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Electronic Supplementary Information

Induction Coil Heater Prepared Highly Fluorescent Carbon Dots as Invisible Ink and Explosive Sensor

Md Palashuddin Sk[a], and Arun Chattopadhyay* [a,b]

[a]Department of Chemistry and [b]Centre for Nanotechnology, Indian Institute of Technology Guwahati, Guwahati -781039; India. Email: arun@iitg.ernet.in

Quantum Yield Calculation

We have calculated Quantum yield with respect to quinine sulphate (QS) in 0.1 M H_2SO4, using the following formula.[1-2]

$$Q_S = Q_R \times \frac{I_S}{I_R} \times \frac{A_R}{A_S} \times \frac{\eta_S^2}{\eta_R^2}$$

Where,

Q_S = quantum yield of sample; Q_R = quantum yield of reference; I_S = area under PL curve of sample; I_R = area under PL curve of reference; A_R = absorbance of the reference; A_S = absorbance of the sample; η_S = refractive index of sample; η_R = refractive index of reference.

Q.Y. of quinine sulphate = 0.54; Refractive Index: water = 1.33

(The concentration of all samples and the reference quinine sulphate were adjusted so that the optical densities of all samples were 0.020 ± 0.003 at the excitation wavelength (365 nm)).

Table S1. Optimization of citric acid and ethylenediamine ratio for Cdot synthesis**

SN	Carbon Source	Surface Passivation Agent	Quantum Yield (%)
1	3 mM Citric Acid	No	1.6
2	3 mM Citric Acid	1 mM Ethylenediamine	12
3	3 mM Citric Acid	2 mM Ethylenediamine	70.1
4	3 mM Citric Acid	3 mM Ethylenediamine	71.4
5	3 mM Citric Acid	4 mM Ethylenediamine	72.6

Table S2. Quantum Yield of Cdots prepared under different reagent conditions**

SN	Carbon Source	Surface Passivation Agent	QY (%)
1	Citric Acid	No	1.34 ± 0.37
2	Citric Acid	Ethylenediamine	75.9 ± 7.3
3	Citric Acid	1,3- Diaminopropane	77.3 ± 5.6
4	Citric Acid	N-(2-Aminoethyl)-1,2-ethandiamin	55.5
5	Citric Acid	o-Phenylenediamine	38.25
6	Citric Acid	p-Phenylenediamine	2.38
7	Citric Acid	N,N-Bis(2-aminoethyl)-1,2-ethandiamin	56.7
8	Citric Acid	Urea	12.90
9	Citric Acid	Thiourea	6.50
10	Citric Acid	4,7,10-Trioxa-1,13-tridecane diamine	12.8
11	Alginate	Ethylenediamine	1.63
12	Glucose	Ethylenediamine	0.41
13	Glutamic Acid	Ethylenediamine	11.56
14	Aspartic Acid	Ethylenediamine	17.16

** It is important to mention here that quantum yield results reported in Table S1 and S2 were obtained from single absorbance measurements. This was done to get the best sample result. On the other hand, the quantum yield reported below for Cdots synthesized from citric acid and ethylenediamine was calculated from the integrated fluorescence intensity versus absorbance plot. Hence the difference would be due to methods used.

Quantum Yield Calculation of Cdots synthesized from Citric acid and Ethylenediamine

Quantum yield was measured according to established procedure[3] by using quinine sulfate in 0.10 M H_2SO_4 solution as the standard. Absolute values were calculated according to the following equation:

$$Q_S = Q_R \times (m_S / m_R) \times (n_S / n_R)^2$$

Where, Q is the quantum yield, m is the slope of the plot of integrated fluorescence intensity *vs* absorbance and n is the refractive index (taken here as 1.33, the refractive index of distilled water). The subscript R refers to the reference fluorophore, quinine sulphate solution. In order to minimize re-absorption effects, absorbance was kept below 0.15 at the excitation wavelength of 365 nm. The values m_S = 5.19 and m_R = 3.81 were obtained from the plot of integrated fluorescence intensity *vs* absorbance. The quantum yield of Cdots (obtained from reaction of citric acid with ethylenediamine) was calculated to be 73.5 %.

