

Supporting Information

Photophysical properties of Milk Carbon dots and their Sulphur and Nitrogen doped Analogues

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Figure S1 ↓ AFM images of (a) Milk-CDs (b) S doped CDs and (c) N doped CDs.

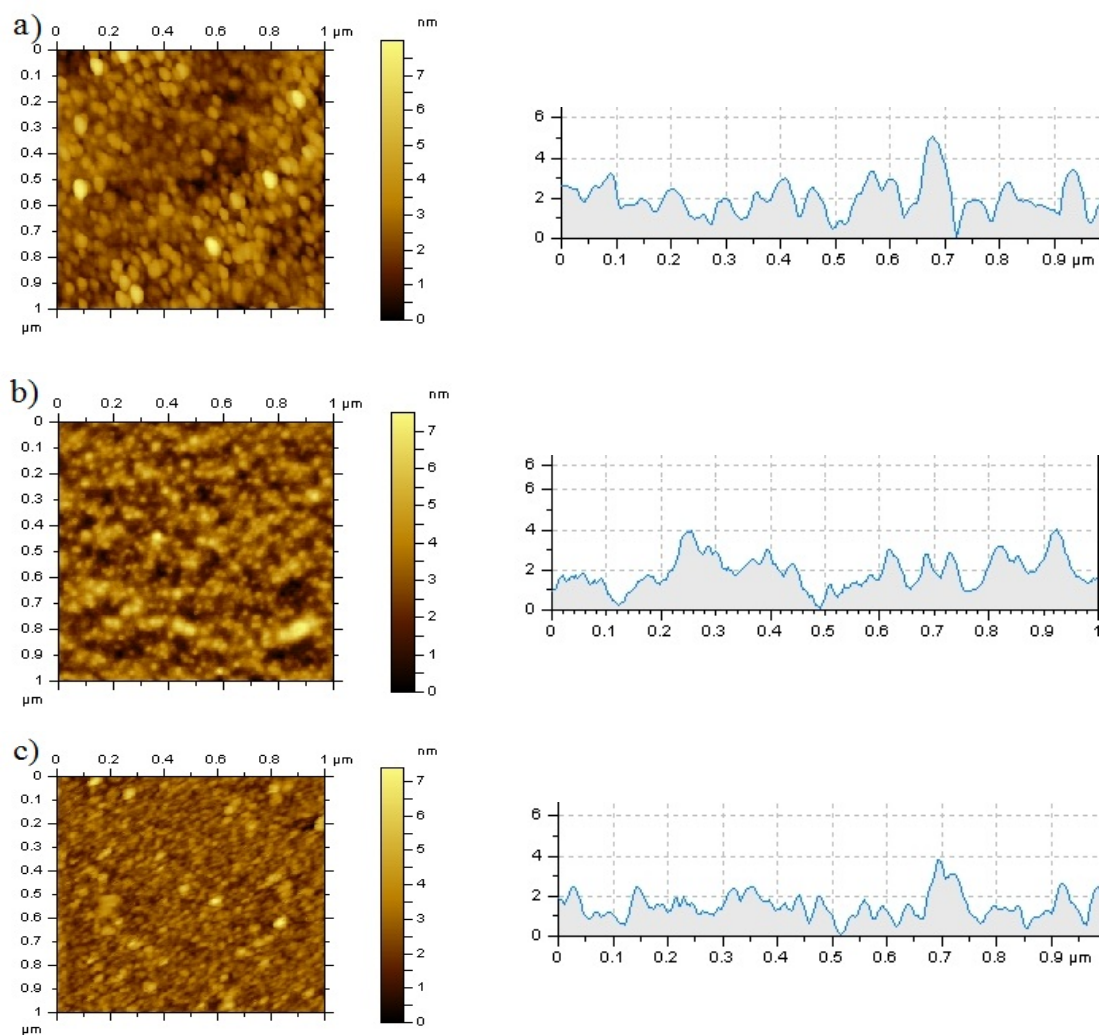
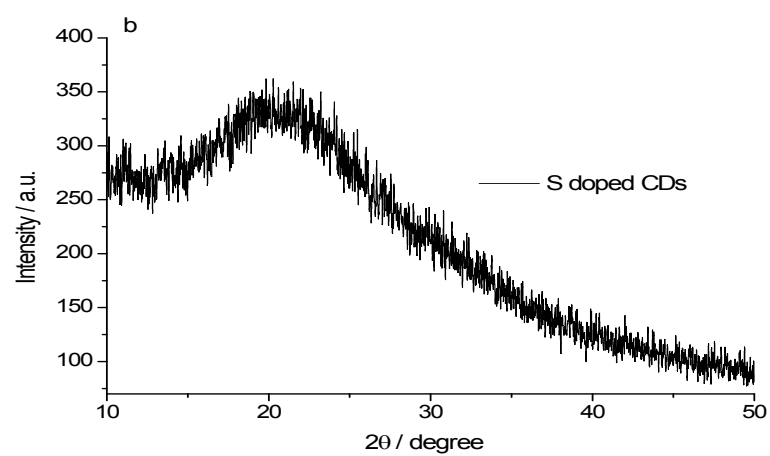
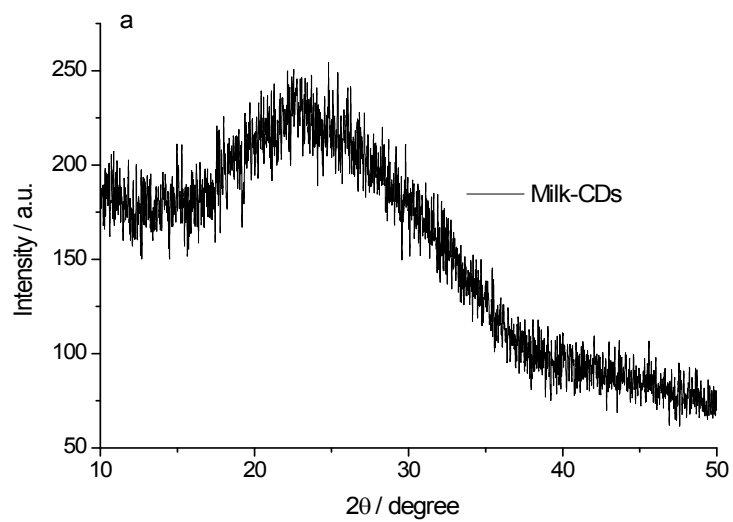


