Synthesis of free-standing ternary Rh-Pt-SnO_2-carbon nanotubes nanostructures as highly active and robust catalyst for ethanol oxidation

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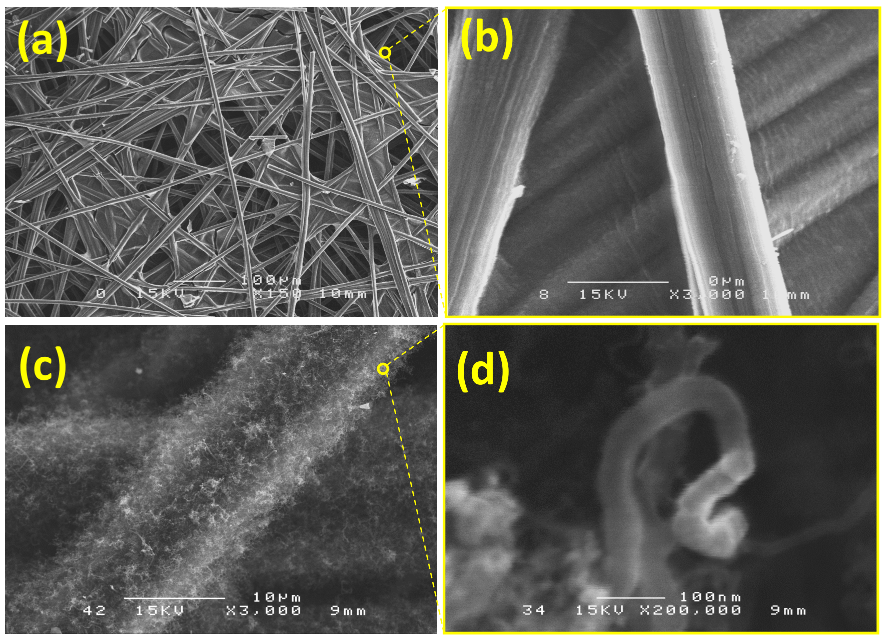

Figure S1 SEM images of carbon paper substrate (a-b) and as synthesized CNTs (c-d).