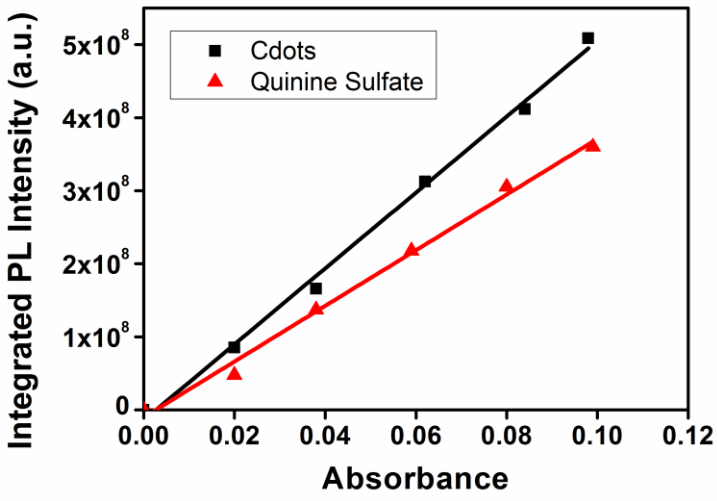

Fig. S1 Integrated fluorescence intensity versus absorbance of Cdots and quinine sulfate. The sample was synthesized from the reaction of citric acid with ethylenediamine.

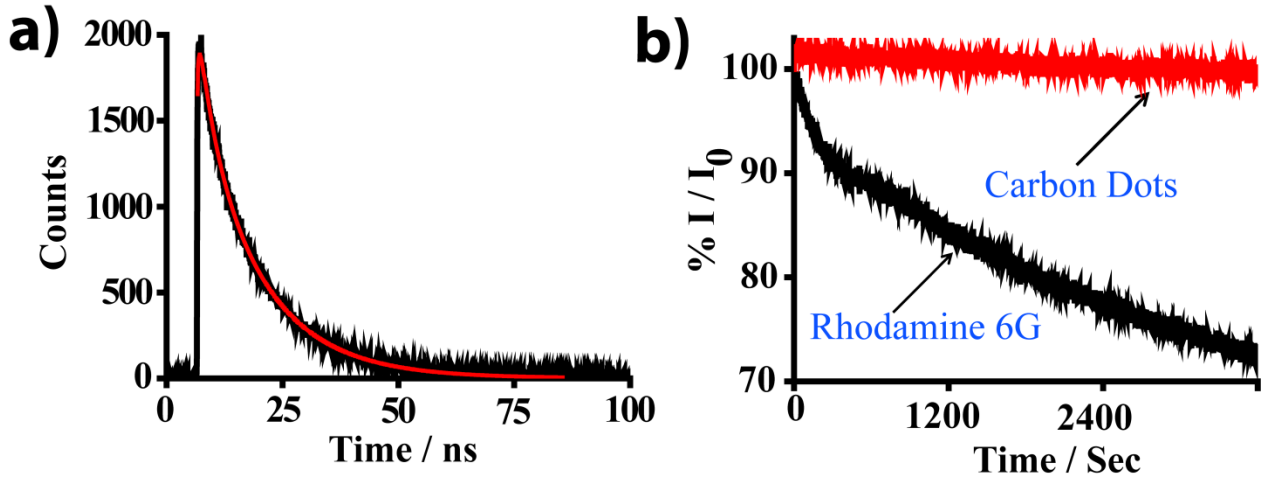

Fig. S2 a) Time-resolved fluorescence decay profile of Cdots in water. The excitation wavelength was set at 375 nm and emission was probed at 450 nm. and b) The effect of photo-irradiation time on the fluorescence intensity of Cdots and the organic fluorophore rhodamine 6G in water.

