Supporting information

Copper Nanowire-Graphene Core-Shell Nanostructure for Highly Stable Transparent Conducting Electrodes

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Synthesis of CuNW

$CuCl_2 \cdot 2H_2O$ (189 mg, 1.11 mmol), hexadecylamine (HDA) (1296 mg, 5.37 mmol), and glucose (450 mg, 2.50 mmol) were dissolved in deionized (DI) water (30 mL). This mixture was stirred at room temperature for overnight. Then, the reaction mixture was heated at 100 °C and stirred for 6h. The color of solution changed from blue to red brown. After the reaction, the suspension was washed with hot DI water (60 °C). To remove the excess HDA and glucose, the suspension was centrifuged for several cycles. Subsequently, the CuNW was rinsed in hexane and isopropyl alcohol (IPA) with centrifuge. Then, the precipitates of the CuNW were dispersed in IPA. The dispersed CuNWs in IPA were filtered through a cellulose acetate membrane filter and dried in nitrogen gas. The dried CuNWs were stored in vacuum.

To determine the proper amount of HDA, the concentration of HDA was controlled with the constant amount of $CuCl_2 \cdot 2H_2O$ (1.11 mmol) and glucose (2.50 mmol). The SEM images in Figure S2 (a)~(c) correspond to 5.37 mmol (1296 mg), 6.71 mmol (1619 mg), and 8.06 mmol (1945 mg) of HDA, respectively. With 6.71 mmol of HDA, reaction mixtures are composed of CuNWs and copper nanocubes (Figure S2 (b)). With 8.06 mmol of HDA, only copper nanocubes were synthesized as shown in Figure S2 (c).

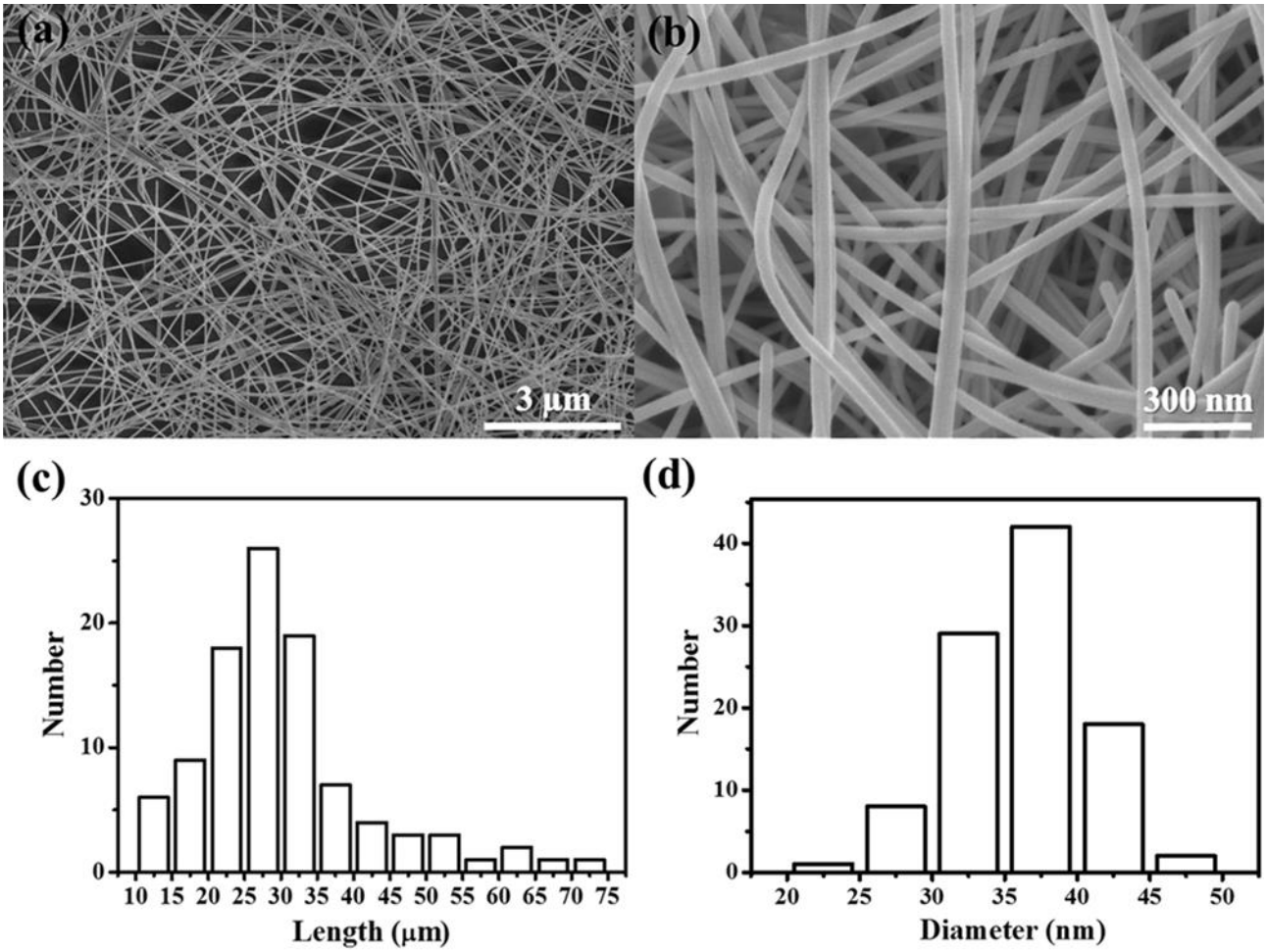

Figure S1. (a) and (b) SEM images of CuNWs. Histograms of (c) length and (d) diameter distribution of CuNWs. The average length and diameter of CuNWs are 30 ± 13 μm and 36 ± 5 nm, respectively.

