Supporting Information

Carbon Dot-Functionalized Solution-Gated Graphene Transistors for Highly Sensitive Detection of Cobalt(II) Ions

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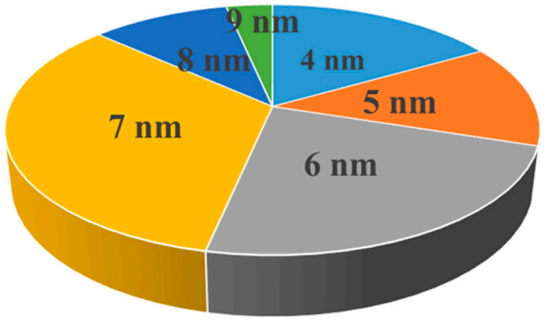

Figure S1. The size distribution of the CDs.

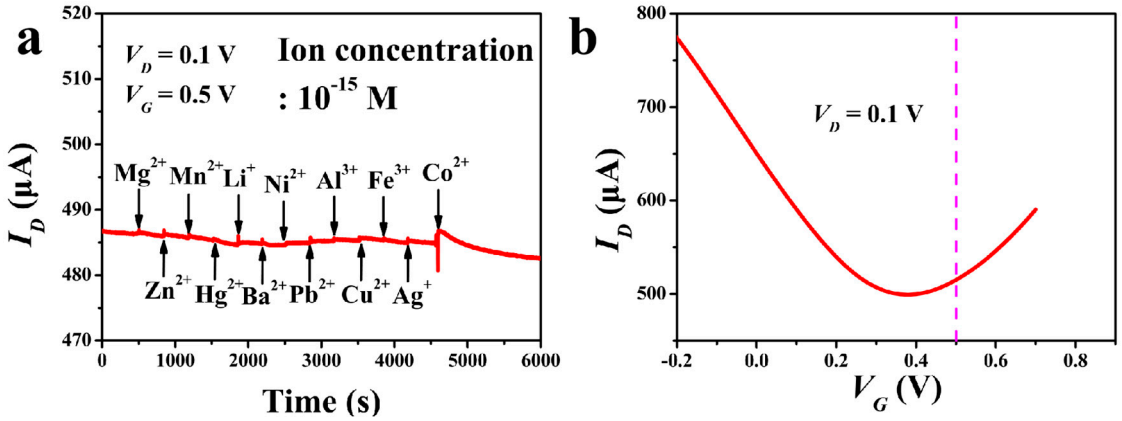

Figure S2. (a) Selectivity measurements of the CD-SGGT sensor. Comparison of the sensor in response to the target Co^{2+} ions or other metal ions, i.e. Ag^{+}, Al^{3+}, Ba^{2+}, Cu^{2+}, Fe^{3+}, Hg^{2+}, Li^{+}, Mg^{2+}, Mn^{2+}, Ni^{2+}, Pb^{2+}, Zn^{2+} ions. (The concentration of all the ions is 1.0×10^{-15} M.) (b) The transfer curves of the SGGT under the corresponding condition.

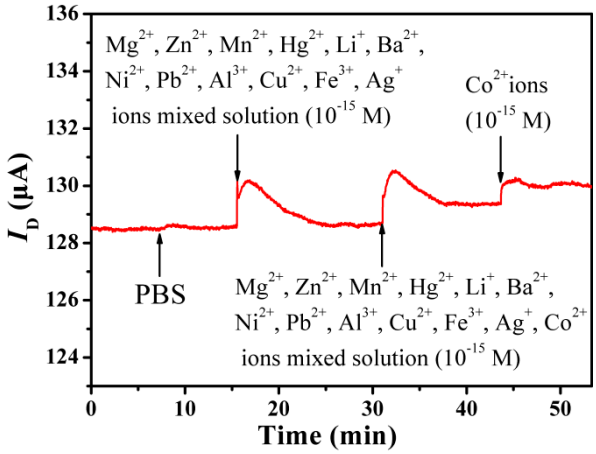

Figure S3. Test of the selectivity of the CD-SGGT sensor, i.e. PBS, (Mg^{2+}, Zn^{2+}, Mn^{2+}, Hg^{2+}, Li^{+}, Ba^{2+}, Ni^{2+}, Pb^{2+}, Al^{3+}, Cu^{2+}, Fe^{3+} and Ag^{+}) ions mixed solution (1.0×10^{-15} M), (Mg^{2+}, Zn^{2+}, Mn^{2+}, Hg^{2+}, Li^{+}, Ba^{2+}, Ni^{2+}, Pb^{2+}, Al^{3+}, Cu^{2+}, Fe^{3+}, Ag^{+} and Co^{2+}) ions mixed solution (1.0×10^{-15} M), Co^{2+} ions (1.0×10^{-15} M).