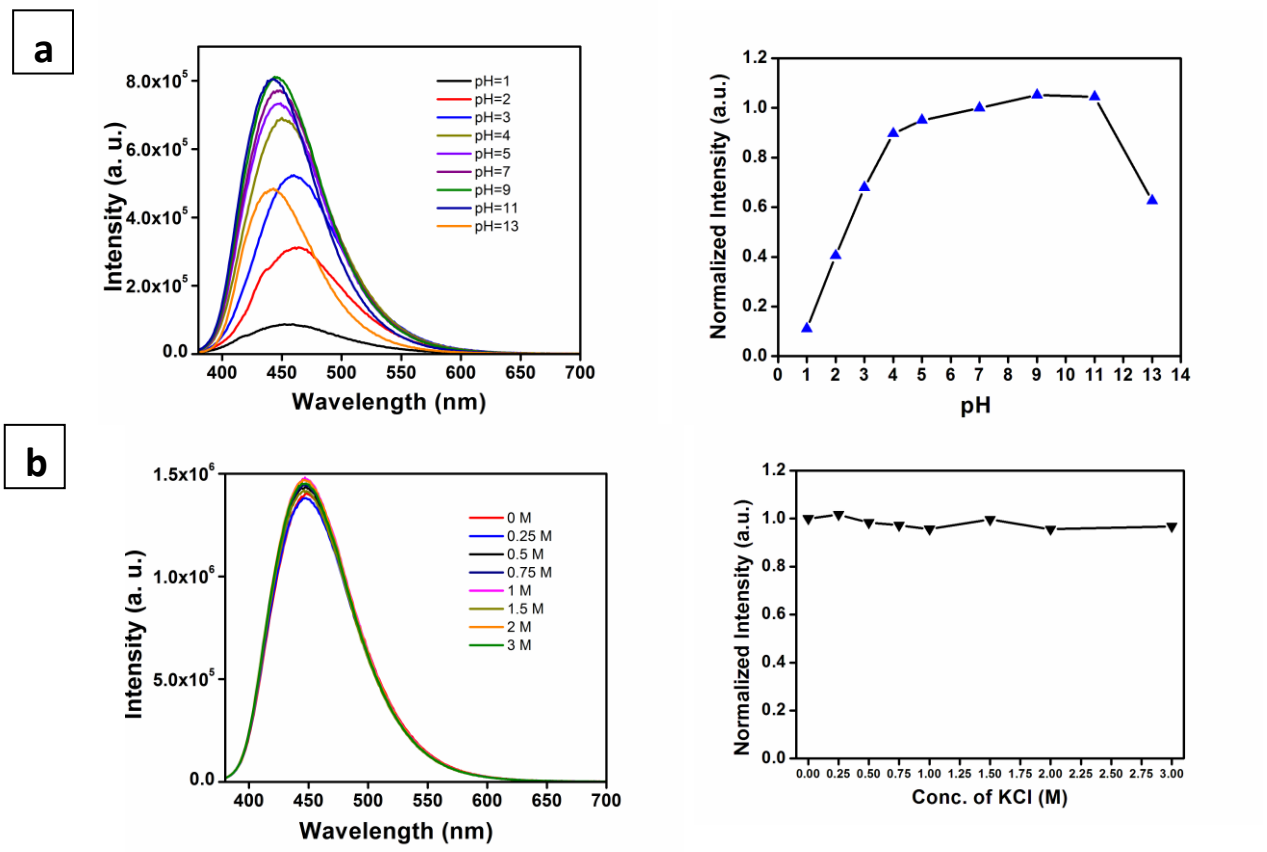

Fig. S3 Dependence of photoluminescence of Cdots on (a) pH and (b) ionic strength of the medium.

