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# A Sensitive Electrochemical Platform Integrated with 3D graphene aerogel for Point-of-Care Testing for Tumor Markers

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**This file contains:**

Biochip Fabrication & Preparation of GO

S1: Supporting figures: Figure S1~S6.

S2: Supporting tables: Table S1~S2.

**S1: Supporting figures: Figures S1~S6.**

**Figure S1. Fabrication of the 3D GA microfluidic biochip.**

The biochip consists of three layers including the ITO coated glass substrate, the microchannel layer and the upper PDMS cap. Porous 3D GA film is functionalized with PCA and modified with antibodies before the channel being sealed. The GA film is obtained via in-situ chemical reduction of graphene oxide with LA in the channel. a) Preparation procedures; b) Antibody Modification; c) Photograph of the microfluidic chip.

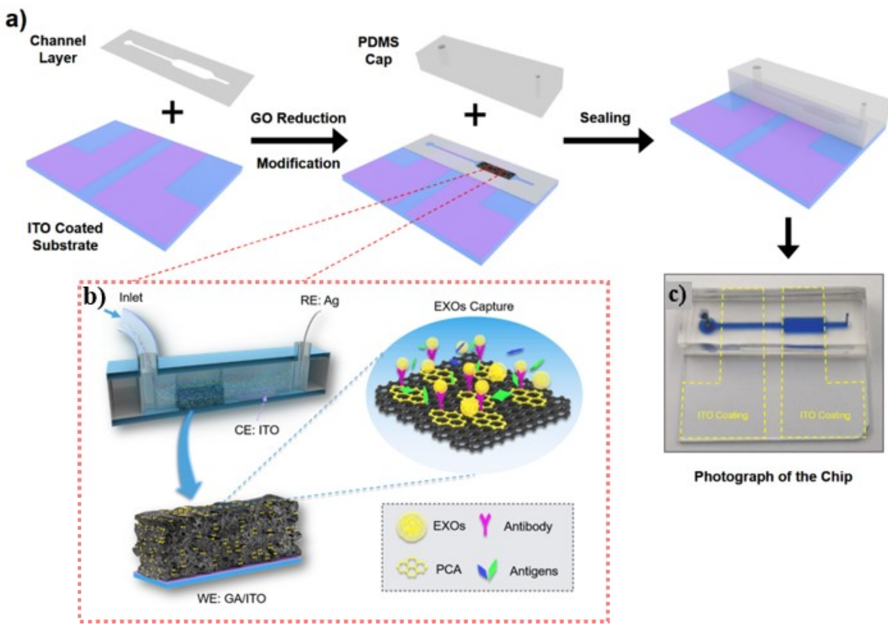


**Figure S2. EIS detection platform.**

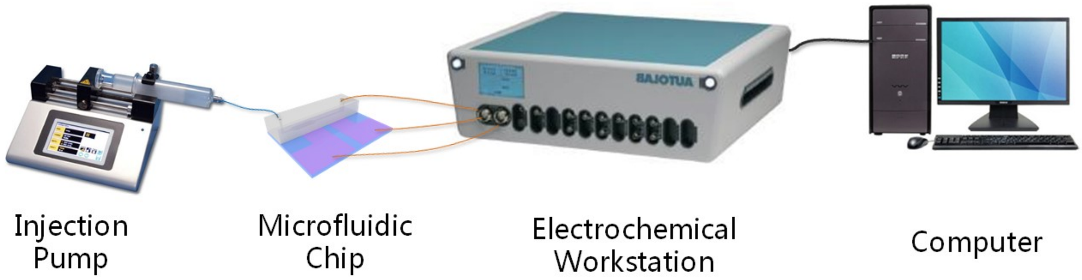
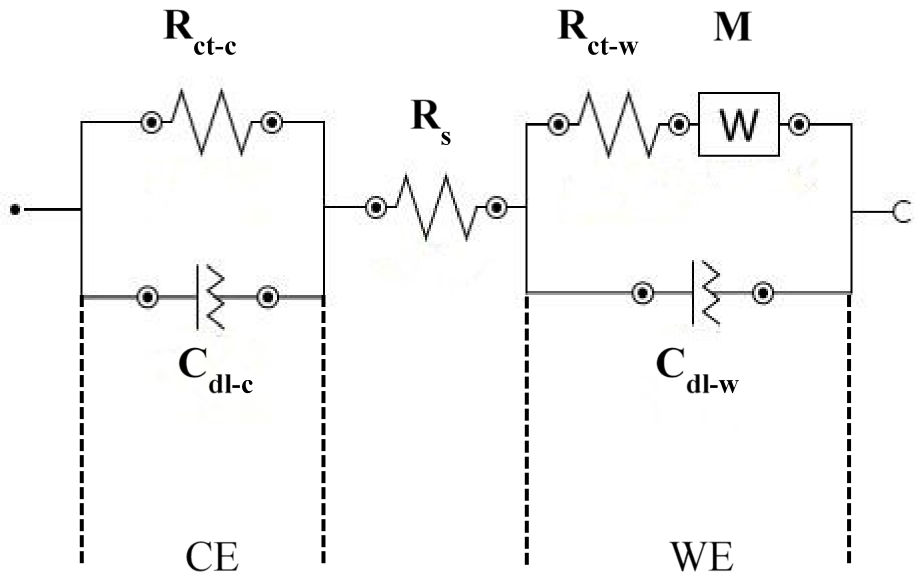


