

Electronic Supplementary Information

Cellulose nanocrystalline and sodium benzenesulfonate-doped polypyrrole nano-hydrogel/Au composites for ultrasensitive detection of carcinoembryonic antigen

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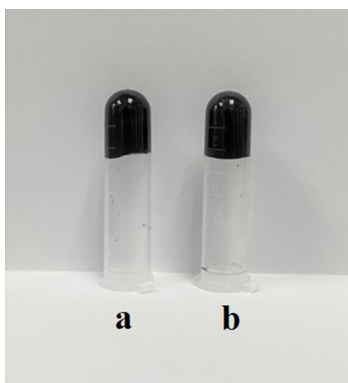


Fig. S1 CNC-PPy gel (a) and BSNa-CNC-PPy gel (b) in centrifuge tubes.

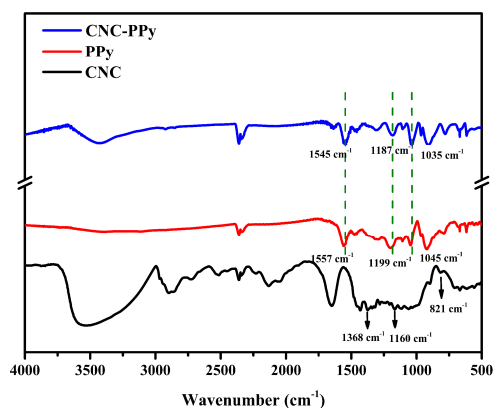


Fig. S2 FTIR spectra of CNC, PPy and CNC-PPy.

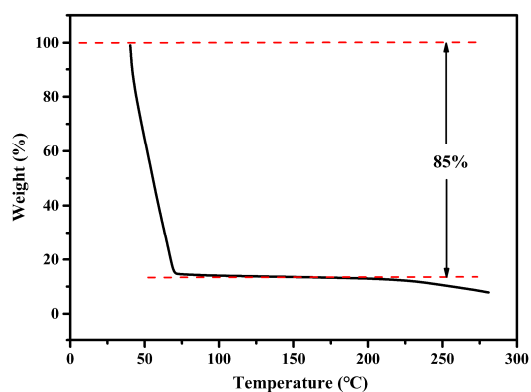


Fig. S3 Thermal gravimetric analysis of BSNa-CNC-PPy gel.

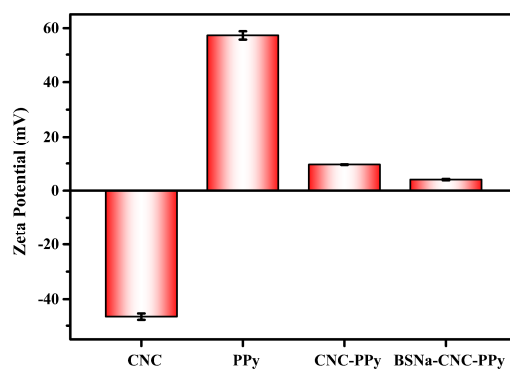


Fig. S4 Zeta potential of different samples.

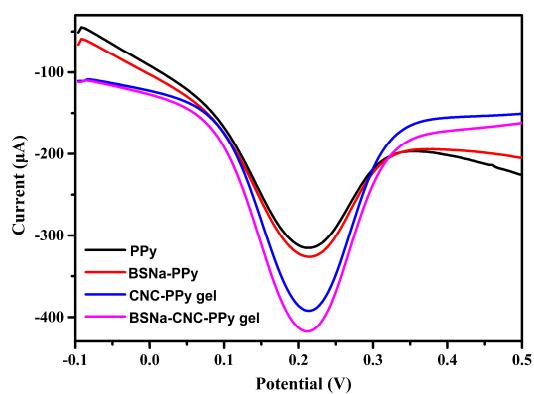


Fig. S5 Comparison of current response variation of GCE modified by different materials.