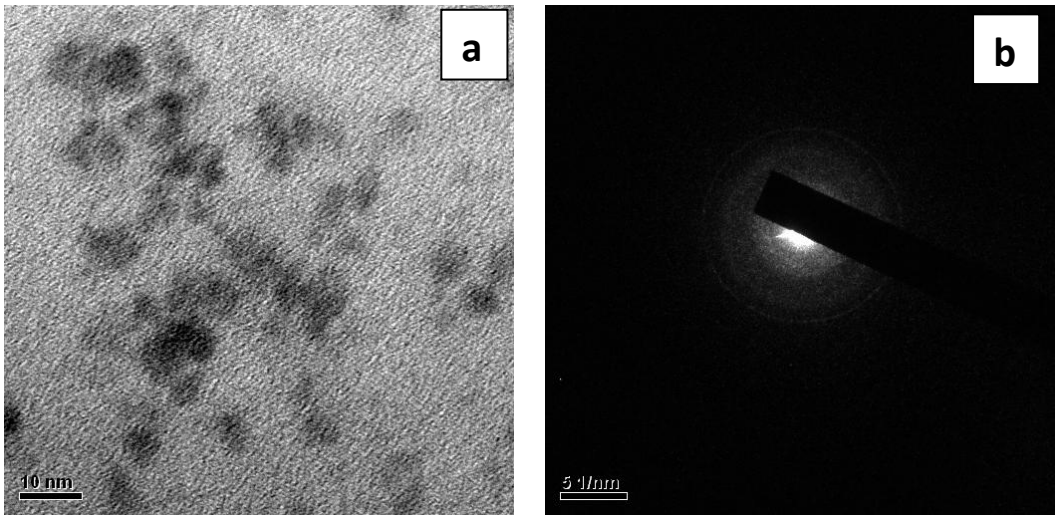

Fig. S4 (a) High resolution TEM image and (b) SAED pattern of Cdots.

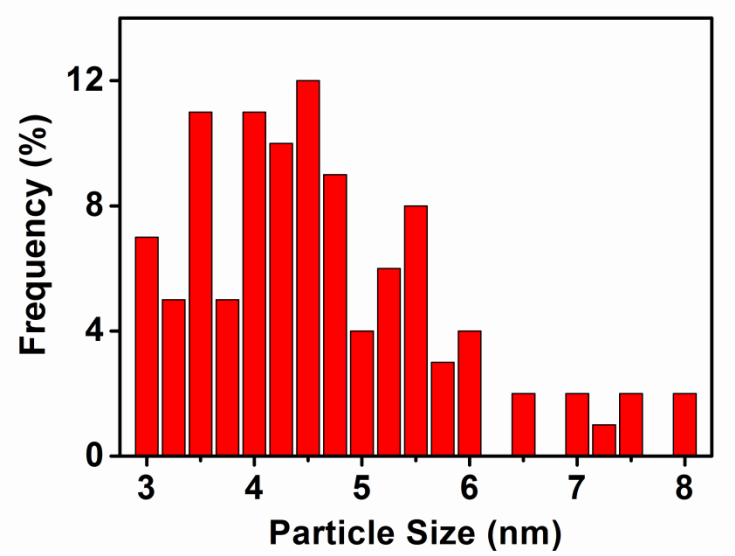

Fig. S5 Size distribution of Cdots as calculated from TEM images.

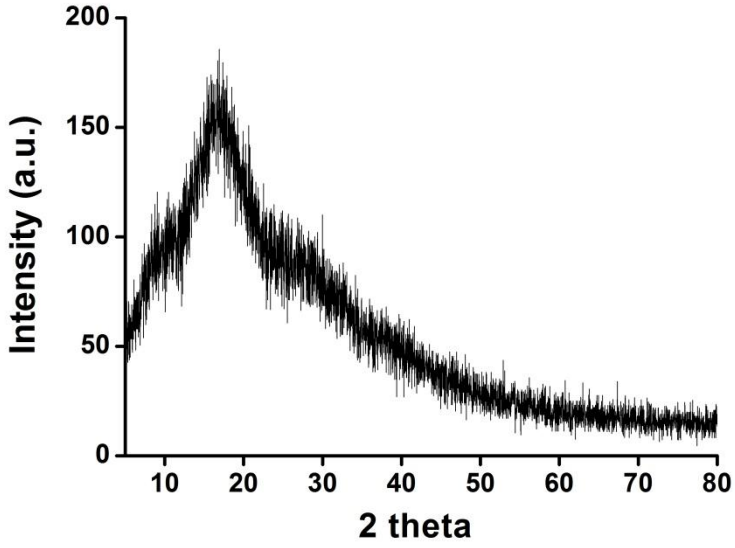

Fig. S6 Powder XRD pattern of Cdots.