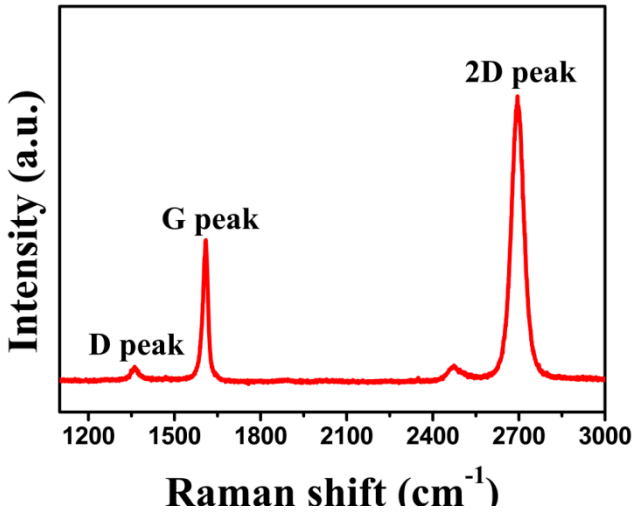

Figure S4. Raman spectrum of a single-layer graphene on Si substrate.

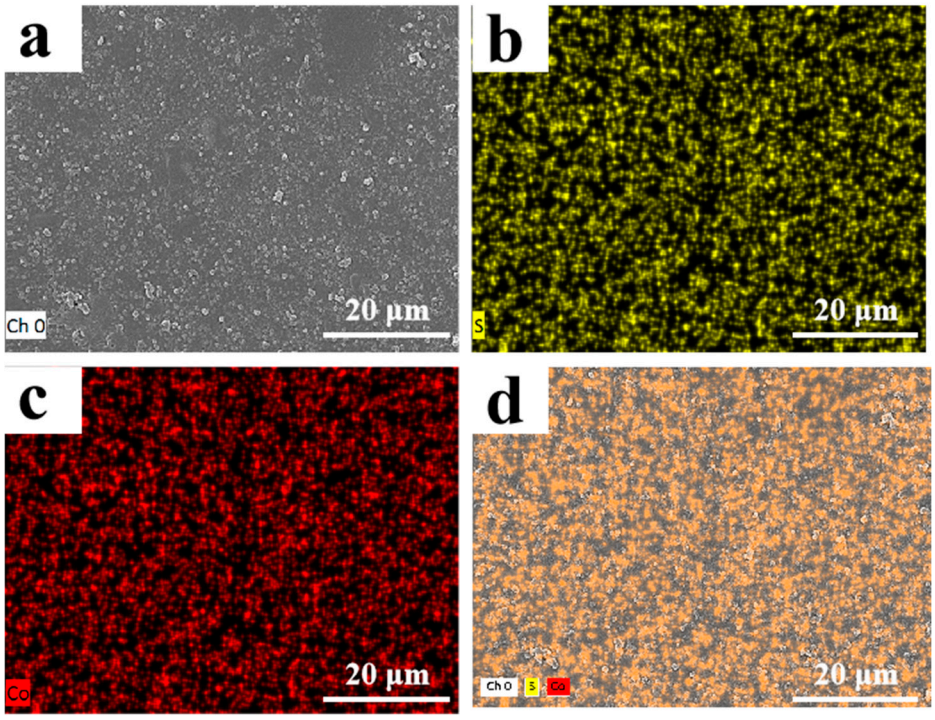

Figure S5. Characterization of the gate surface after detection. (a) SEM image of the gate electrodes after detecting Co^{2+} ions. (b), (c), (d) Element mapping result of the gate electrodes after detecting Co^{2+} ions.

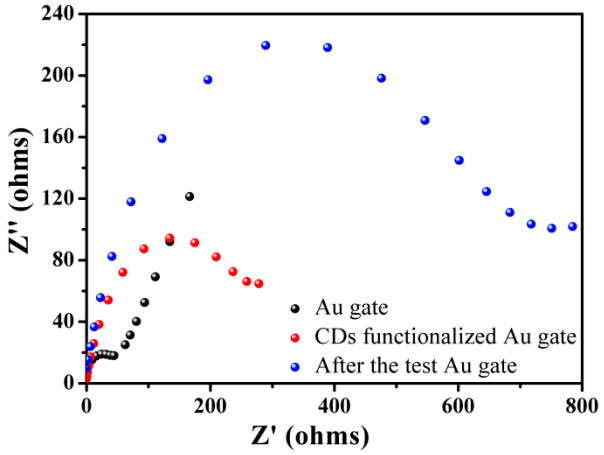

Figure S6. Impedance test on gate surface (bare gold, functionalized CDs and after test).

