Supplementary Information

A smartphone-based electrochemical POCT for CEA based on signal amplification of Zr_6MOFs

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1. Materials and instruments

Materials.

Zirconyl chloride octahydrate ($ZrOCl_2 \cdot 8H_2O$), benzoic acid, tetrakis (4-carboxyphenyl) porphyrin (H_2TCPP) were purchased from Shanghai Macklin Biochemical Co., Ltd. (China). CEA was purchased from Shanghai Linc-Bio Science Co. Ltd (Shanghai, China). Chloroauric acids ($HAuCl_4$) was obtained from Macklin Biochemical Co., Ltd.(Shanghai, China). Tris (2-carboxyethyl) phosphine hydrochloride (TCEP) were purchased from Aladdin Inc. (Shanghai, China). 6-Mercapto-1-hexanol (MCH), NaCl, KCl and $MgCl_2$ were obtained from Shanghai Reagent Corporation (China). Human alpha fetoprotein (AFP), prostate specific antigen (PSA) and human immunoglobulin G (HIgG) were purchased from Linc-Bio Science Co. Ltd. (Shanghai, China). Human serum albumin (HSA) and thrombin were obtained from Sigma-Aldrich. All chemical reagents were analytical grade and used without further purification. Milli-Q water (18 mΩ•cm resistivity) obtained from a Millipore system was employed to prepare all solutions.

All oligonucleotides with sequences listed below were purchased at Shanghai Sangon Biological Engineering Technology & Services Co., Ltd. (Shanghai, China):

Aptamer: 5'-ATACCAGCTTATTCAATT-3'

cDNA: 5'-SH-$(CH_2)_6$-TTTTTTAATTGAATAAGCTGGTAT-3'

Fc-DNA: 5'-ATACCAGCTTATTCAATT-Fc-3'

The solution used in this work was as follows: Phosphate buffered saline (0.1 M PBS, pH 7.4) consists of 0.1 M Na_2HPO_4 and 0.1 M NaH_2PO_4 for electrochemical process; DNA hybridization buffer (pH 8.0, 50 mM Tris base, 5 mM $MgCl_2$ and 100 mM NaCl).

Instruments

All electrochemical measurements were performed with a portable Sensit Smart USB (PalmSens, Netherlands). The morphologies of synthesized materials were characterized with a field emission scanning electron microscope (Thermo Fisher

Scientific FIB-SEM GX4(10.16.0.97)). Transmission electron microscopy (TEM) images were obtained on a FEI G2 electron microscope operating at 200 kV. Dynamic light scattering (DLS) and Zeta potential were measured on a Zetasizer Nano ZSP (Malvern Instrument Ltd, UK). X-ray diffraction (XRD) (SmartLab 9 kW) was performed on a D/MAX-TTRIII(CBO) series XRD instrument at 40 kV and 200 mA.

2. Synthesis of Zr_6MOFs and Fc-DNA/Zr_6MOFs

Zr_6MOFs were synthesized according to the literature method.[1,2] Briefly, H_2TCPP (0.13 mmol), $ZrOCl_2$•$8H_2O$ (0.93 mmol), and benzoic acid (23 mmol) were dissolved 100 mL of DMF in a 250 mL round-bottom flask, and the solution was stirred at 90 °C for 5 h. The formed Zr_6MOFs were purified by repeated washing with DMF, and redispersed in DMF for further use.

Purified Zr_6MOFs suspended in DMF were solvent exchanged with Milli-Q water thoroughly to remove remaining DMF. 0.5 mL Fc-DNA solution (30 μM) was slowly added into Zr_6MOFs suspension, and the solution was vigorously stirred overnight. Afterward, 100 μL Tris buffer (pH 7.4, 50 mM Tris base, 100 mM NaCl) was slowly added to the mixture under stirring, respectively. After brief sonication and further incubation, the mixture was transferred to a microtube, free DNA was recovered from the Fc-DNA/Zr_6MOFs suspension by centrifugation and washing.

3. Characterization of Zr_6MOFs and Fc-DNA/Zr_6MOFs

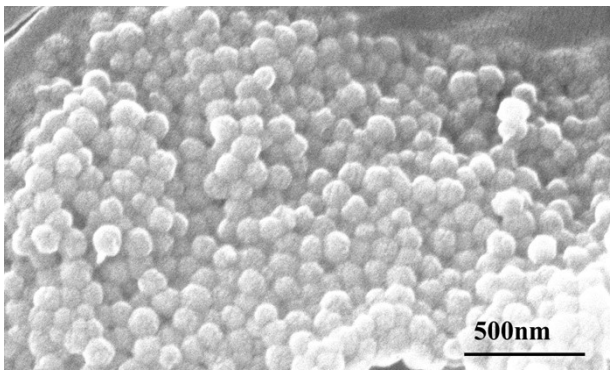

Fig. S1. SEM images of the Zr_6MOFs

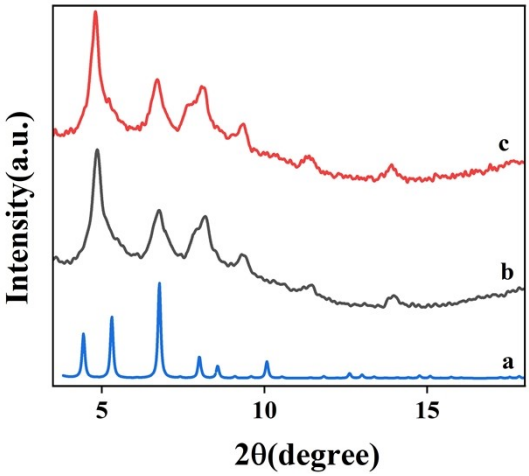

Fig. S2. PXRD of (a) simulated data of Zr_6MOFs, (b) Zr_6MOFs and (c) Fc-DNA/Zr_6MOFs