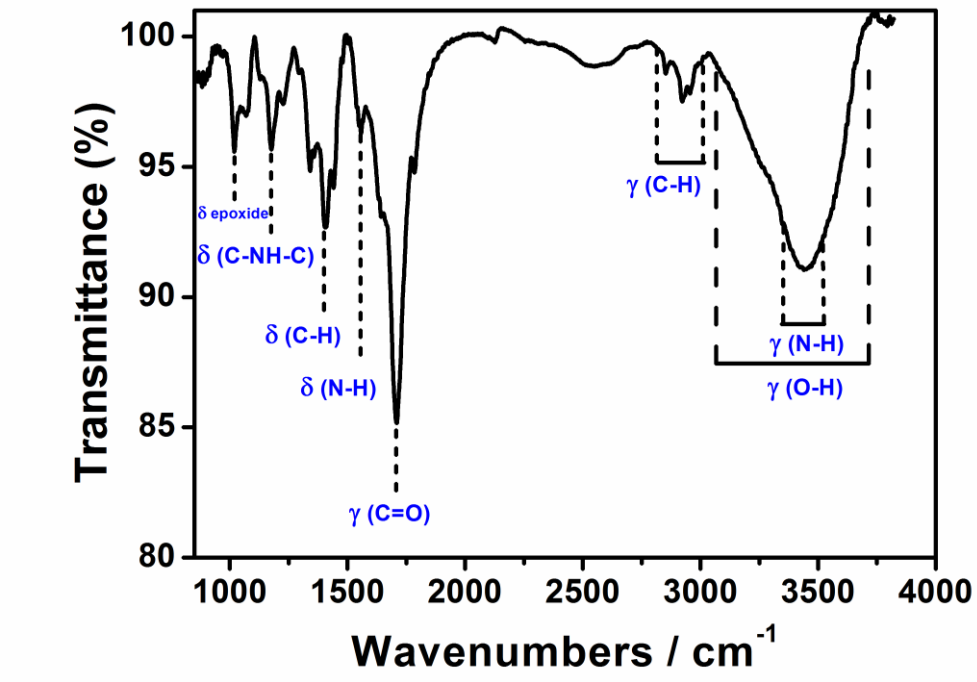

Fig. S7 FTIR spectrum of Cdots.

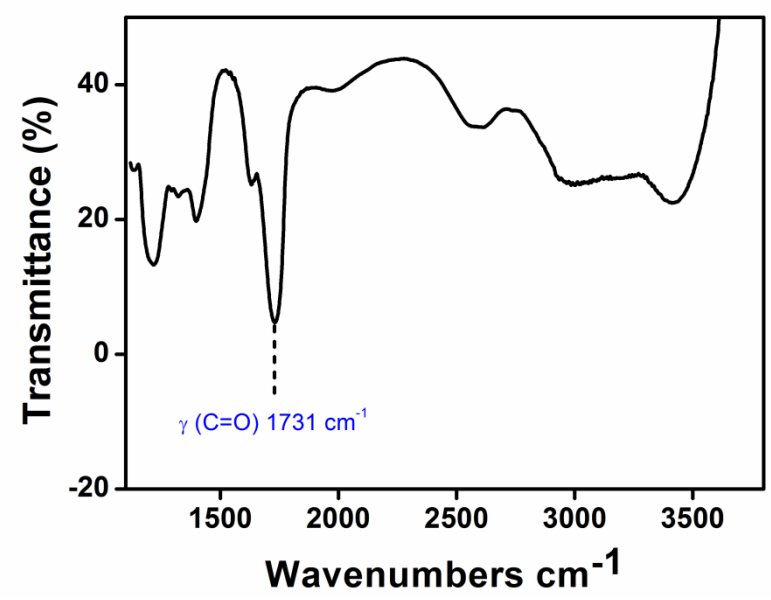

Fig. S8 FTIR spectrum of citric acid.

