Supplementary material

Electrochemical aptasensor based on *Chrysanthemum indicum* L.-derived carbon materials for detection of carcinoembryonic antigen

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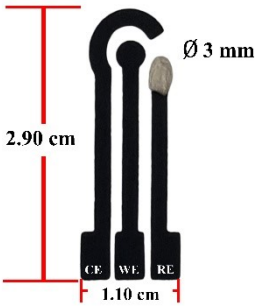

Fig. S1. Representation of the prepared SPCE.

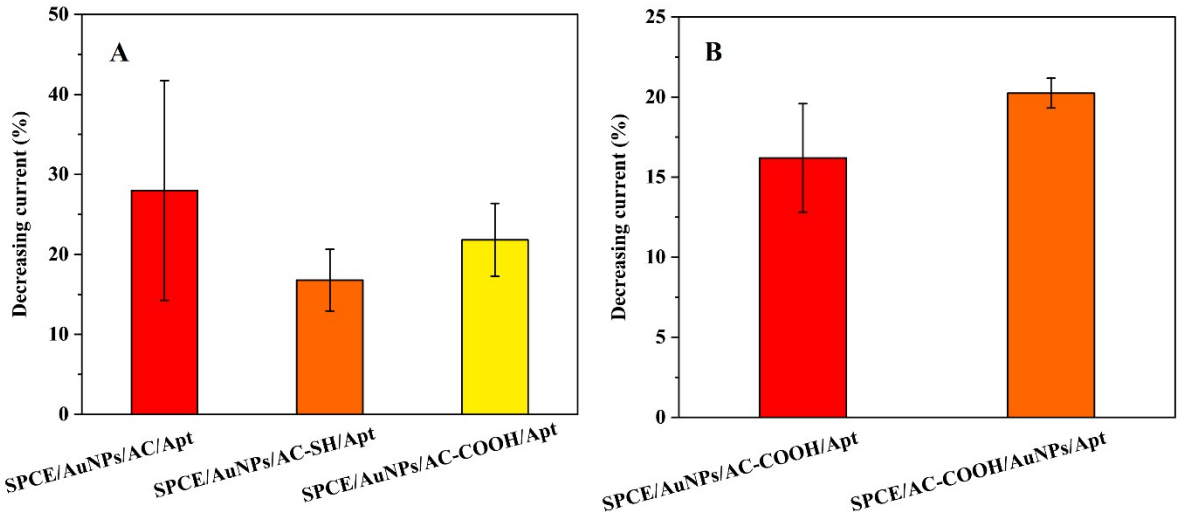

Fig. S2. Effect of (A) different modifiers and (B) the AuNPs modification sequence on the aptamer immobilization.

Table S1 Elemental analysis of carbon materials using EDS

Element	Element (%weight)		
	AC	AC-COOH	AC-SH
C	15.01	89.20	70.31
O	7.16	13.16	18.88
Na	15.38	0.01	0.01
Cl	30.61	2.52	1.27
K	2.40	N.D.	N.D.
Zn	29.43	0.11	0.13
Si	N.D.	N.D.	4.36
S	N.D.	N.D.	5.04
Ratio	Atomic ratio		
	AC	AC-COOH	AC-SH
O/C	1.43	0.15	0.27
S/C	N.D.	N.D.	0.07

N.D. = Not Detected.

Table S2 BET surface area, pore volume, and pore diameter of AC-COOH and AC-SH

Materials	AC-COOH	AC-SH
S_{BET} (m^2/g)	627.43	5.40
S_{micro} (m^2/g)	366.54	1.98
S_{meso} (m^2/g)	260.89	3.42
V_{total} (cm^3/g)	0.411	0.024
V_{micro} (cm^3/g)	0.188	0.001
V_{meso} (cm^3/g)	0.223	0.023
V_{micro}/V_{total} (%)	45.67	4.52
V_{meso}/V_{total} (%)	54.33	95.48