**Figure S3. Equivalent circuit of the three-electrode system in the micro-fluidic biochip.**




| Electrical element | Corresponding impedance expression |
|---|---|
| Solution resistance | $R_s$ |
| Double layer capacitance | $1/1/j\omega C_{dl}$ |
| Charge transfer resistance | $R_{ct}$ |
| Restricted linear diffusion with reflecting boundary | $Z_M(\omega) = R_d \frac{coth\sqrt{\tau_d j\omega}}{\sqrt{\tau_d j\omega}}$ |

**Figure S4. Optimization of Antibody Concentration.**

EIS responses of GA/ITO electrode modified with different concentrations (1 μg/mL, 5 μg/mL, 10 μg/mL) of antibodies.

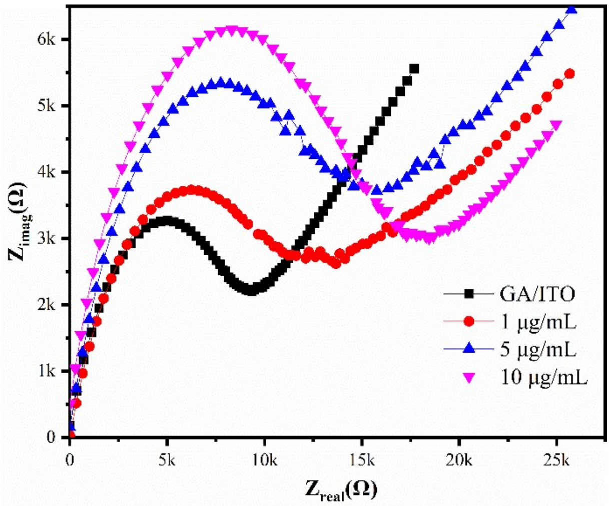


**Figure S5. Selectivity of the biochip and the detection of CEA in diluted serum samples.**

EIS responses of different analytes including AFP, AFP& CEA, AFP& IgG, AFP& Glucose, IgG, Glucose.

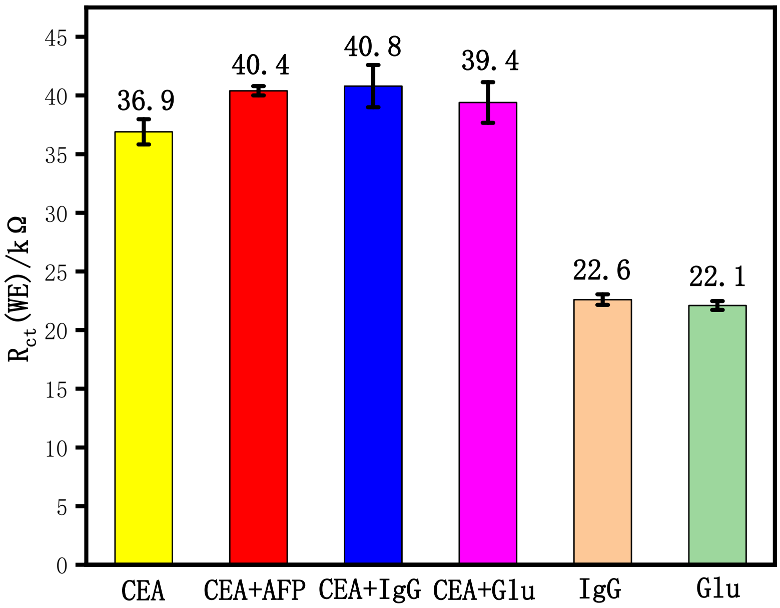
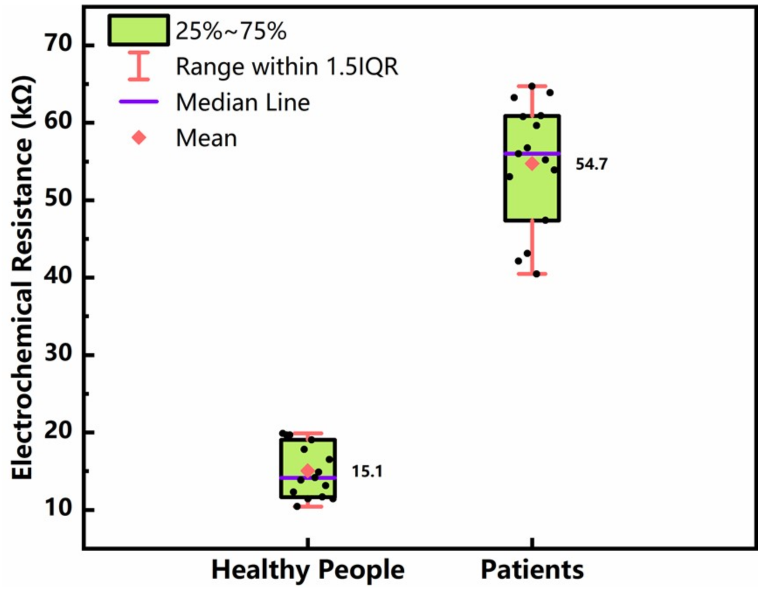