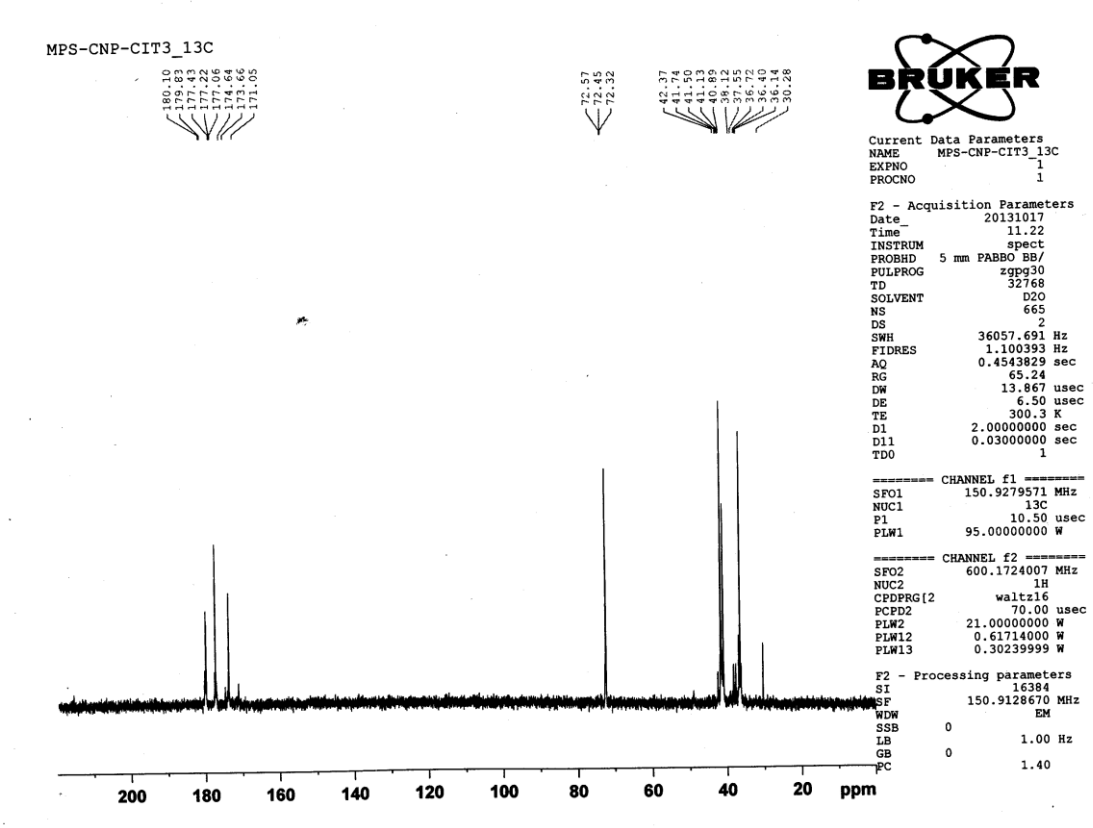

Fig. S9 ^{13}C NMR spectrum of Cdots.

Fig. S10 Images of currency notes (of 20) under illumination of visible light (left panel) and UV light (right panel).