Figure S2 ↓ XRD spectra of (a) Milk-CDs (b) S doped CDs and (c) N doped CDs.



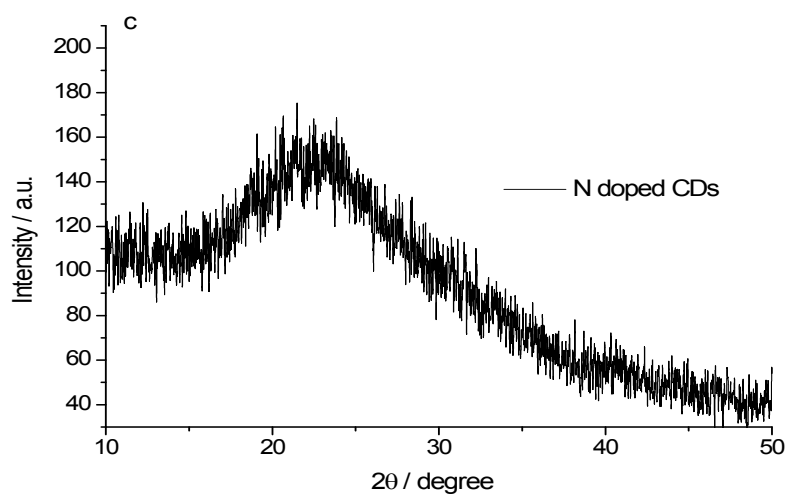


Figure S3 ↓ IR spectrum of Milk-CDs prepared at different times.