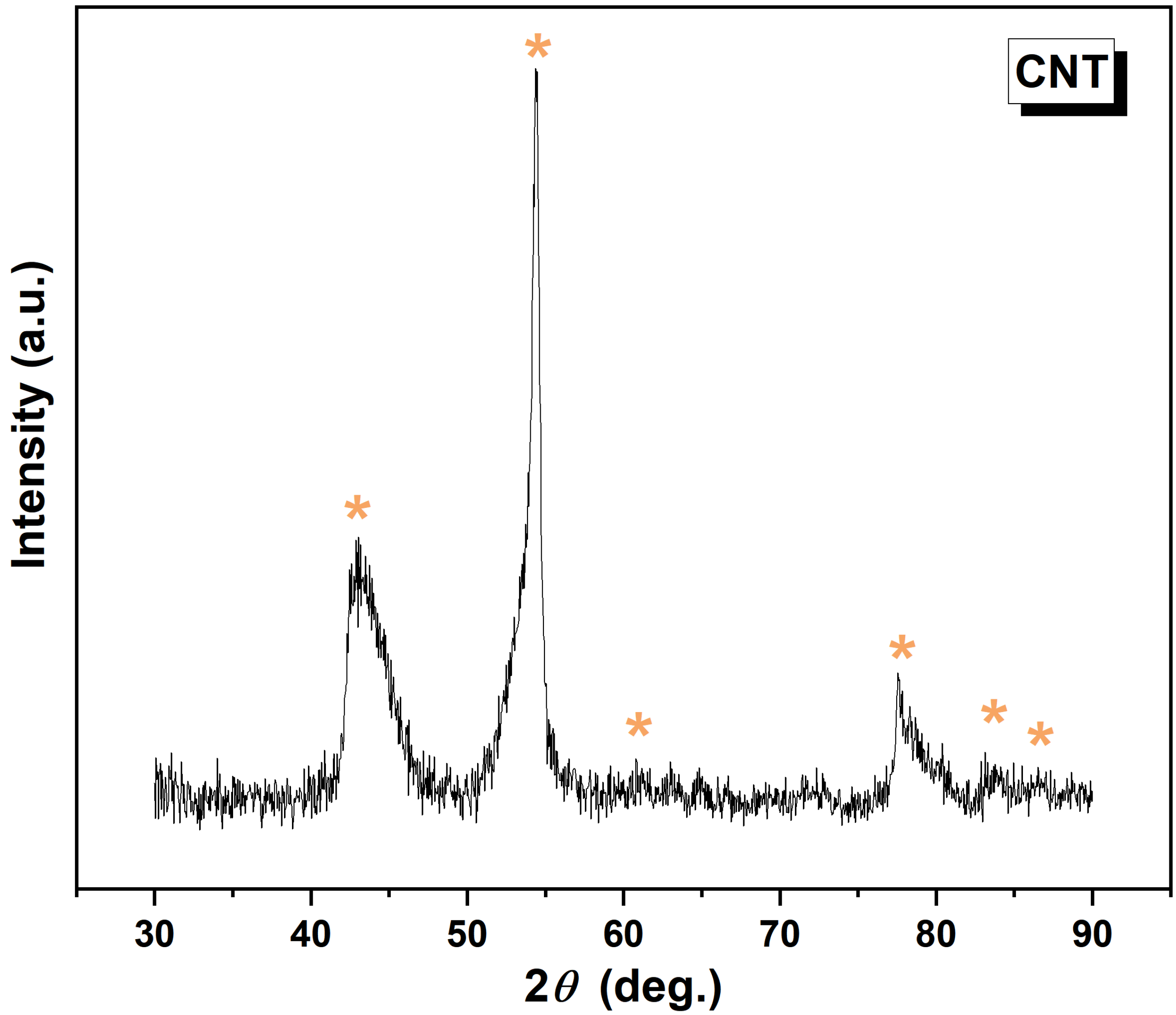

Figure S2 XRD of pristine CNTs as synthesized by CVD method.