Carbon Dots as Sensors

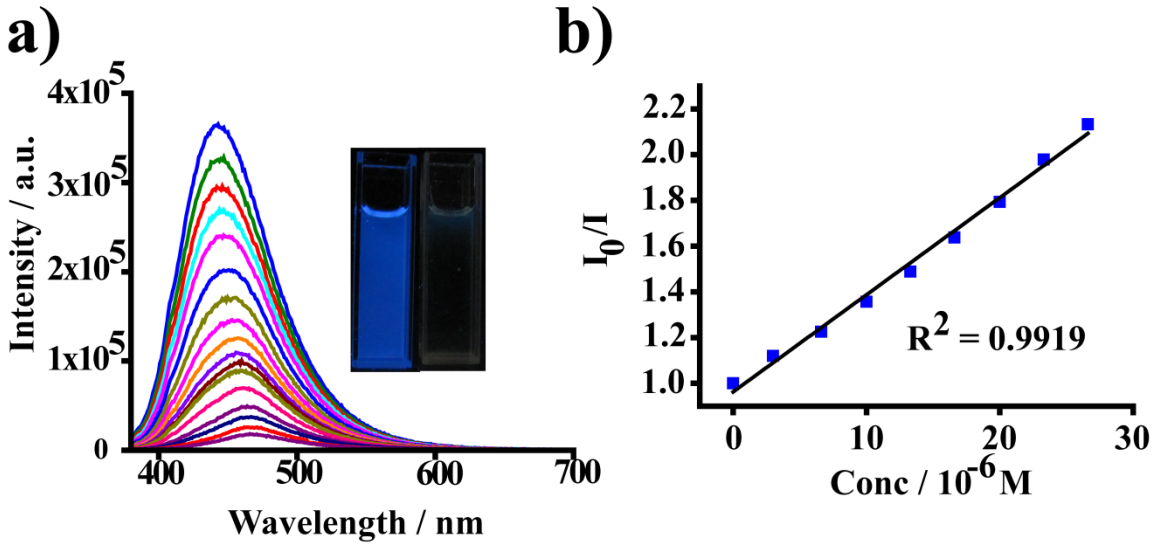

Fig. S11 (a) Quenching of fluorescence of Cdots (0.01mg / mL) by picric acid (0 to 120 µM) in DMF (λex=365 nm). (b) Stern-Volmer plot of the quenching of fluorescence (conc. of picric acid used was up to a maximum of 13.3 µM).

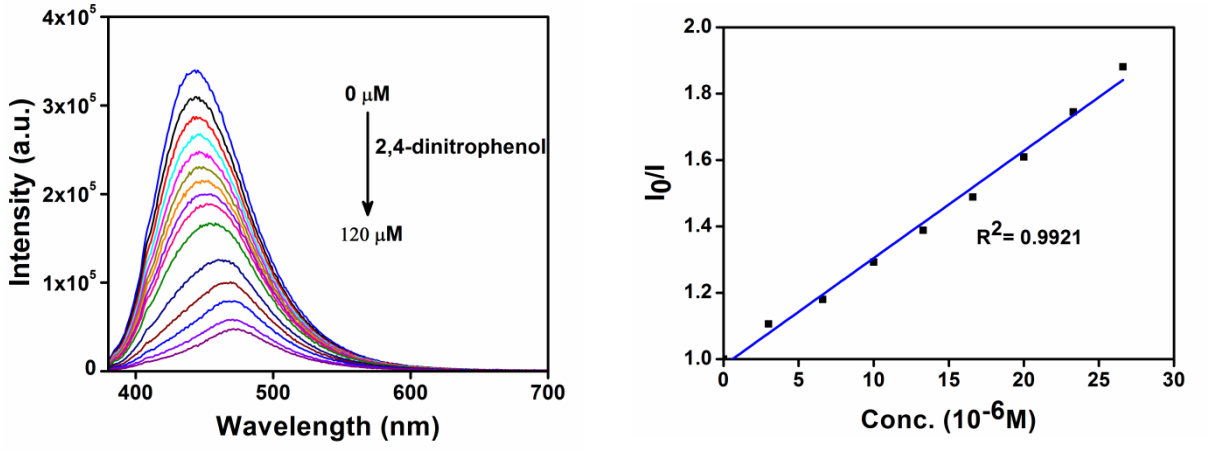

Fig. S12 Quenching of fluorescence of Cdots (0.01mg / mL) by 2,4-dinitrophenol (with concentration varying from 0 to 120 µM) in DMF (λex=365 nm). Stern-Volmer plot with respect to the quenching of fluorescence (conc. of 2,4-dinitrophenol used was up to 26.6 µM).