D_p (nm)	2.62	17.65

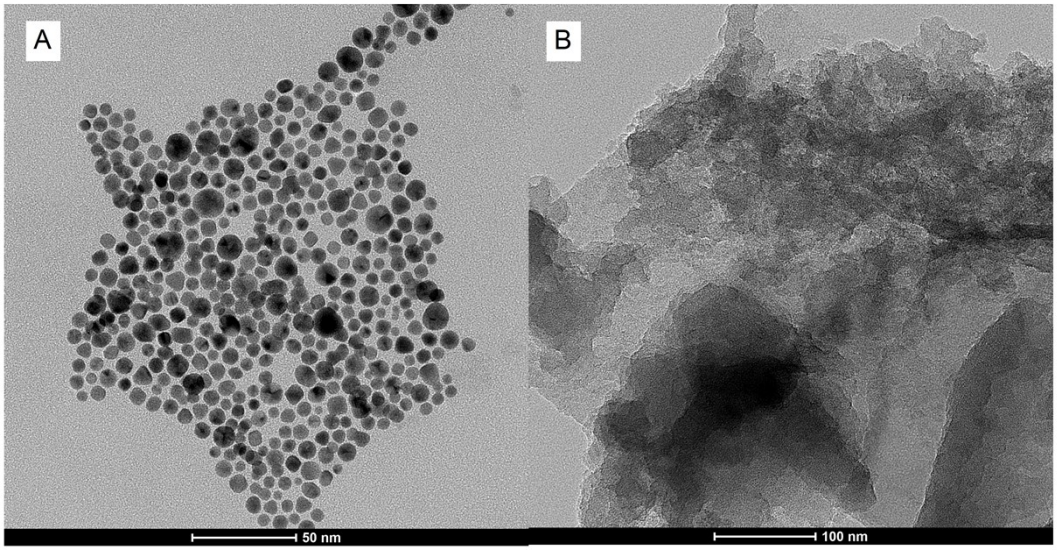

Fig. S3. TEM images of (A) AuNPs and (B) AC-COOH.

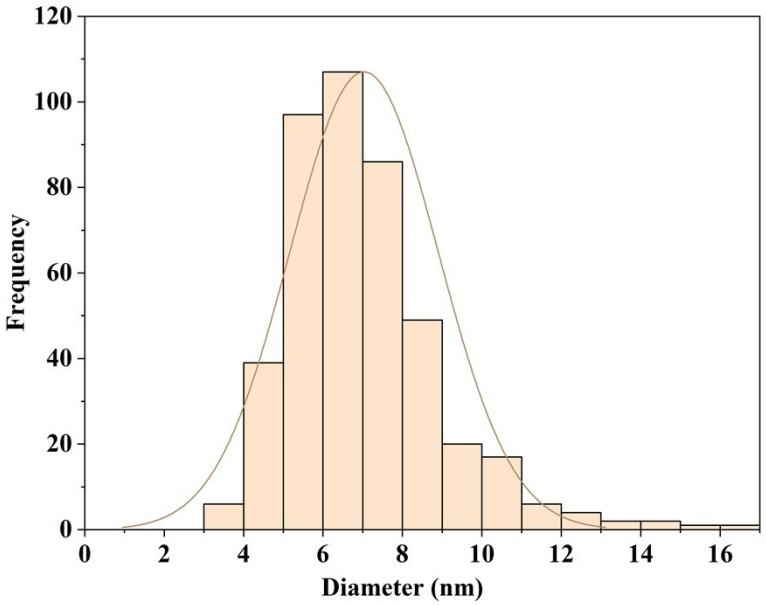

Fig. S4. The particle size distribution of AuNPs.

Table S3 Elemental analysis of the modified electrode surfaces

Electrode	Element (%weight)			
	C	O	Au	N
SPCE	85.1	14.4	-	-

SPCE/AC-COOH/AuNPs	78.4	18.1	2.1	-
SPCE/AC-COOH/AuNPs/Apt/BSA	57.7	10.9	1.4	6.4
SPCE/AC-COOH/AuNPs/Apt/BSA-CEA	55.5	12.8	1.7	7.1