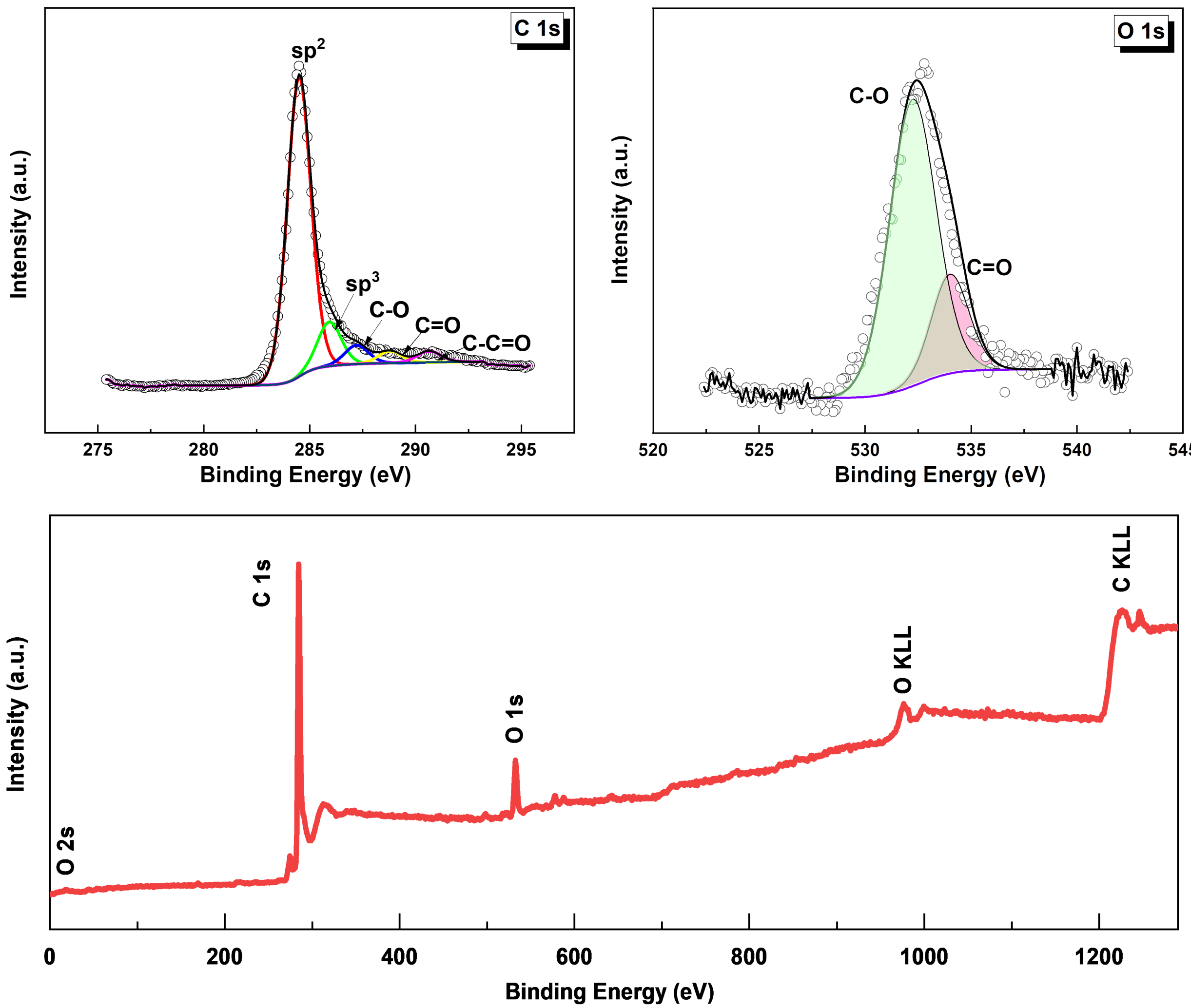

Figure S3 XPS survey scan and high-resolution XPS of C 1s and O 1s core-levels of the CNTs.

Table S1 XRD parameters

Catalysts	2θ (deg.)	d_{111} (Å)	a (Å)	CS (Å)
Pt/CNT	39.78	2.264	3.922	70.63
Pt/SnO_2/CNT	39.76	2.265	3.923	61.25
Rh_5/Pt/CNT	39.74	2.266	3.926	57.60
Rh_5/Pt/SnO_2/CNT	39.72	2.267	3.927	54.73