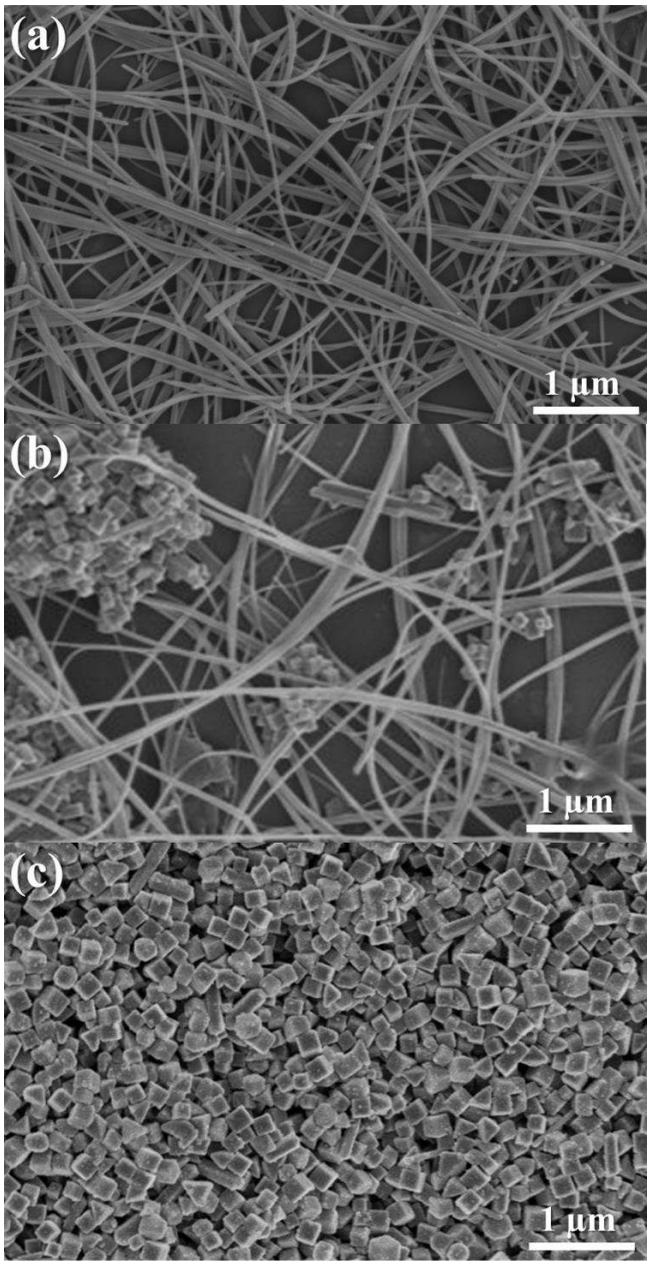

Figure S2. SEM images of copper nanostructures synthesized using different amounts of hexadecylamine (HDA) (a) 5.37, (b) 6.71, and (c) 8.06 mmol with $CuCl_2 \cdot 2H_2O$ (1.11 mmol), and glucose (2.50 mmol).