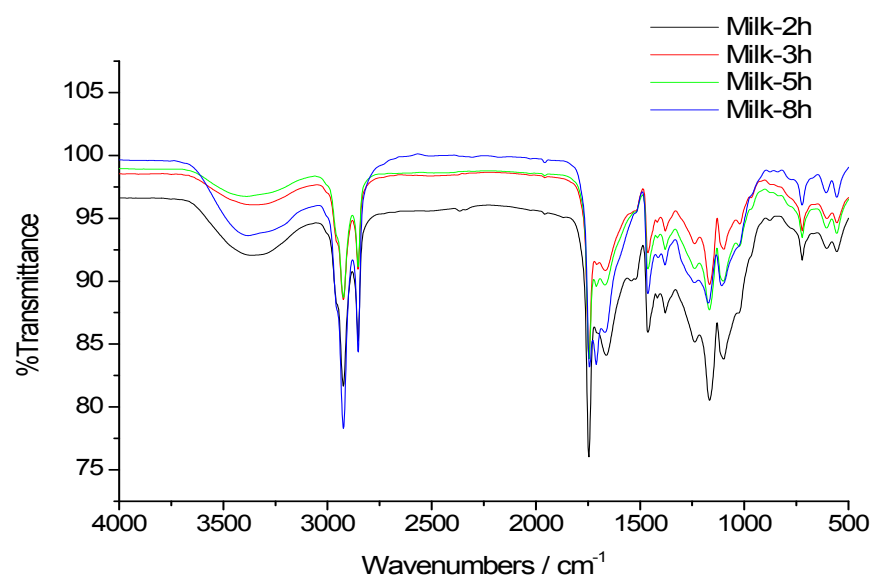


Figure S4 ↓ IR and Raman spectrum of Milk-CDs (8h); S doped CDs; N doped CDs.