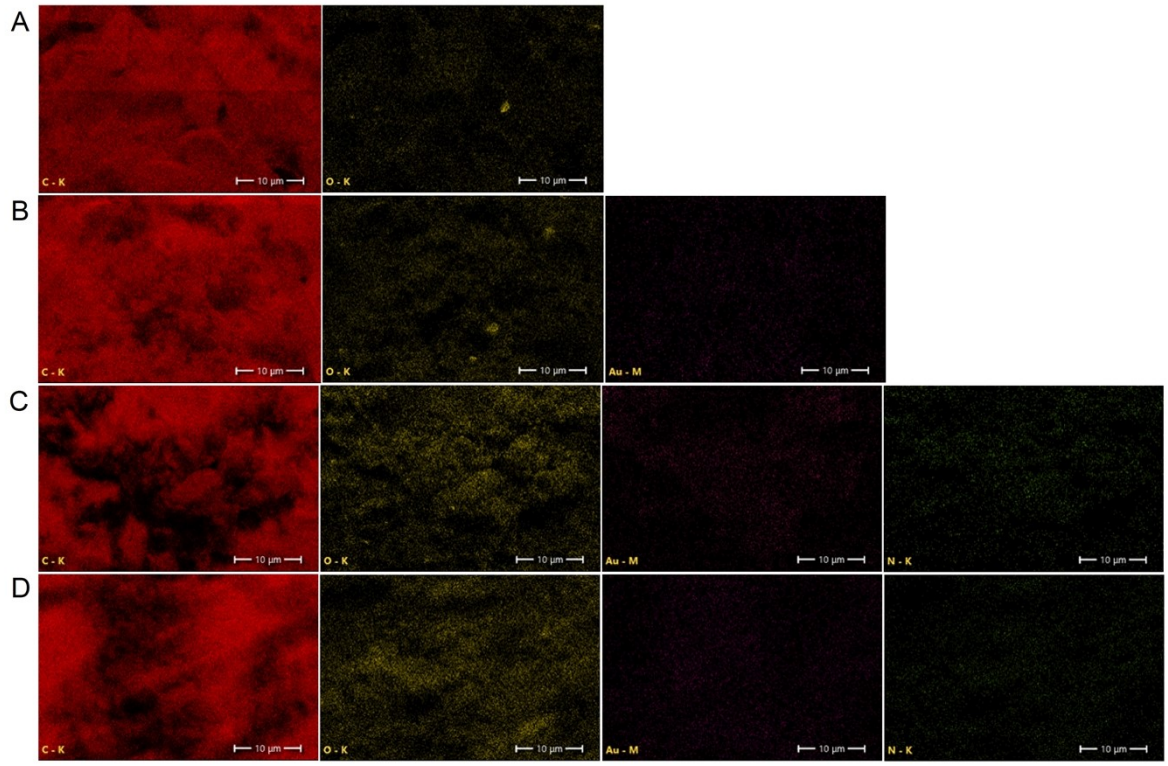

Fig. S5. The EDS mapping images of elemental composition on the different modified electrode surfaces (A) SPCE, (B) SPCE/AC-COOH/AuNPs, (C) SPCE/AC-COOH/AuNPs/Apt/BSA, and (D) SPCE/AC-COOH/AuNPs/Apt/BSA-CEA.

