A fluorometric and colorimetric dual-mode sensor based on nitrogen and iron co-doped graphene quantum dots for detection of ferric ion in biological fluids and cellular imaging

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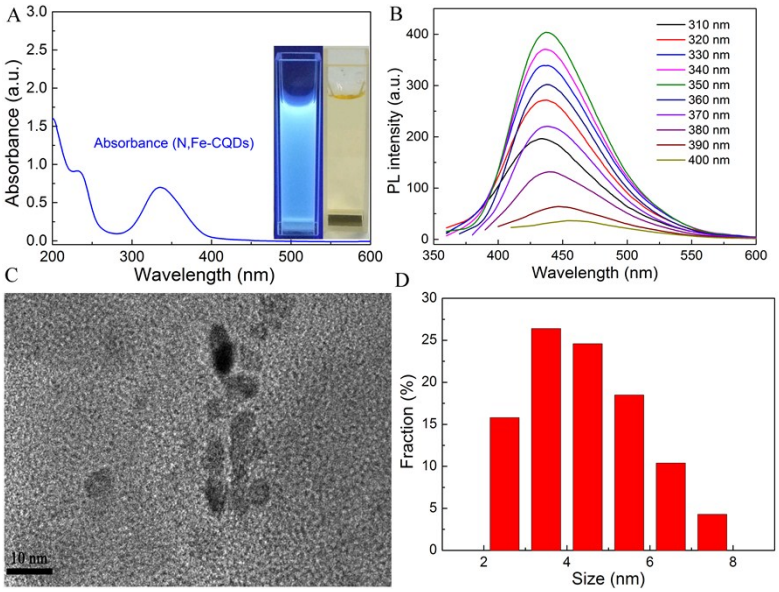

Fig. S1 (A) UV-vis absorption spectra of N, Fe-GQDs, inset is the photographs of N, Fe-GQDs under the 365 nm UV light (left) and sunlight (right). (B) Fluorescence emission spectra of N, Fe-GQDs with excitation by different wavelengths. (C) The high-resolution TEM (HRTEM) image of N, Fe-GQDs. (D) The size distribution of N, Fe-GQDs.

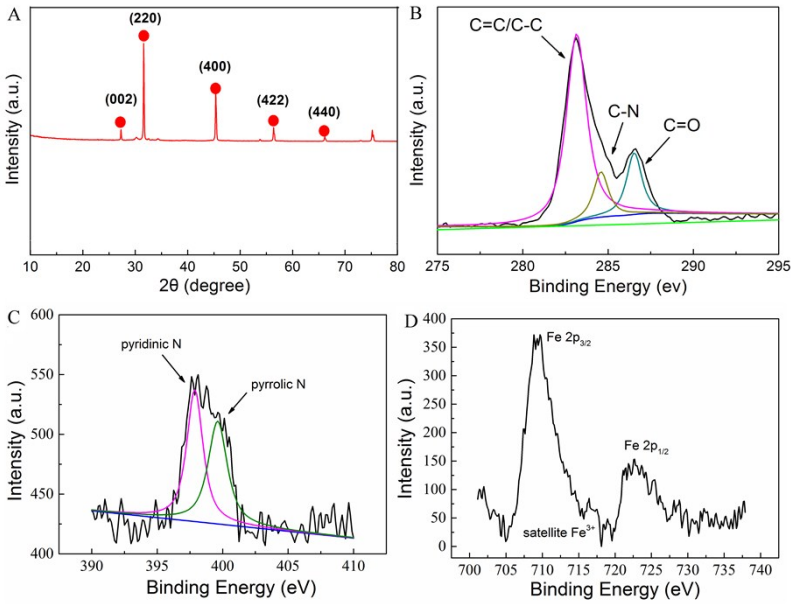

Fig. S2 (A) XRD patterns of N, Fe-GQDs. (B) The high-resolution XPS spectrum of C 1s in N, Fe-GQDs. (C) The high-resolution XPS of N 1s in N, Fe-GQDs. (D) The high-resolution XPS of Fe 2p in N, Fe-GQDs.

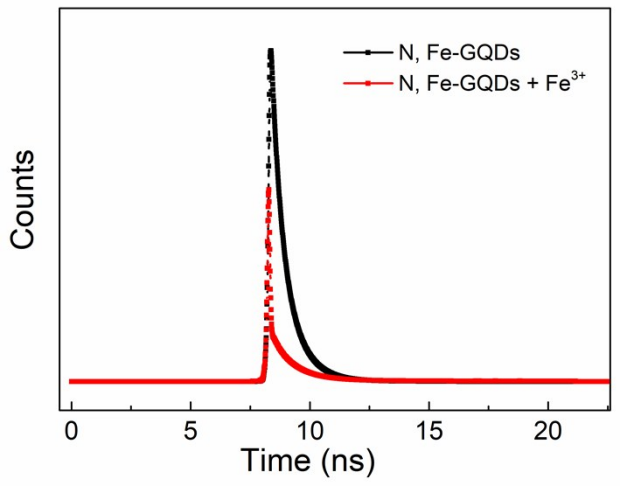

Fig. S3 Fluorescence decay spectra of N, Fe-GQDs in the absence (black) and presence (red) of Fe^{3+} ions.

Fig. S4 The photograph of corresponding color changes of N, Fe-GQDs in the presence of different Fe^{3+} concentrations.