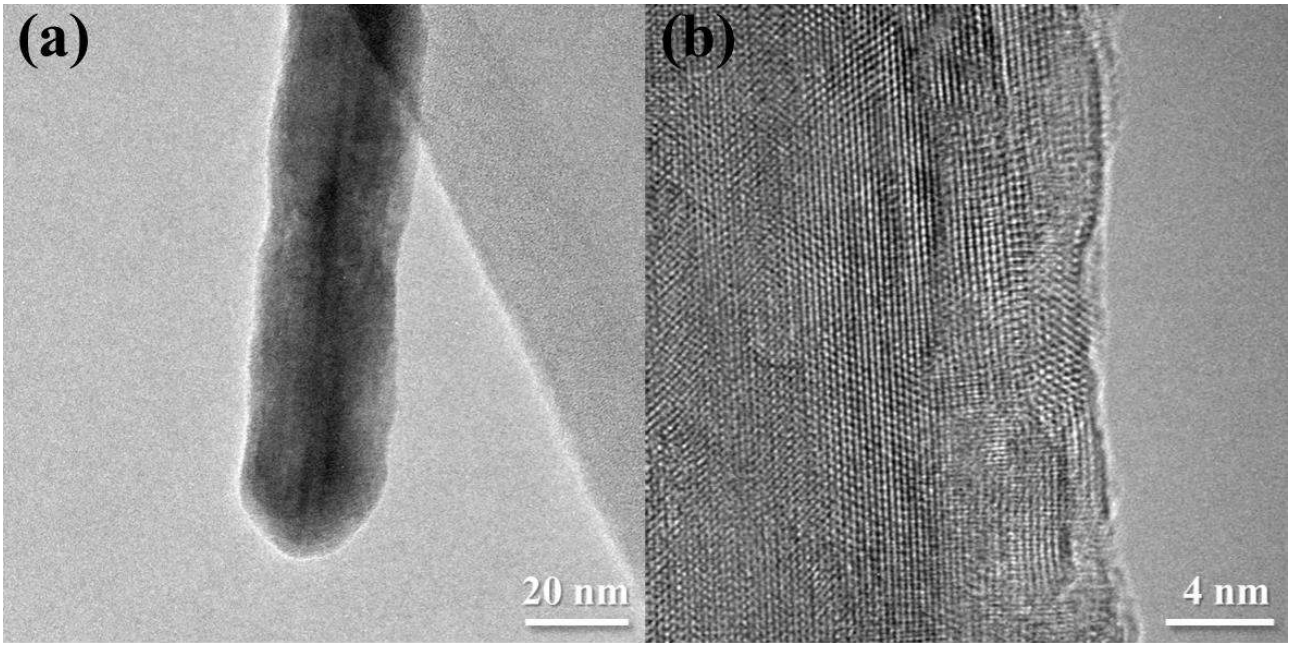

Figure S3. TEM images of CuNW.

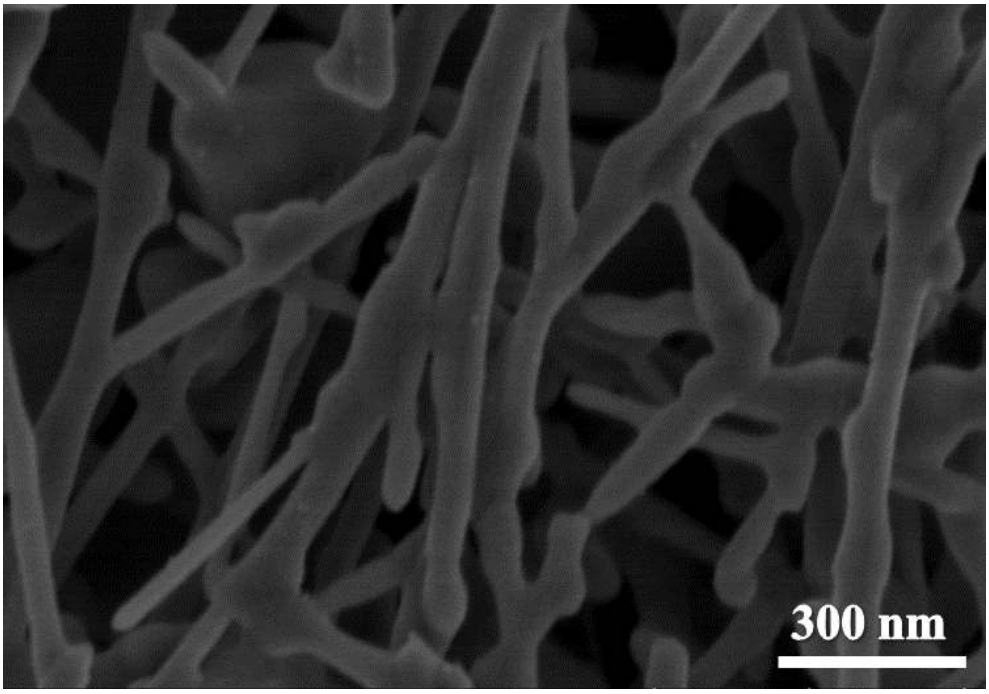

Figure S4. SEM image of CuNWs after the LT-PECVD process at 600 °C for 3 min.

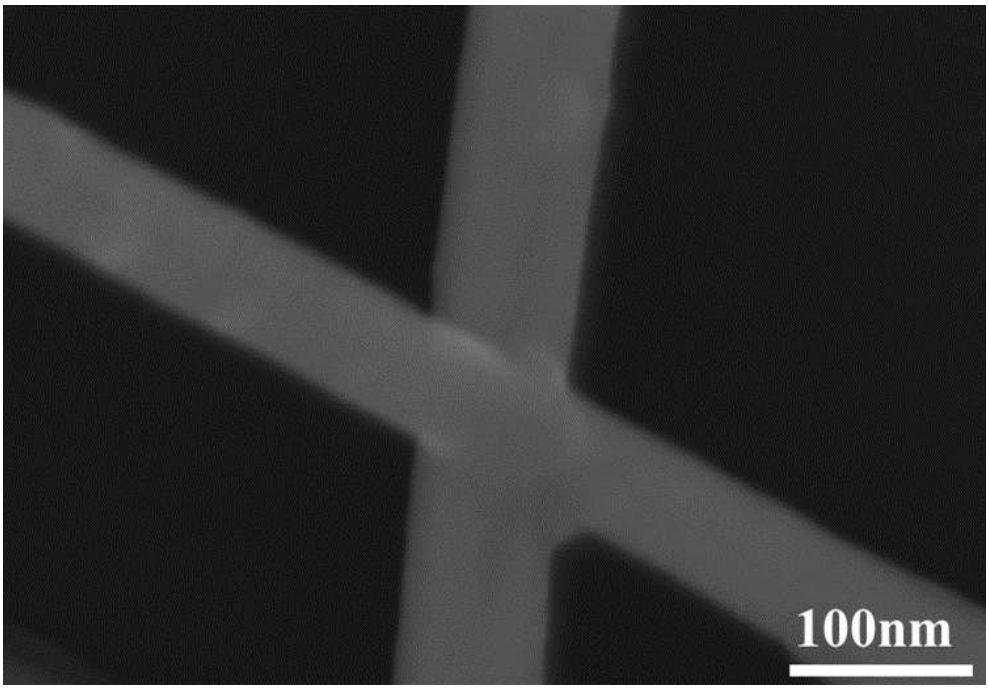

Figure S5. SEM image of the junction of CuNW-G core-shell nanostructures after the LT-PECVD process.