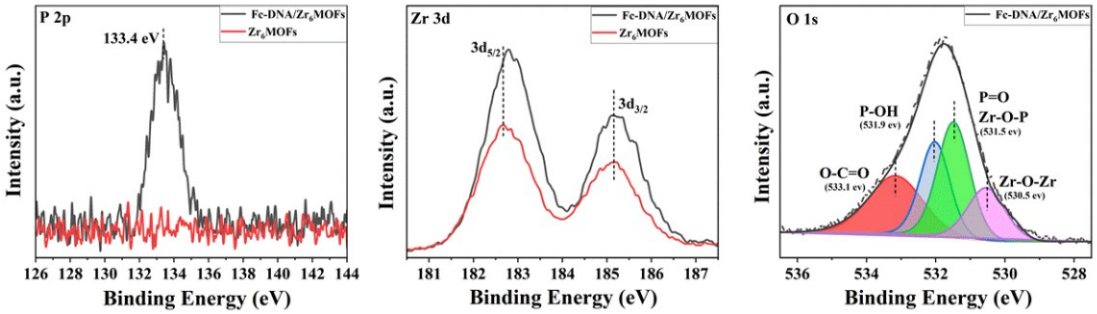

Fig. S3. P 2p, Zr 3d, and O 1s XPS spectra of Zr_6MOFs and Fc-DNA/Zr_6MOFs.

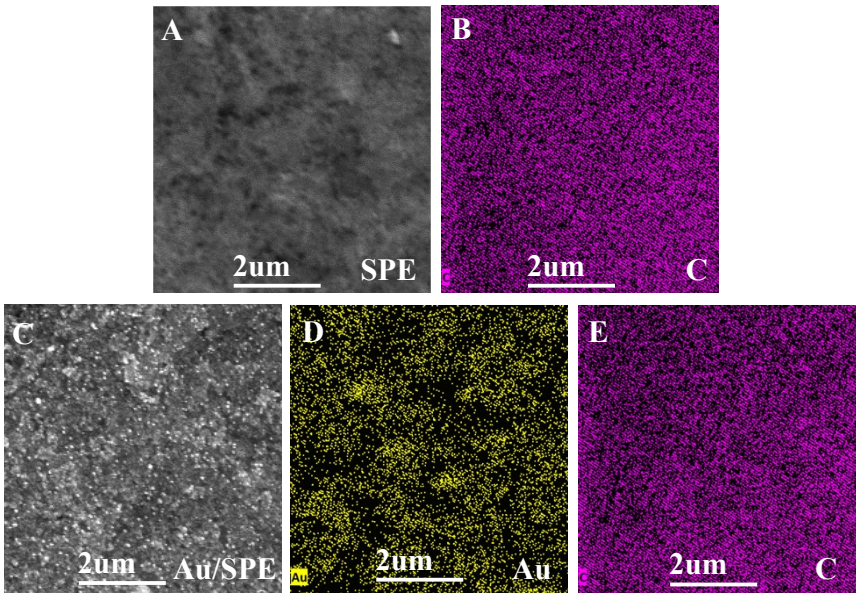

Fig. S4. SEM mapping of bare SPE (A, B) and Au/SPE (C-E).

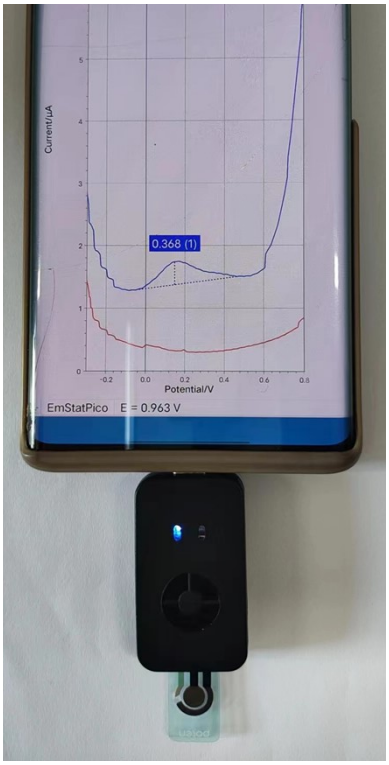

Fig. S5. The smartphone-based electrochemical POCT platform.

Table S1. Comparison of the analytical performances of the developed aptasensor and various reported methods .

Methods	**Time** (T_{CEA} +T_{signal})	**Linear range** ($ng \cdot mL^{-1}$)	**Detection limit** ($pg \cdot mL^{-1}$)	**References**
Fluoroimmunoassay	30 + 0 min	0.5 - 120	210	3
Colorimetric detection	30 + 0 min	50 - 1000	5×10^4	4
Color encoded assay	40 + 40 min	0.5 - 100	500	5
Electrochemial immunoassay	4 h	0.01 - 50	6.2	6
Electrochemical impedimetric biosensors	120 + 0 min	0.00002 - 20	0.01	7
Electrochemiluminescence	2 h + 2h	0.0001 - 100	0.0389	8
Electrochemical aptasensor	30 + 2 min	0.03 - 6.00	5.38	9
Electrochemical aptasensor	30 + 30 min	1 - 5000	210	10
Electrochemical aptasensor	40 + 0 min	0.001 - 5.0	0.74	11
Electrochemical aptasensor	45 + 60 min	**0.001 - 100**	**0.33**	**This work**

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