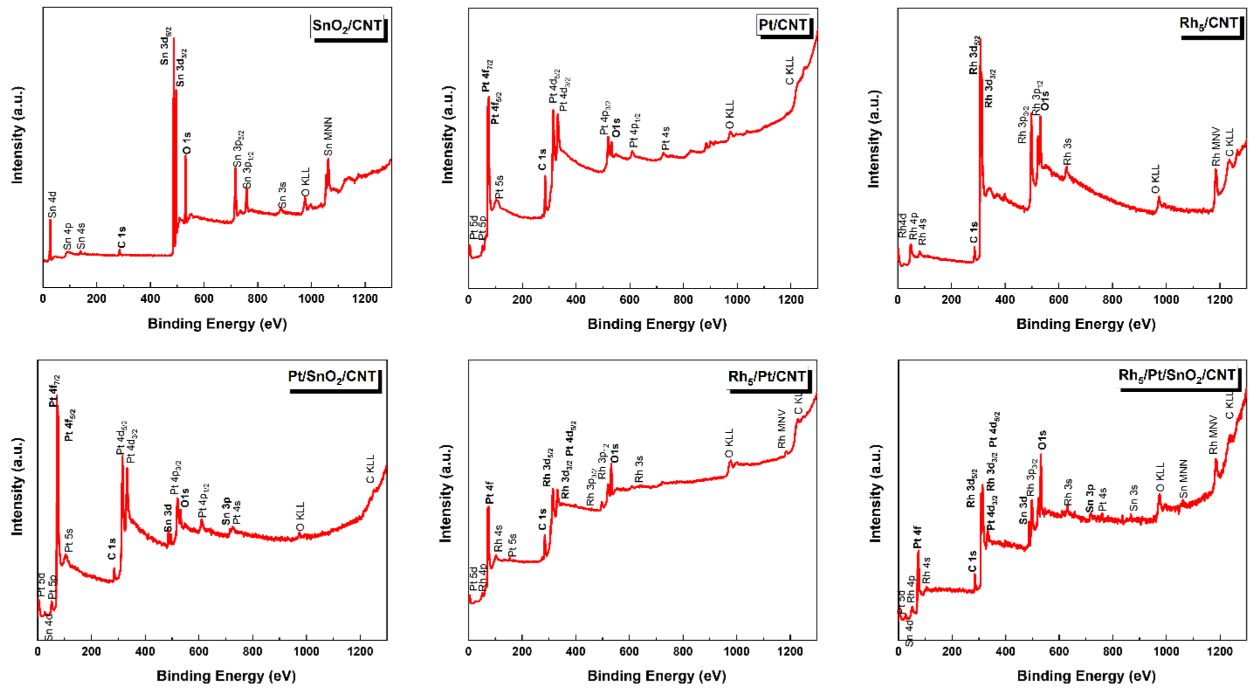

Figure S4 XPS survey scans of the catalysts grown by PLD onto CNTs substrate.

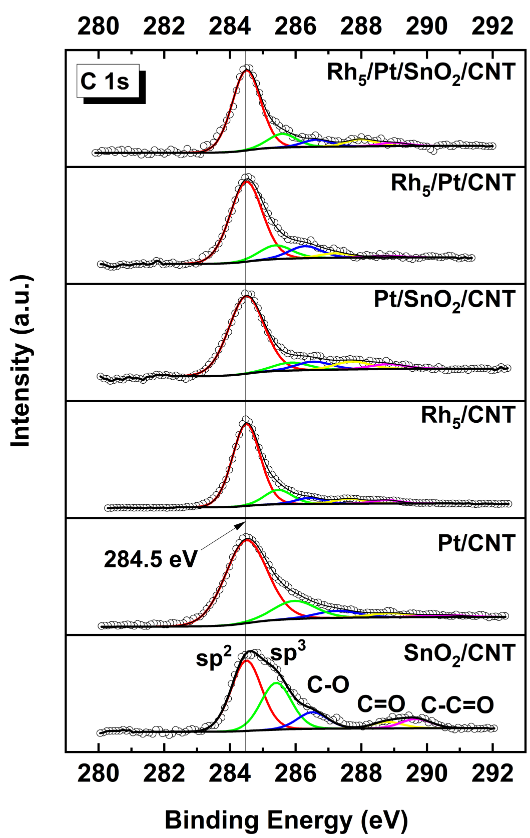

Figure S5 High-resolution XPS of C 1s core-level.