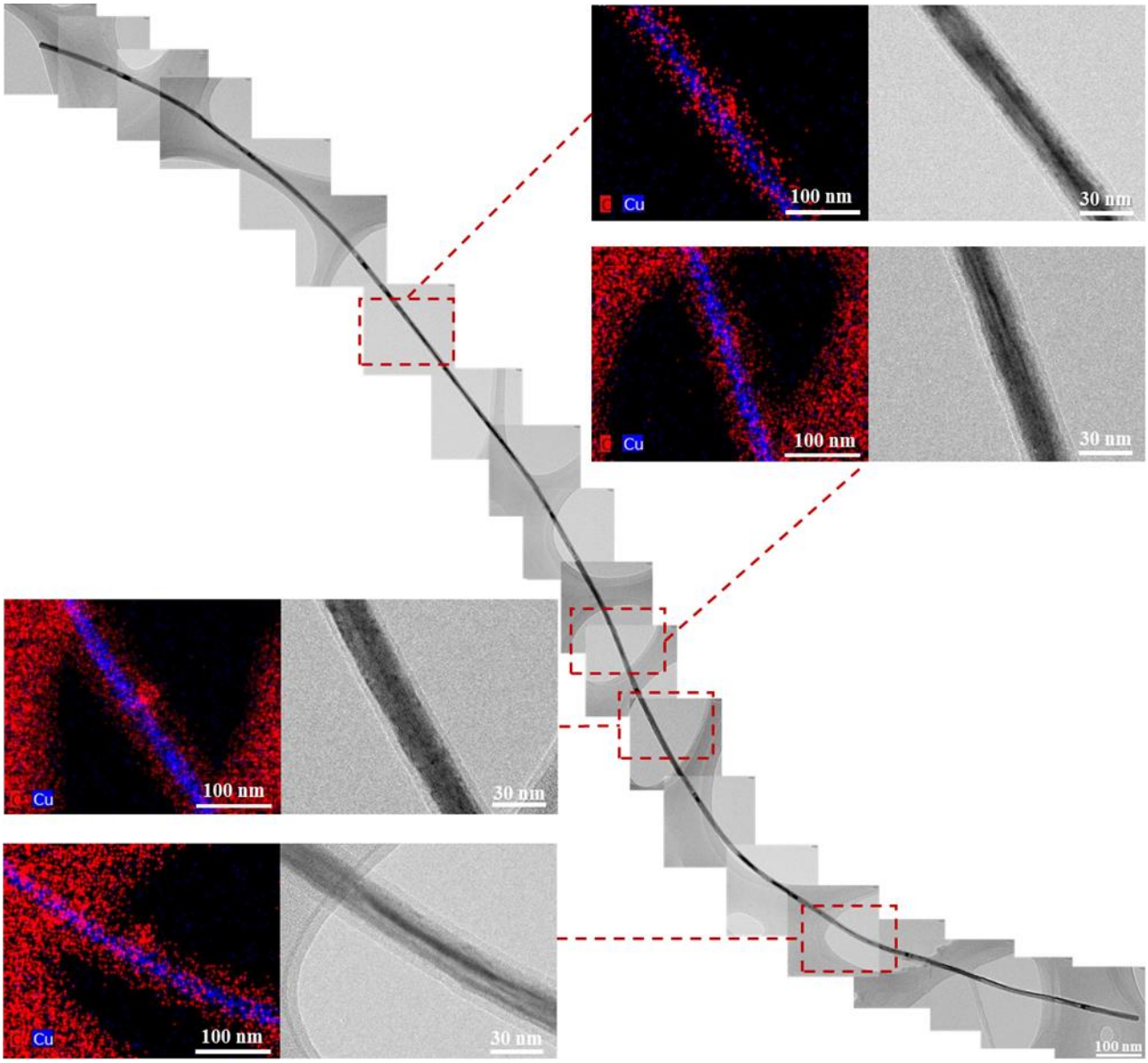

Figure S6. Integrated TEM image of CuNW-G core-shell nanostructure. Inset : EDS mapping analysis and TEM images of the selected areas of the CuNW-G core-shell nanostructure.