**Figure. S6**. **The EIS responses of real specimens from patients and healthy people.**



**S2: Supporting tables: Table S1~S2.**

**Table S1. Comparison with other reports on CEA/AFP detection**

| **No.** | **Sensitive Material** | **Method** | **Test Range (ng/mL)** | | **Detection Limit (pg/mL)** | | **Ref** |
|---|---|---|---|---|---|---|---|
| | | | **AFP** | **CEA** | **AFP** | **CEA** | |
| 1 | carboxy graphene nanosheets | Electrochemial Immunoassay | 0.5 - 60 | | 50.0 | 100.0 | 1 |
| 2 | chitosan nanocomposites | Electrochemial Immunoassay | 0.05 - 100 | | 30.0 | 20.0 | 2 |
| 3 | chitosan coated copper and cadmium hexacyanocobaltate nanocubes | Electrochemial Immunoassay | 0.025 - 250 | | 10.9 | 17.5 | 3 |
| 4 | platinum porous nanoparticles hybrid with metal ions | Electrochemial Immunoassay | 0.05 - 200 | | 50.0 | 2.0 | 4 |
| 5 | cadmium, lead and copper alginate nanobeads | Electrochemial Immunoassay | 0.01 - 100 | | 10.0 | 8.6 | 5 |
| 6 | Fe Oxides | Fluoroimmunoassay | - | | 70.0 | 300.0 | 6 |
| 7 | multicolor quantum dots | Immunochroma-Tographic Assay | - | | 300.0 | 200.0 | 7 |
| 8 | gold nanoparticles and mesoporous silica | Electrochemial Immunoassay | 0.5-100 | 0.5-50 | 100 | | 8 |
| 9 | multicolored Au NCs-$MoS_2$ | Fluoroimmunoassay | 0.5-60 | 0.5 - 120 | 160 | 210 | 9 |
| 10 | streptavidin-phycobiliproteins | ELISA | 0 - 50 | | 250 | 280 | 10 |
| 11 | gold nanoparticle and silver nanoparticles | Color Encoded Assay | 0.5 - 100 | | 500 | | 11 |
| **12** | **Porous 3D graphene aerogel** | **Microfluidic Electrochemial Immunoassay** | **0.01 -10** | **0.01 - 50** | **7.9** | **6.2** | **This work** |

**Table S2. Comparison with other reports on EXOs detection**

| No. | Sensitive Material | Method | Test Range ($\mu L^{-1}$) | Detection Limit ($\mu L^{-1}$) | Ref |
|---|---|---|---|---|---|
| 1 | Probe DNAs & $Ru(NH_3)_6^{3+}$ | Electrochemical Immunoassay | - | 70 | 12 |
| 2 | Quantum dots | Electrochemical Immunoassay | $10^2$ - $10^7$ | 100 | 13 |
| 3 | Graphene oxide-DNA aptamer | Fluoroimmunoassay | $3.0 \times 10^4$ - $6.0 \times 10^4$ | $2.1 \times 10^4$ | 14 |
| 4 | Copper Nanoparticles | Fluoroimmunoassay | $7.5 \times 10^4$ - $1.5 \times 10^7$ | $4.8 \times 10^4$ | 15 |
| 5 | HER-2 antibody | Electrochemical Immunoassay | - | $4.7 \times 10^5$ | 16 |
| 6 | Surface marker mediated signal amplification | Electrochemical Immunoassay | $10^2$ – $10^6$ | 200 | 17 |
| 7 | Bivalent-cholesterol-labled DNA anchor | Fluoroimmunoassay | $2.3 \times 10^3$ - $2.3 \times 10^5$ | $2.2 \times 10^3$ | 18 |
| **8** | **Porous 3D graphene aerogel** | **Microfluidic Electrochemistry** | **$2.5 \times 10^1$ - $2.5 \times 10^7$** | **9.8** | **This work** |

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