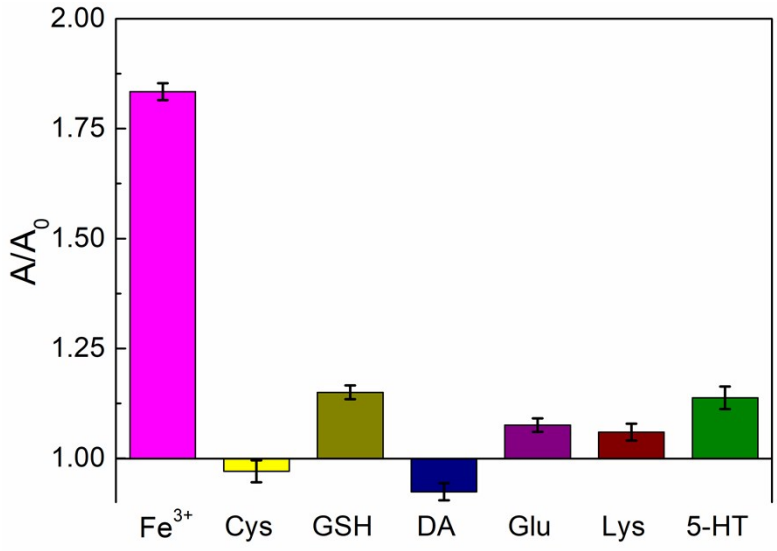

Fig. S5 Absorption spectra response of N, Fe-GQDs at 335 nm in the presence of different biomolecules and Fe^{3+} (300 μM). A_0 and A are the absorbance at 335 nm in the absence and presence of biomolecules and Fe^{3+}, respectively.

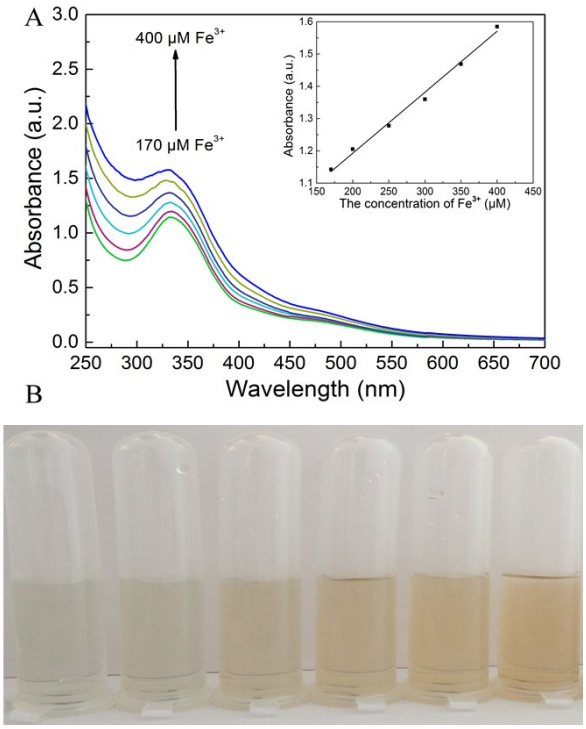

Fig. S6 (A) UV-vis absorption spectra of N, Fe-GQDs in the presence of different Fe^{3+} concentrations in lake water, Fe^{3+} concentration is 170, 200, 250, 300, 350 and 400 μM (from bottom to top), respectively. Inset is the relationship between the absorbance at 335 nm and the Fe^{3+} ions concentrations in lake water. (B) The photograph of N, Fe-GQDs in the presence of the corresponding Fe^{3+} concentrations in lake water under sunlight.

Table S1 Comparison of different fluorescence probes for Fe^{3+} detection.

Products	Detect method	Linear range (μM)	Detect limit (μM)	Ref
CDs	Fluorometry	12.5-100	9.97	1
N-CQDs	Fluorometry	0-20	-	2
CDs	Fluorometry	8-100	0.8	3
CQDs	Fluorometry	0-50	1.3	4
CDs	Fluorometry	16-166	6.05	5
$P_2O_7^{4-}$–AuNPs	Colorimetry	10-60	5.6	6
AuNPs	Colorimetry	1–37	0.85	7
AgNPs	Colorimetry	0.08-80	0.08	8
N, Fe-GQDs	Fluorometry	10-110	3.21	This work
	Colorimetry	0-450	1.34	

CDs: Carbon dots
CQDs: Carbon quantum dots
N-CQDs: N-dope carbon quantum dots
AgNPs: Ag nanoparticles
AuNPs: Au nanoparticles

Table S2 Fe^{3+} determination results in human serum and urine samples.

Sample	Spike (μM)	Found (μM)	Recovery (%)	RSD (%, n=3)
serum	20.00	20.84 (19.91[a])	104.20	2.17
	50.00	48.81 (51.01[a])	97.62	1.92
	100.00	93.60 (97.79[a])	93.60	3.31
urine	20.00	18.74 (20.89[a])	93.70	2.58
	50.00	51.17 (48.63[a])	102.34	4.90
	100.00	108.20 (102.31[a])	108.20	2.04

[a] The concentration in bracket was found by ICP-OES.

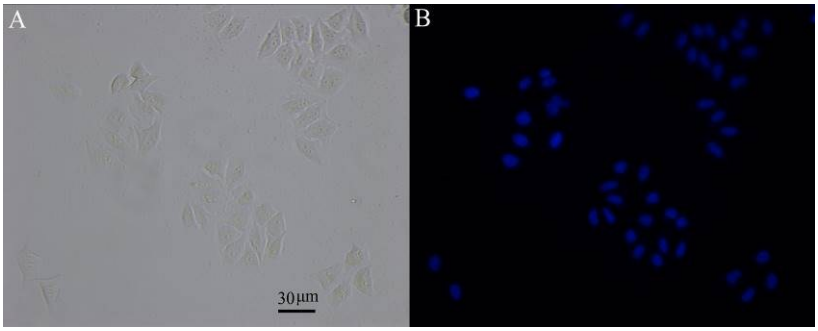

Fig. S7 The fluorescence microscopy images of HeLa cells treated with N, Fe-GQDs, (A) the bright-field images, (B) the fluorescent images.

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