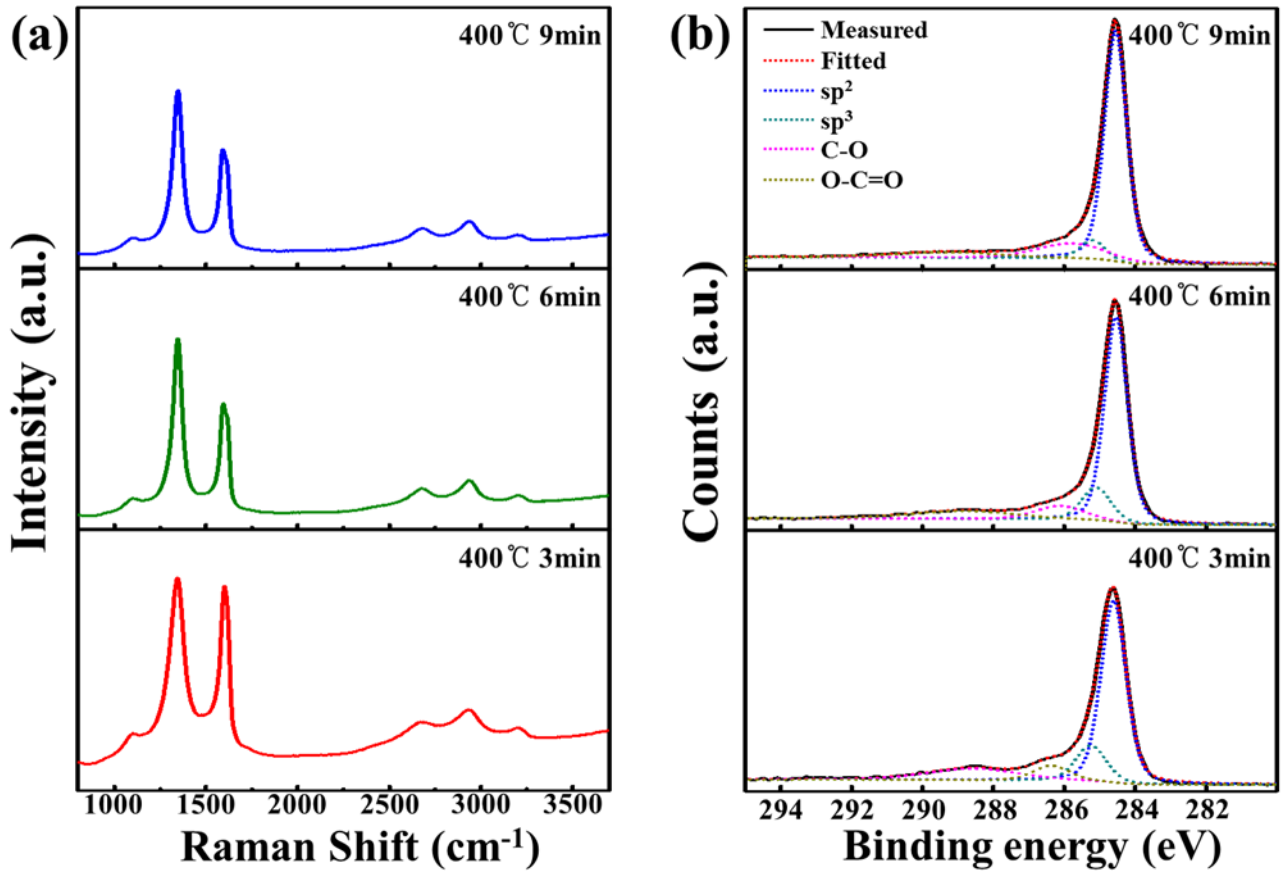

Figure S7. (a) Raman spectra of CuNW-G core-shell nanostructures prepared by LT-PECVD process at 400 °C and different processing times (excitation wavelength: 532 nm) (b) High resolution C 1s spectra of CuNW-G core-shell nanostructures prepared by LT-PECVD process at 400 °C and different processing times.

Table S1. Analysis of Raman spectroscopy of CuNW-G core-shell nanostructures prepared at different LT-PECVD process conditions.

Temperature	Time	Raman Shift [cm^{-1}]			I_D/I_G	I_{2D}/I_G
		D-band	G-band	2D-band		
400°C	3min	1343.68	1600.17	2670.47	1.04	0.34
	6min	1345.60	1594.38	2674.33	1.52	0.34
	9min	1347.54	1592.45	2678.18	1.59	0.36
500°C	3min	1343.68	1594.38	2674.32	1.49	0.33
	6min	1345.60	1586.67	2676.25	1.77	0.40
	9min	1345.60	1584.74	2682.04	1.87	0.42

Table S2. XPS binding energy and chemical composition of CuNW-G core-shell nanostructures prepared at different LT-PECVD process conditions.

Temperature	Time	sp2	sp^3	C-O	O-C=O
400°C	3min	284.61 eV (63.40%)	285.25 eV (15.01%)	286.36 eV (7.44%)	288.57 eV (14.16%)
	6min	284.54 eV (65.80%)	285.10 eV (13.54%)	286.13 eV (9.30%)	288.81 eV (11.36%)
	9min	284.55 eV (71.87%)	285.20 eV (6.47%)	285.80 eV (14.02%)	289.31 eV (7.64%)
500°C	3min	284.63 eV (65.48%)	285.31 eV (14.02%)	286.41 eV (6.66%)	288.41 eV (13.84%)
	6min	284.57 eV (68.81%)	285.24 eV (11.41%)	286.23 eV (8.29%)	288.51 eV (11.49%)
	9min	284.59 eV (72.72%)	285.28 eV (9.34%)	286.21 eV (8.26%)	288.71 eV (9.68%)