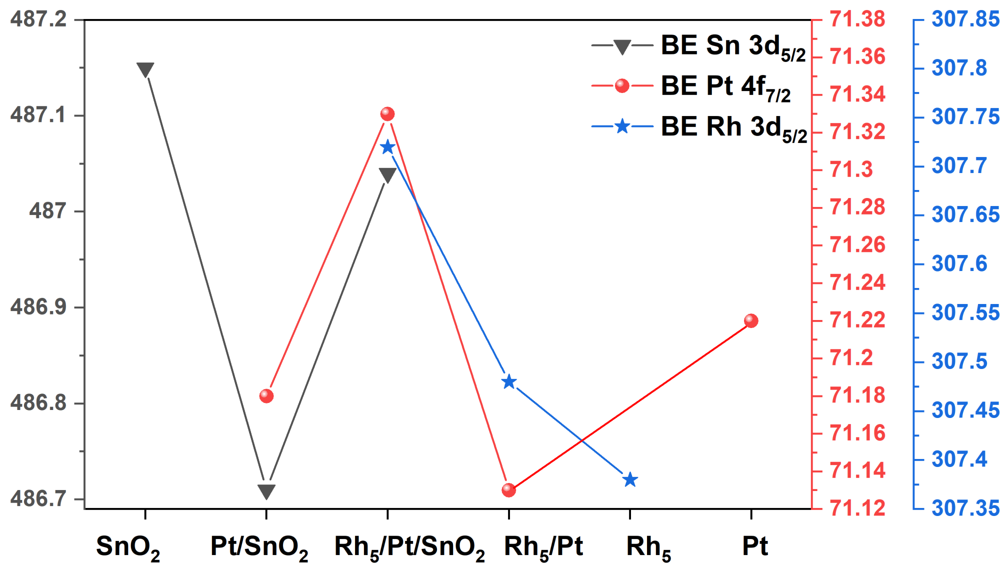

Figure S6 Binding energies of Sn $3d_{5/2}$, Pt $4f_{7/2}$ and Rh $3d_{5/2}$.

Table S2 Atomic surface composition estimated by XPS.

	C (%)	O (%)	SnO_2 (%)	Pt (%)	Rh (%)	Rh_2O_3 (%)	Rh $3p_{3/2}$ (%)
Pt/CNT	62.35	8.75	-	28.9	-	-	-
SnO_2/CNT	15.33	56.14	28.52				
Rh_5/CNT	46.84	25.42	-	-	21.47	5.44	
Pt/SnO_2/CNT	44.15	21.59	4.47	29.79	-	-	-
Rh_5/Pt/CNT	51.26	21.36	-	12.73	10.71	3.94	-
Rh_5/Pt/SnO_2/CNT	25.51	30.32	2.07	14.1	9.4	2.98	10.6