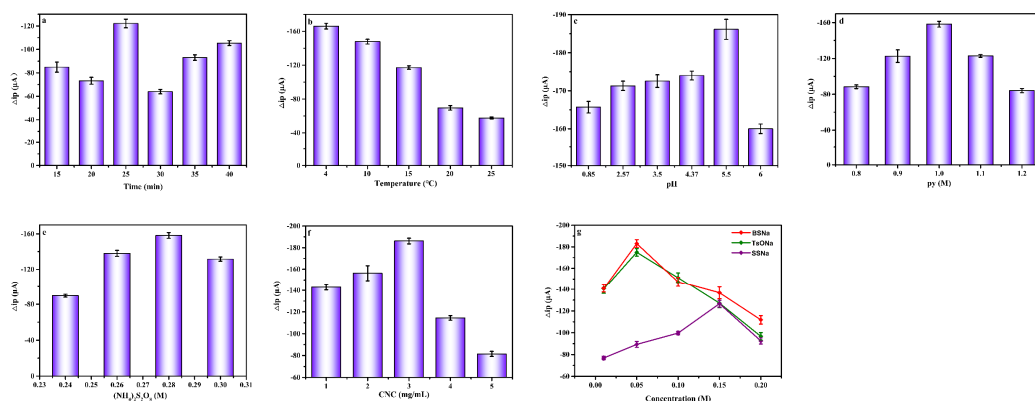


Fig. S6 Effect of the reaction time (a); temperature (b); pH (c); concentration of py (d); concentration of $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (e); C_{CNC} (f) and sulphonate dopants (g) on the SWV responses for CNC-PPy modified immunosensor. (a) pH = 0.85, $C_{\text{CNC}} = 2$ mg/mL, $T = 4$ °C, $C_{\text{py}} = 1$ M, $C_{(\text{NH}_4)_2\text{S}_2\text{O}_8} = 0.25$ M; (b) pH = 0.85, $C_{\text{CNC}} = 3$ mg/mL, $t = 25$ min, $C_{\text{py}} = 1$ M, $C_{(\text{NH}_4)_2\text{S}_2\text{O}_8} = 0.28$ M; (c) $C_{\text{CNC}} = 3$ mg/mL, $T = 4$ °C, $t = 25$ min, $C_{\text{py}} = 1$ M, $C_{(\text{NH}_4)_2\text{S}_2\text{O}_8} = 0.28$ M; (d) pH = 0.85, $C_{\text{CNC}} = 3$ mg/mL, $T = 4$ °C, $t = 25$ min, $C_{(\text{NH}_4)_2\text{S}_2\text{O}_8} = 0.28$ M; (e) pH = 0.85, $C_{\text{CNC}} = 3$ mg/mL, $T = 4$ °C, $t = 25$ min, $C_{\text{py}} = 1$ M; (f) pH = 5.5, $C_{\text{CNC}} = 3$ mg/mL, $T = 4$ °C, $t = 25$ min, $C_{\text{py}} = 1$ M, $C_{(\text{NH}_4)_2\text{S}_2\text{O}_8} = 0.28$ M.

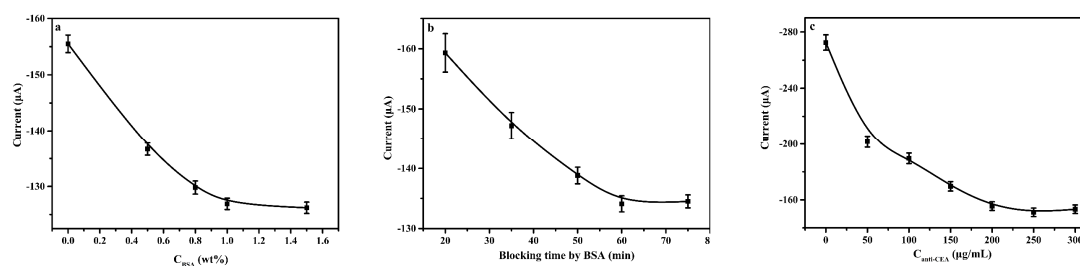


Fig. S7 Effects of amounts of BSA (a), blocking time of BSA (b) and amounts of anti-CEA on the current responses of the developed immunosensor.

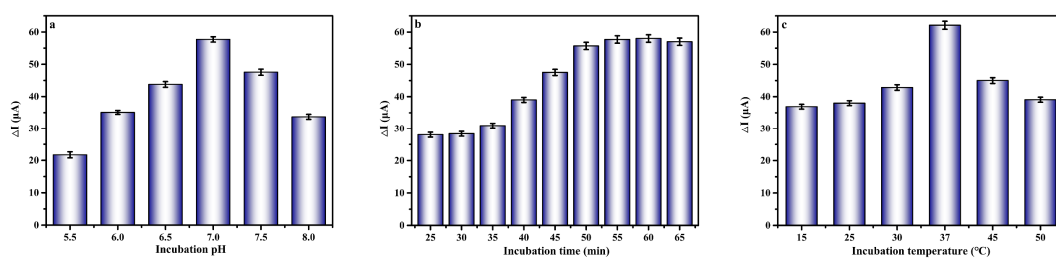


Fig. S8 Effects of the incubation pH (a), incubation time (b) and incubation temperature (c) on the SWV responses of the immunosensor for $50 \text{ ng} \cdot \text{mL}^{-1}$ CEA.

Table. S1 Comparison of CNC-PPy gel and BSNa-CNC-PPy gel

materials	CNC-PPy gel	BSNa-CNC-PPy gel	Ref
BET (m ² /g)	68.17	76.59	26.2 ^[1] 17.6 ^[2] 25.2 ^[3]
ECSA (mm ²)	13.77/7.06 (bare) = 1.95	15.15/7.06 (bare) = 2.14	21.41/12.56 = 1.7 ^[4]
SWV response (μA)	-256.4	-272.5	
Conductivity (S/cm)	1.62	1.74	0.46 ^[1]
Reproducibility	bad	good	

Table. S2 Comparison of linear range and detection limit of some modified electrodes materials

Sensors	Linear range (ng/mL)	Detection limit (ng/mL)	Ref
PPy hydrogel/Au	1.0×10 ⁻⁶ - 200	1.6 × 10 ⁻⁷	[1]
GNP-THi-GR	1×10 ⁻² - 0.5	4 × 10 ⁻³	[5]
AuNPs/(PB-rGO-MWCNTs) _n	2×10 ⁻¹ - 40	6 × 10 ⁻²	[6]
AuNPs/PB-PEDOT	5×10 ⁻² - 40	1 × 10 ⁻²	[7]
AuNPs/CNOs/SWCTs/chitosan	1×10 ⁻⁴ - 400	1 × 10 ⁻⁴	[8]
polyCBMA/PANI composite	1×10 ⁻⁵ - 0.1	3.05 × 10 ⁻⁶	[9]
BSNa-CNC-PPy hydrogel/Au	1.0×10 ⁻⁶ - 200	0.6 × 10 ⁻⁷	This work

References

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