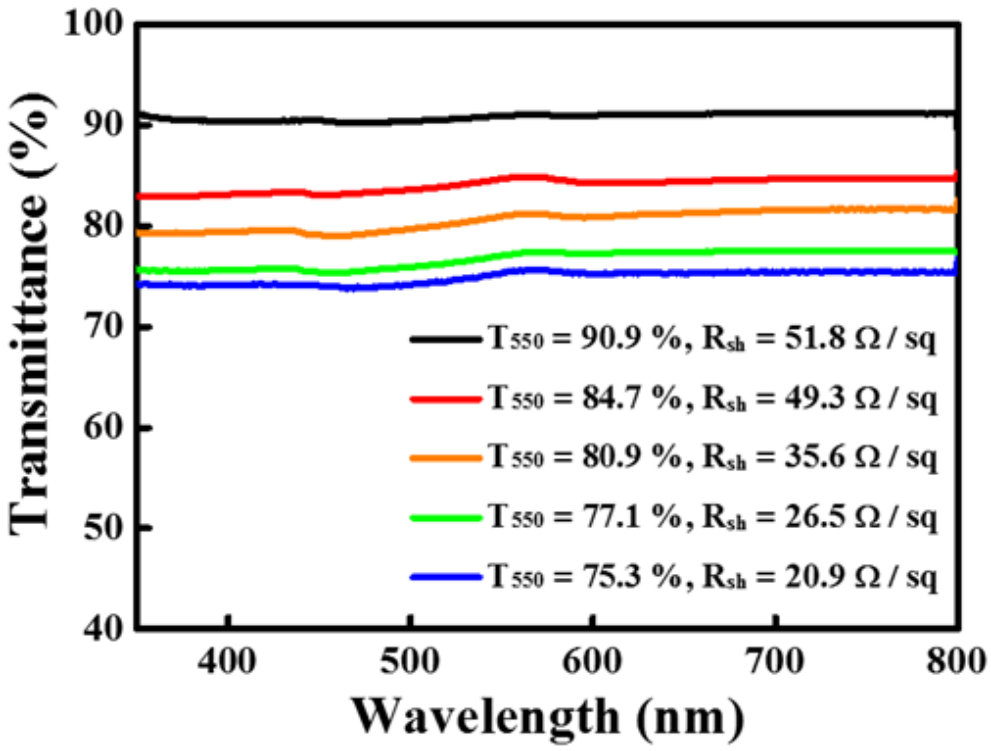

Figure S8. UV/Vis spectra and sheet resistance values of CuNW TCEs.

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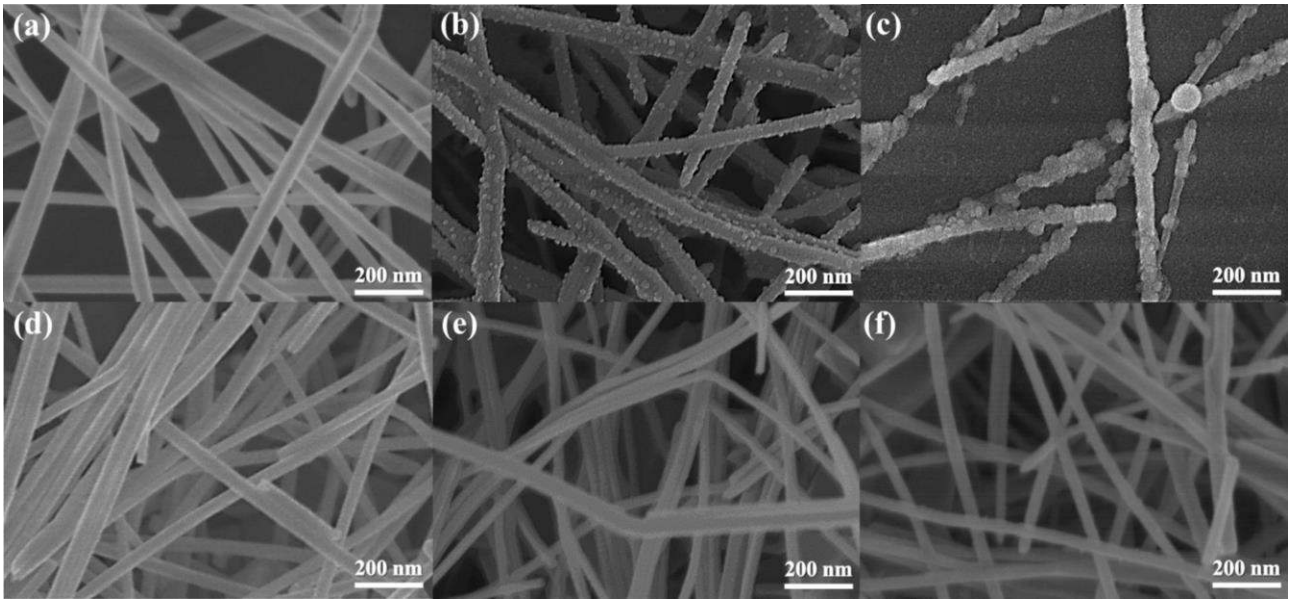

Figure S9. SEM images of CuNWs in air at room temperature on the (a) 1st day, (b) 3rd day, and (c) 7th day and CuNW-G core-shell nanostructures at an ambient condition on the (d) 1st day, (b) 3rd day, and (c) 7th day.