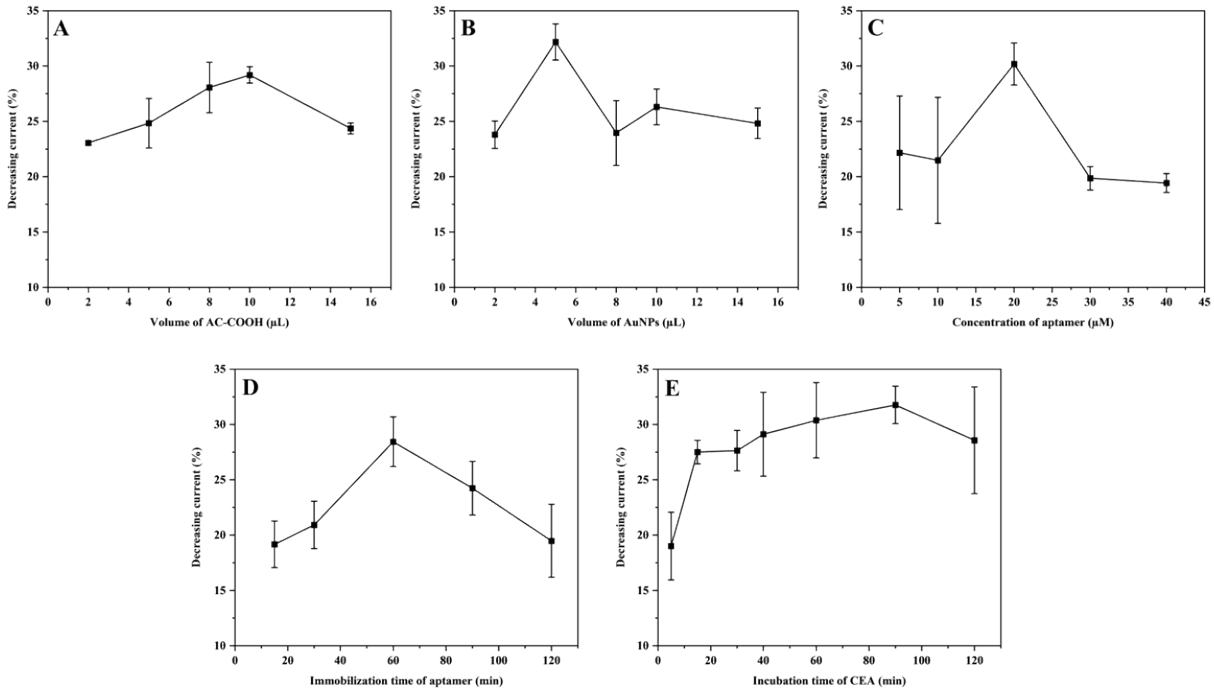

Fig. S6. The effects of (A) volumes of AC-COOH, (B) volumes of AuNPs, (C) aptamer concentration, (D) immobilization time, and (E) incubation time of CEA on the sensor response.

Table S4 Comparison of analytical performances of the proposed aptasensor with reported electrochemical immunosensors for CEA determination

Sensor	Technique	Concentration of recognition molecule	Immobilization time of recognition molecule	Incubation time of CEA	Linear range	LOD	Ref.
GCE/GO-antibody/CEA/ GNR-aptamer	SWV	10 µM	1 hour	1 hour	0.1 pg mL^{-1} – 10 ng mL^{-1}	0.05 pg mL^{-1}	34
Gold electrode/MCH-Apt/CEA/ ConA/HRP	DPV	20 µM	500 s	1 hour	5 – 40 ng mL^{-1}	3.4 ng mL^{-1}	35
SPGE/$Apts_1$-$Apts_2$/CEA-CS	DPV	300 µM (Apt_1, Apt_2)	14 hours	40 minutes	3 pg mL^{-1} – 40 ng mL^{-1}	0.9 pg mL^{-1}	36
Pt/Au/DN-graphene-CEAapt_2-Tb	DPV	2.5 µM (CEAapt_2)	18 hours	1 hour	0.001 – 20 ng mL^{-1}	0.0007 ng mL^{-1}	37
Gold electrode/Ab_1/CEA/Ab_2-AuNPs-Fc	SWV	200 µg mL^{-1} (Ab_1) 7.5 µg mL^{-1} (Ab_2)	18 hours (Ab_1) 1 hours (Ab_2)	1 hour	0.05 – 20 ng mL^{-1}	0.01 ng mL^{-1}	38
GCE-AMCM/AuNPs/GA-Ap	EIS	5 µM	4 hours	1 hour	0.001 – 100 ng mL^{-1}	0.0009 ng mL^{-1}	39
SPCE/AC-COOH/AuNPs/Apt	DPV	20 µM	1 hour	15 minutes	25 – 1000 ng mL^{-1}	1.28 ng mL^{-1}	This work

Ab_1: antibody 1, Ab_2: antibody 2, AMCM: Amino functionalized mesoporous silica, $Apts_1$: Aptamer 1, $Apts_2$: Aptamer 2, ConA: Concanavalin A, CS: Complementary strand, DN: Diaminonaphthalene, Fc: ferrocene, GCE: Glassy carbon electrode, GNR: Gold nanorods, GO: Graphene oxide, HRP: Horse radish peroxidase, MCH: 6-Mercapto-1-hexanol, SPGE: Screen-printed gold electrode, SWV: Square wave voltammetry, Tb: thrombin