Table S1. Comparison on recently reported various methods for detection of Co^{2+} ions.

Detection Method	Materials	LOD	Linear Range	Ref
Fluorescence	N-CNDs	230.5 nM	2. 5 μM - 25 μM	[1]
Fluorescence	N,S-GQDs	1.25 mM	0 - 40 mM	[2]
Colorimetric	coumarin	7.09 μM	0 - 90 μM	[3]
Absorption	Au@AuAg	0.2 nM	1 nM - 100 nM	[4]
SERS	TPY	1 nM	0 - 100 nM	[5]
Fluorescence	BMBA	1.73 μM	0 - 1.02 mM	[6]
SGGT	N,S-CDs	0.1 aM	0.1 aM - 1 fM	This work

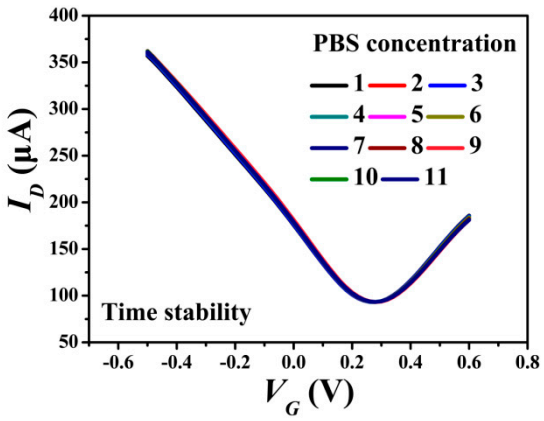

Figure S7. The transfer curve of CD-SGGT was tested 11 times consecutively.

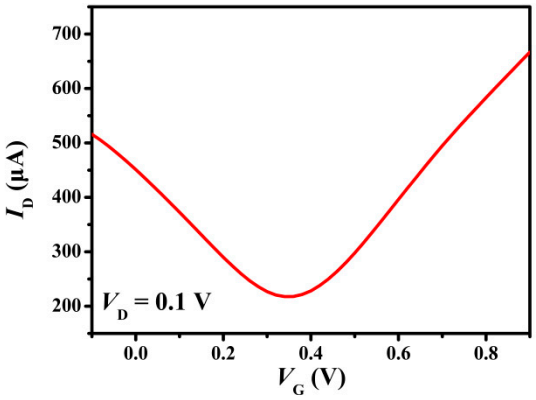

Figure S8. The transfer curves of the SGGT under the corresponding condition. (Figure 6b)

Reference

1. Du, F.; Cheng, Z.; Kremer, M.; Liu, Y.; Wang, X.; Shuang, S.; Dong, C., A label-free multifunctional nanosensor based on N-doped carbon nanodots for vitamin B12 and Co^{2+} detection, and bioimaging in living cells and zebrafish. *J. Mater. Chem. B* **2020,** *8* (23), 5089-5095.

2. Boonta, W.; Talodthaisong, C.; Sattayaporn, S.; Chaicham, C.; Chaicham, A.; Sahasithiwat, S.; Kangkaew, L.; Kulchat, S., The synthesis of nitrogen and sulfur co-doped graphene quantum dots for fluorescence detection of cobalt(ii) ions in water. *Mater. Chem. Front.* **2020,** *4* (2), 507-516.

3. Vashisht, D.; Kaur, K.; Jukaria, R.; Vashisht, A.; Sharma, S.; Mehta, S. K., Colorimetric chemosensor based on coumarin skeleton for selective naked eye detection of cobalt (II) ion in near aqueous medium. *Sens. Actuators B Chem.* **2019,** *280*, 219-226.

4. He, Z.; Zhu, J.; Li, X.; Weng, G. J.; Li, J. J.; Zhao, J. W., Surface etching-dependent geometry tailoring and multi-spectral information of Au@AuAg yolk-shell nanostructure with asymmetrical pyramidal core: The application in Co^{2+} determination. *J. Colloid Interface Sci.* **2022,** *625*, 340-353.

5. Tsoutsi, D.; Guerrini, L.; Hermida-Ramon, J. M.; Giannini, V.; Liz-Marzan, L. M.; Wei, A.; Alvarez-Puebla, R. A., Simultaneous SERS detection of copper and cobalt at ultratrace levels. *Nanoscale* **2013,** *5* (13), 5841-6.

6. Mahajan, P. G.; Dige, N. C.; Desai, N. K.; Patil, S. R.; Kondalkar, V. V.; Hong, S. K.; Lee, K. H., Selective detection of Co^{2+} by fluorescent nano probe: Diagnostic approach for analysis of environmental samples and biological activities. *Spectrochim. Acta A Mol. Biomol. Spectrosc.* **2018,** *198*, 136-144.