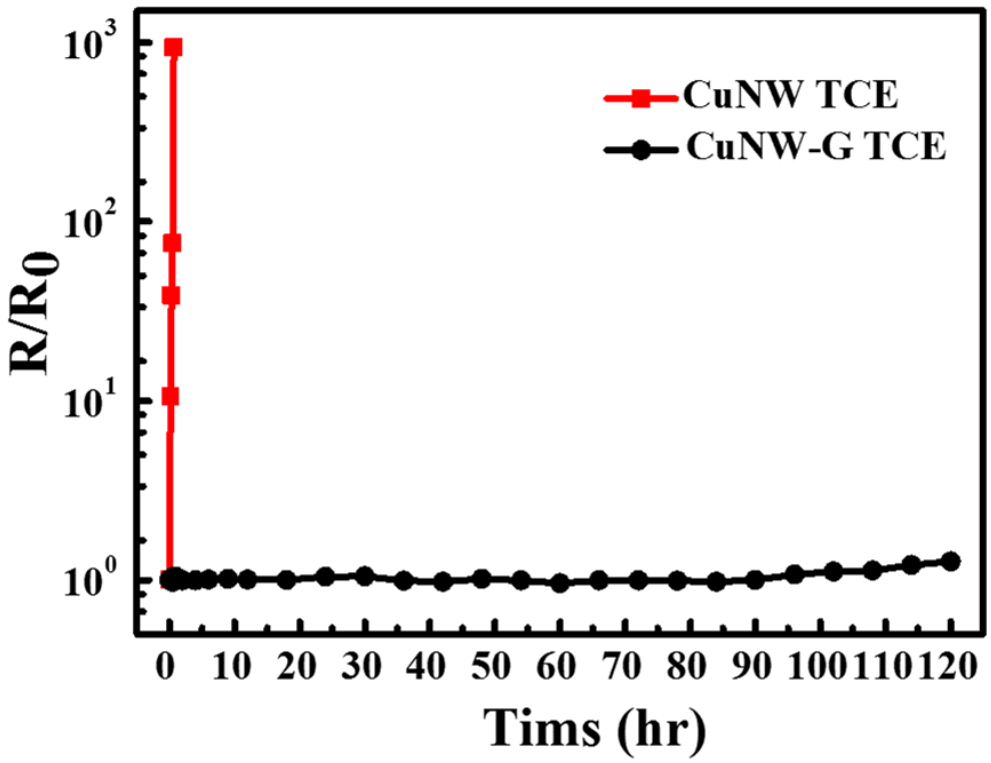

Figure S10. Sheet resistance change of CuNW and CuNW-G TCEs during a stability test at 70 °C and 70 % RH.

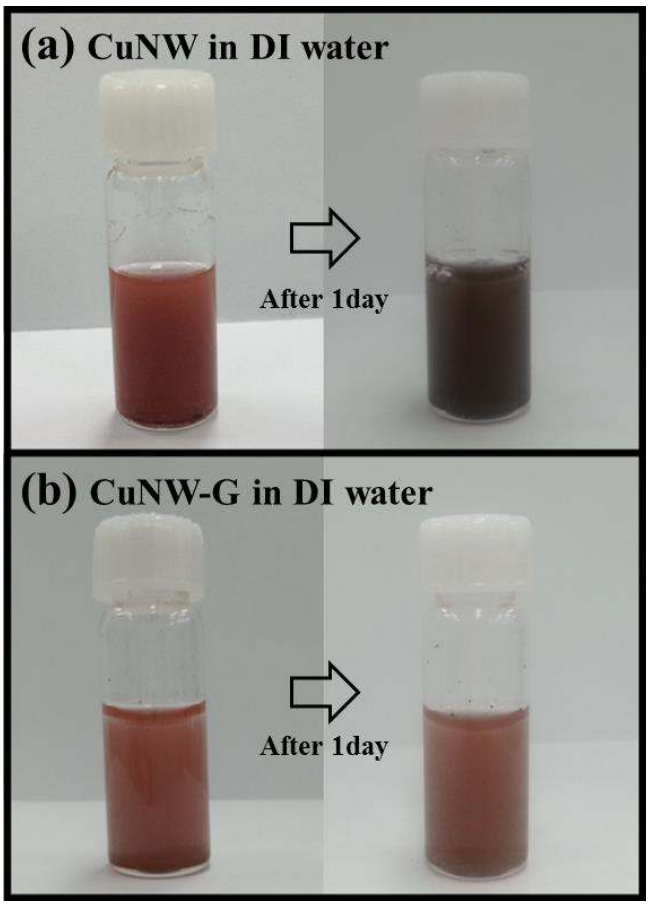

Figure S11. Photographs of (a) CuNW and (b) CuNW-G dispersions in deionized (DI) water before and after a stability test.

