98.20	1805.67	94.10	767.33	83.29	277.67
1 mM	97.55	1044	93.85	406	83	113.4
5 mM	97.6	1138	93.48	313	82.89	119.7
10 mM	97.75	1281	93.6	358	83.02	113.8
20 mM	97.65	1553	94.03	488	83.35	124.9
50 mM	97.42	1738	93.05	550	81.08	116

(j) Co doped SWCNT TCF

tp-SWCNT	Co doping					
	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)	T (%)	Rsq (ohm/sq)
Raw	98.20	1805.67	94.10	767.33	83.29	277.67
1 mM	97.62	1187	93.8	393	83.2	127.7
5 mM	97.82	1295	93.5	364	83.24	127
10 mM	98	1351	93.27	344	83.44	122.2
20 mM	98.01	1284	93.24	336	82.35	111.3
50 mM	96.41	1138	92.15	455	80.92	132.3

Table S2. Data sheet of transition metal doping on the SWCNT TCF: (a-e) hp-SWCNT based TCF properties, (f-j) tp-SWCNT based TCF properties.