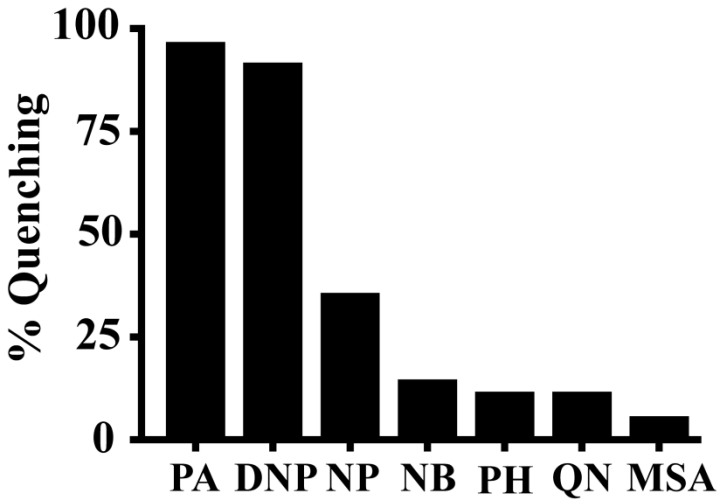

Fig. S13 Extent of quenching of fluorescence of Cdots (0.01 mg/ml in DMF) following addition of various analytes up to the concentration of 120 μM. (PA= picric acid, DNP= 2,4-dinitrophenol, NP= 4-nitrophenol, NB= nitrobenzene, PH= phenol, QN= 1,4-benzoquinone and MSA= 4-methoxybenzoic acid).

Quenching Mechanism

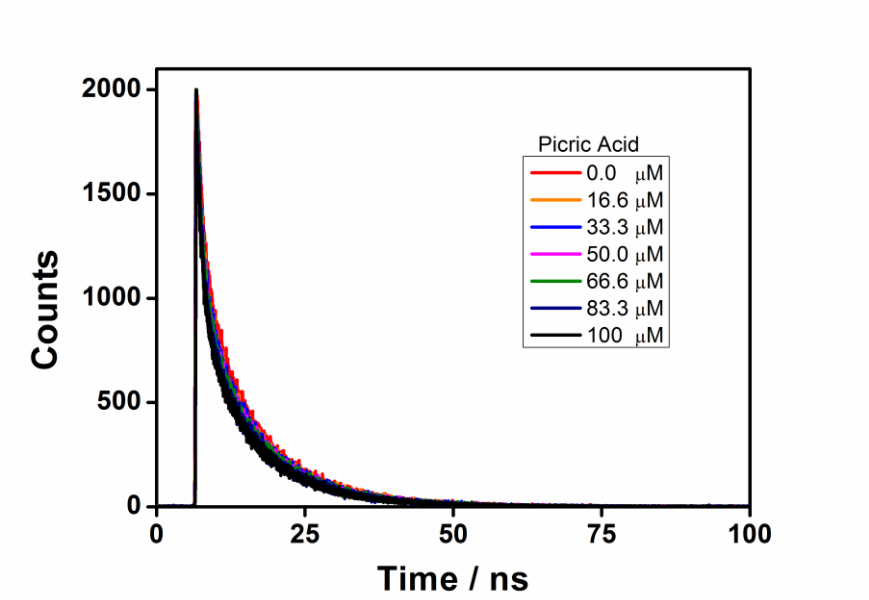

Fig. S14 Time-resolved fluorescence decay curves of Cdots in DMF in absence and presence of gradually increasing concentration of picric acid. The excitation and emission (probe) wavelengths were set at 375 nm and 450 nm respectively.

Table S3. Decay parameters of the fluorescence of carbon dots in DMF in absence and presence of gradually increasing concentration of picric acid.

Conc. (μM)	A_1 (%)	τ_1 (ns)	A_2 (%)	τ_2 (ns)	$\langle\tau\rangle$ (ns)
0	23.14	1.431	76.86	9.642	9.3
16.6	22.09	1.426	77.91	9.66	9.3
33.3	22.11	1.428	77.89	9.628	9.3
50	22.6	1.417	77.4	9.59	9.25
66.6	37.88	1.415	62.12	9.612	8.94
83.3	23.33	1.401	76.67	9.513	9.2
100	26.96	1.355	73.04	9.483	9.1

References

(1) Q. Zhang, Y. Gao, S. Zhang, J. Wu, H. Zhou, J. Yang, X. Tao, Y. Tian, *Dalton Trans*, 2012, **41**, 7067.

(2) J. E. Murphy, M. C. Beard, A. G. Norman, S. P. Ahrenkiel, J. C. Johnson, P. Yu, O. I. Micic, R. J. Ellingson, A. J. Nozik, *J. Am. Chem. Soc*, 2006, **128**, 3241.

(3) J. R. Lakowicz, Principles of Fluorescence Spectroscopy, 2nd ed.; Kluwer Academic/Plenum Publishers: New York, 1999.