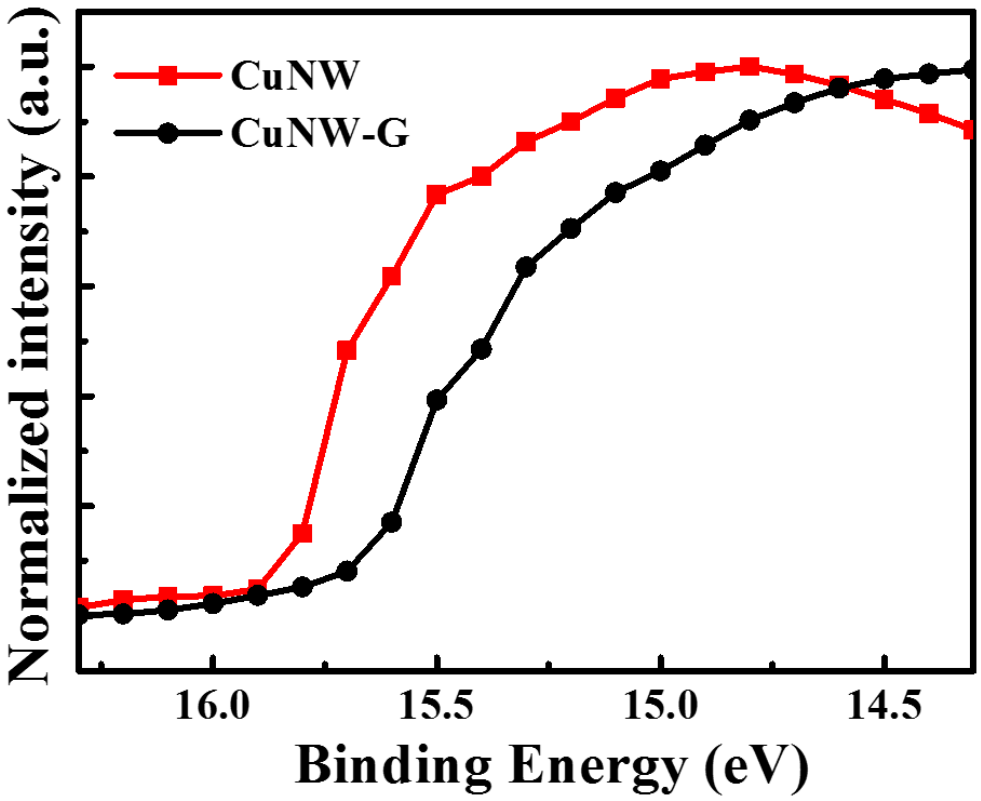

Figure S12. UPS spectra of CuNW and CuNW-G core-shell nanostructure.

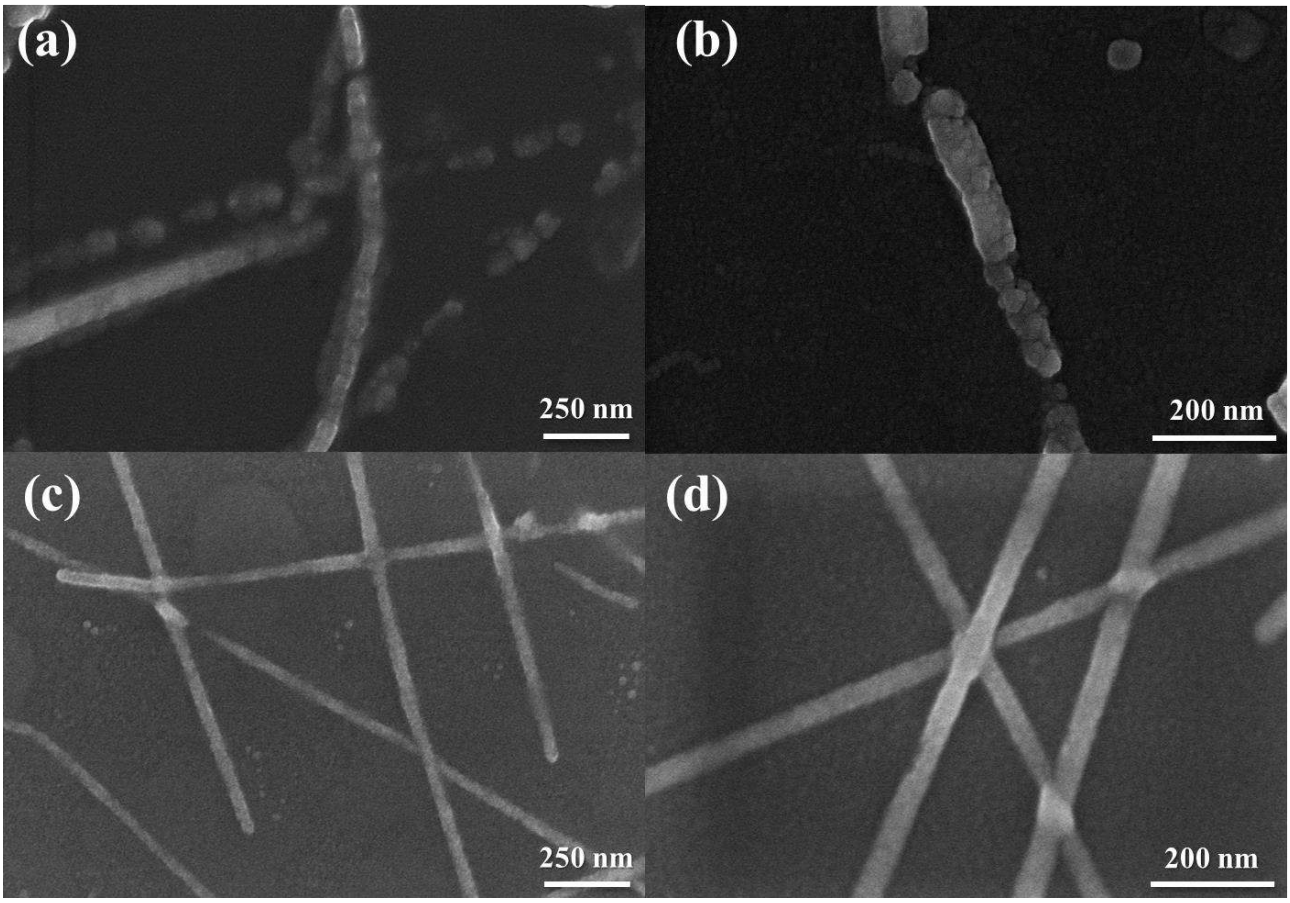

Figure S13. SEM images of (a), (b) CuNW/PEDOT:PSS film and (c), (d) CuNW-G /PEDOT:PSS film after 1 hr of PEDOT:PSS coating