## **Supporting Information (SI)**

# Graphene Oxide Coated Gold Nanostars based Sensing Platform for Ultrasensitive Electrochemical Detection of Circulating Tumor DNA

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### SI.1. Synthesis of gold nano-stars (AuNSs)

A two-step procedure was used to synthesize the gold-nanostars:

(i) The seed solution of the gold-nanostars (AuNSs) was prepared using the modified seed-mediated growth method.<sup>1</sup> 12 nm Au seeds were prepared by boiling a 100 ml solution of 1 mM HAuCl<sub>4</sub>, then 15 ml of 1% trisodium citrate were added into the solution under vigorous stirring. The resulting solution was cooled to room temperature after being kept boiling for an additional 15 mins. The seed solution was then filtered using a 0.22 μm nitrocellulose membrane and stored at 4 °C for future usage.
(ii) Crewth of the perpendent in the second of the AuNSe surthering 100 μL of the cold conduction.

(ii) Growth of the nanostars: In the case of the AuNSs synthesis, 100  $\mu$ L of the gold seed solution was added to 10 ml of a 0.25 mM HAuCl<sub>4</sub> solution. Subsequently, 100  $\mu$ L of 2 mM AgNO<sub>3</sub>

solution and 50  $\mu$ L of 0.1 M Ascorbic Acid solution were simultaneously added. In order to increase the dispersity of the resulting AuNSs, a 100  $\mu$ L of 0.1 M hexadecyltrimethylammonium bromide solution was added. The solution was centrifuged at 4000 rpm for 5 mins and redispersed in 1 ml water for future usage.<sup>1</sup>

#### SI.2. Synthesis of gold nano-stars-graphene oxide (AuNS-rGO) nanocomposite

In order to synthesize the AuNSs-ErGO nanocomposite, 0.5 mg/ml GO nanosheet was dispersed in 0.1 M PBS (pH 7.4) solution and stirred for 20 mins, then sonicated for an hour. Later, 0.5 mM AuNSs solution was added during the sonication of GO (15 mins time frame). The resulting GO nanosheet wrapped AuNSs nanocomposite was stored for future usage.

#### SI. 3. The optimization of the rGO-AuNSs deposition protocol

The surface modification technique of the electrochemically-cleaned GC electrode was optimized via drop-coat and electrochemical depositions of the GO-AuNSs nanocomposite. EIS results reported the drop-coated GO-AuNS nanocomposite as having an unstable surface and poor electron conductivity due to the lack of covalent bonds (C-N) with the electrode's surface. However, the EIS results of the electrodeposited GO-AuNSs nanocomposite is more promising; it is surface-stable and electronically conductive, both of which can be attributed to the prevalence of covalent (C-N) bonds (Fig. SI. 1).



**Fig. SI. 1.** Nyquist plots at different protocol of GO-AuNSs deposition of GCE/ErGo-AuNSs composite electrodes measured in 0.1 M KCl including 2 mM [Fe(CN)<sub>6</sub>]<sup>-3/-4</sup> solution.

The formation of rGo-AuNS nanocomposite film on the GCE electrode was confirmed by the presence of increasing peak currents of the CV cycles (Fig. SI. 4). This simultaneous reduction of the electrochemically-reduced GO (rGO) wrapped AuNSs nanohybrid was relatively more stable due to its dissolubility in common solvents.

#### SI. 4. Optimization of the CV cycle of rGo-AuNSs electrodeposition

The electrochemical signals of the ErGO-AuNSs film were affected by the preparatory conditions precipitated by the CV cycles of electrodeposition. The electrochemical signals of the rGo-AuNSs realized a maximum at 14 cycles, followed by a decrease with fluctuating scans (Fig. SI. 2), which prompted the selection of a 14 CV cycle configuration. The presence and amount of rGo-AuNSs could be essential for the occurrence of electron transfer. The loading of rGo-AuNSs via the CV method optimization results of EIS confirmed that increased amounts of rGo-AuNSs on the surface results in thicker films, which negatively affects charge transfer and electrochemical responses.

This occurrence is attributed to the stacking effect of thicker films, which decreases the conductivity of the nanocomposite sensor. Thinner films on GCE's surface translates to lower amounts of binding sites on the thin film ErGO-AuNSs, which significantly weakens the physisorption between GCE and ErGO-AuNSs.



Fig. SI. 2. Nyquist plots of GO-AuNSs deposition cycle optimization measured in 0.1 M KCl including 2 mM [Fe(CN)<sub>6</sub>]<sup>-3/-4</sup> solution.

# SI. 5. Optimization of the potential window for electrodeposition of rGo-AuNSs nanocomposite

The potential window was also optimized from -1.2 to 0.7 V, which was the most favorable electrochemical preparation condition for rGO-AuNSs film formation on the GCE's electrode surface relative to other potential windows from -0.6 to 1.6 V (Fig. SI. 3). The concentration of GO nanosheets used was 0.5 mg/mL, while the optimized potential window was -1.2 to 0.7 V for the electrodeposition of ErGO-AuNS nanohybrid of the electrochemically-cleaned GC electrode. The maximum EIS response was observed for the potential window from -1.2 to 0.7 V for

electrochemical reduction and the simultaneous electrodeposition of Go-AuNSs on the GC's electrode.



Fig. SI. 3. Nyquist plots of GO-AuNSs deposition potential window optimization measured in 0.1 M KCl including 2 mM [Fe(CN)<sub>6</sub>]<sup>-3/-4</sup> solution.

#### SI. 6. Electrochemical deposition of GO-AuNSs nanocomposite

The electrochemical deposition of GO-AuNSs on the cleaned GC electrode was performed using CV methods. The CV cycles confirm the simultaneous reduction of GO and its coelectrodeposition along with AuNSs in the form of the GO-AuNSs nanocomposite. 0.5 mg/mL of GO and 2.5 mg/mL AuNSs were used to form a dispersion. The CV electrodeposition of rGO-AuNS composite was performed at a potential range of -1.2 to 0.7 V and a scan rate of 50 mVs<sup>-1</sup> for 14 CV cycles (Fig. SI. 4). The dispersion was N<sub>2</sub> gas bubbled for 10 mins before the CV electrodeposition.



**Fig. SI. 4.** Cyclic voltammograms for the simultaneous electrochemical deposition/reduction of 0.5 mgml<sup>-1</sup> GO nanosheets and AuNS in 0.1M PBS solution (pH 7.4) on the GCE electrode at the scan rate of 50 mV/s for 14 cycles.

The simultaneously increasing peak currents from the CV cycles signifies the formation of the ErGo-AuNSs nanocomposite film on GCE's electrode. It is also evident that the increasing number of CV cycles resulted in the profiles seen in (Fig. SI. 4) to shift upwards towards the positive direction of the Y-axis. It can be seen that in the first cycle, a sizable cathodic peak appears at -0.5 V, which can be attributed to the reduction of oxygen functionalities in the GO. The conductive film from the electrochemical deposition of rGO-AuNSs on the GC electrode was confirmed to have taken place due to the increasing peak currents that are usually caused by the formation of CV cycles. The electrochemical method involves the simultaneous new reduction/electrodeposition of non-conductive GO and AuNNs to form an electrochemicallyreduced GO (ErGO)-wrapped AuNSs, the product of which is reported to be highly stable due to its non-solubility in common solvents. The nanosized AuNSs was homogenously distributed while also densely wrapped by the rGO film, which occurred due to the concentrations of the GO and AuNSs solutions and the deposition CV cycles and scan rates.