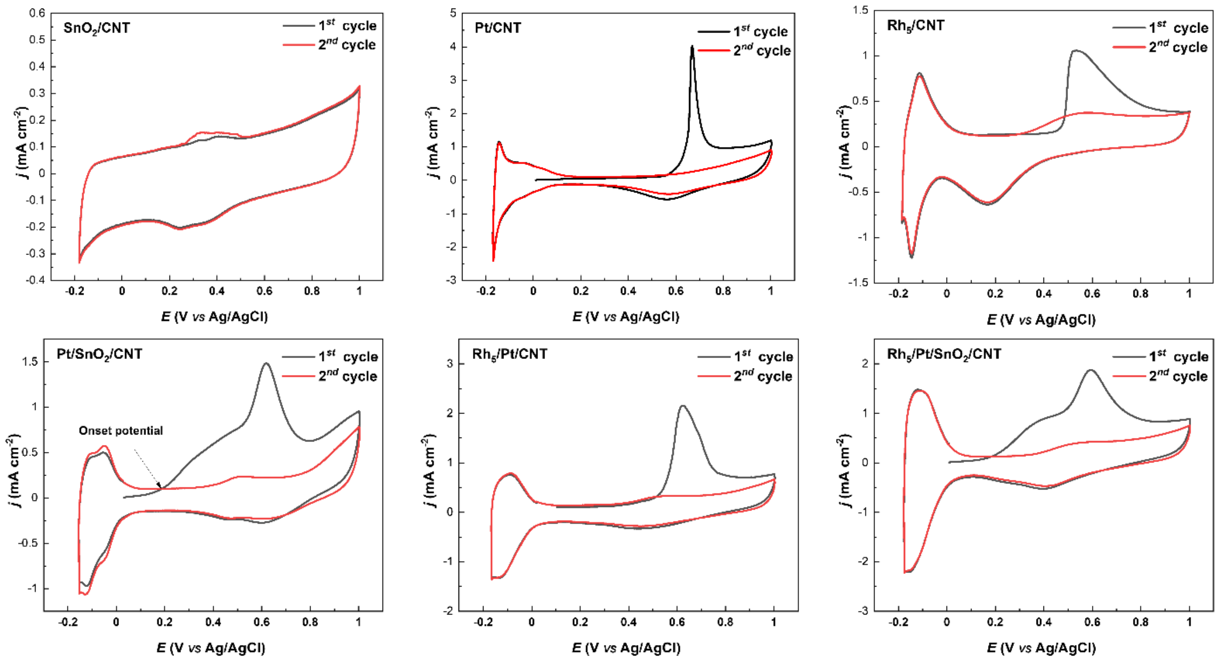

Figure S7 CO-stripping voltammetry in the base electrolyte 0.5 M H_2SO_4 recorded at 50 mV s^{-1}.

Table S3 Comparative electroactivity of electrocatalysts in 0.5 M H_2SO_4 solution.

Substrate	*CP*			*CNTs*		
Catalyst	*ESA* (cm^2)	*ASA* ($m^2\ g^{-1}$)	*RF*	*ESA* (cm^2)	*ASA* ($m^2\ g^{-1}$)	*RF*
Pt	0.90	2.43	3.8	3.01	8.16	9.79
Pt/SnO_2	2.38	6.44	7.7	3.82	10.33	12.40
Rh_5/Pt	0.90	2.44	2.9	3.56	9.63	11.55
Rh_5/Pt/SnO_2	5.77	15.63	18.7	7.62	20.64	24.76

Table S4 Comparative electrochemical EOR activity in 1 M C_2H_5OH + 0.5 M H_2SO_4 solution.

Substrate	*CP*			*CNTs*		
Catalyst	E_{onset} (V)	j_p (mA cm^{-2})	*MA* (mA mg^{-1}_{Pt})	E_{onset} (V)	j_p (mA cm^{-2})	*MA* (mA mg^{-1}_{Pt})
Pt	0.232	9.55	79.54	0.23	18.87	157.25
Pt/SnO_2	0.168	19.06	158.8	0.16	23.16	193.00
Rh_5/Pt	0.272	11.8	98.08	0.26	21.34	177.83
Rh_5/Pt/SnO_2	0.167	21.53	179.4	0.16	27.77	213.42

Table S5 Comparative durability EOR activity in 1 M C_2H_5OH + 0.5 M H_2SO_4 solution.

Substrate	*CP*			*CNTs*		
Catalyst	$j_{t=0}$ (mA cm^{-2})	j_{ss} (mA cm^{-2})	*MA* (mA mg^{-1}_{Pt})	$j_{t=0}$ (mA cm^{-2})	j_{ss} (mA cm^{-2})	*MA* (mA mg^{-1}_{Pt})
Pt	13.6	1.66	13.83	23.60	7.12	59.33
Pt/SnO_2	22.27	6.07	50.58	30.60	12.73	106.08

Rh_5/Pt	10.83	4.94	41.16	28.20	11.59	96.58
$Rh_5/Pt/SnO_2$	28.08	7.00	58.33	32.90	15.86	132.17

Table S6 Comparative Electrochemical CO oxidation activity

Substrate	*CP*			*CNTs*		
Catalyst	$E_{onset\text{-}COox}$ (V)	$ESA_{CO\text{-}ox}$ (cm^2)	$ASA_{CO\text{-}ox}$ ($m^2\ g^{-1}{}_{Pt}$)	$E_{onset\text{-}COox}$ (V)	$ESA_{CO\text{-}ox}$ (cm^2)	$ASA_{CO\text{-}ox}$ ($m^2\ g^{-1}{}_{Pt}$)
Pt	0.60	5.66	15.31	0.57	4.04	10.92
Pt/SnO_2	0.14	5.30	14.30	0.19	5.06	13.70
Rh_5/Pt	0.53	6.23	17.00	0.52	4.39	15.76
$Rh_5/Pt/SnO_2$	0.17	10.84	29.32	0.17	6.91	18.71