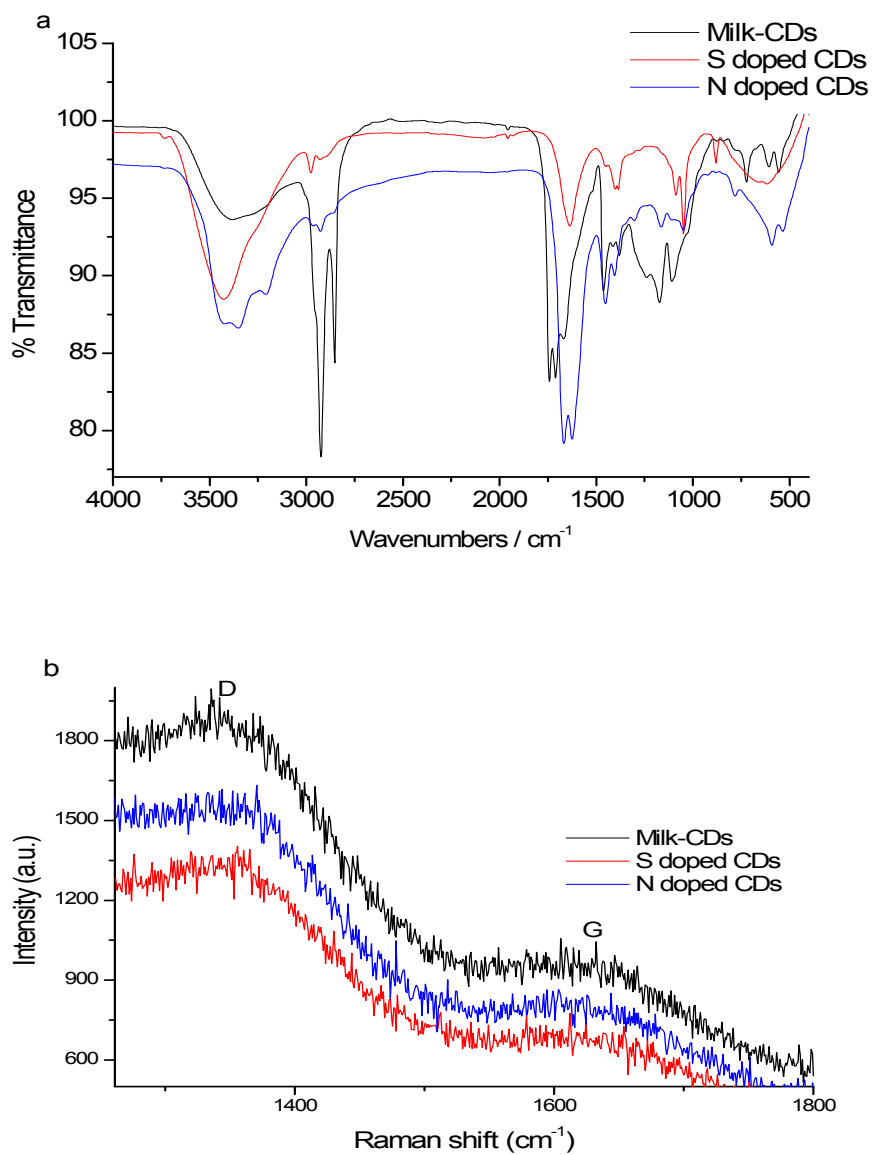


Figure S5 ↓ Normalized absorption spectra of Milk-CDs, S doped CDs, N doped CDs in water.

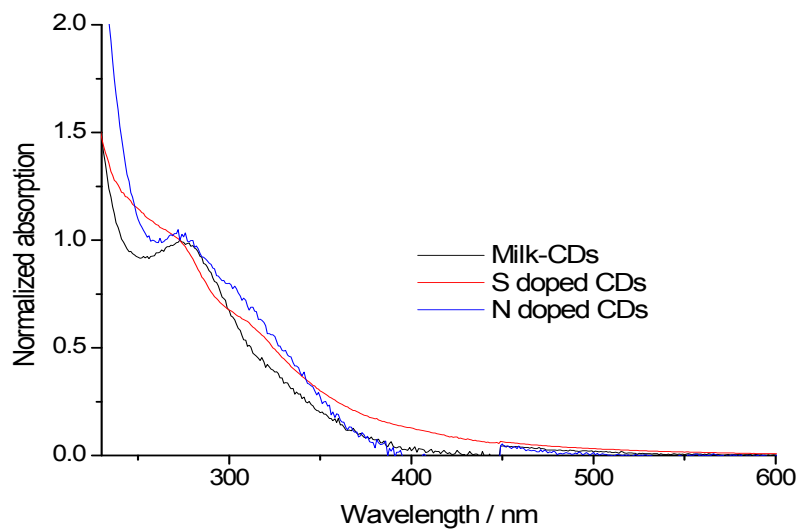


Figure S6 ↓ Fluorescence emission spectra of S doped CDs (a); N doped CDs (b) excitation at different wavelength. The inset shows the optical photos of the S doped CDs and N doped CDs recorded at room light and UV-lamp irradiation

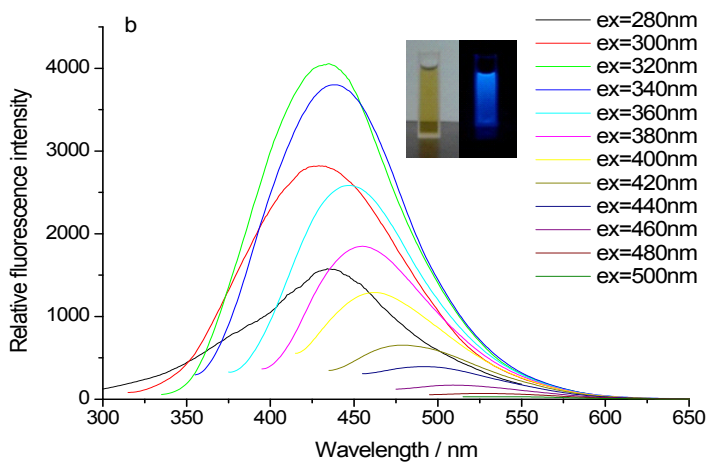
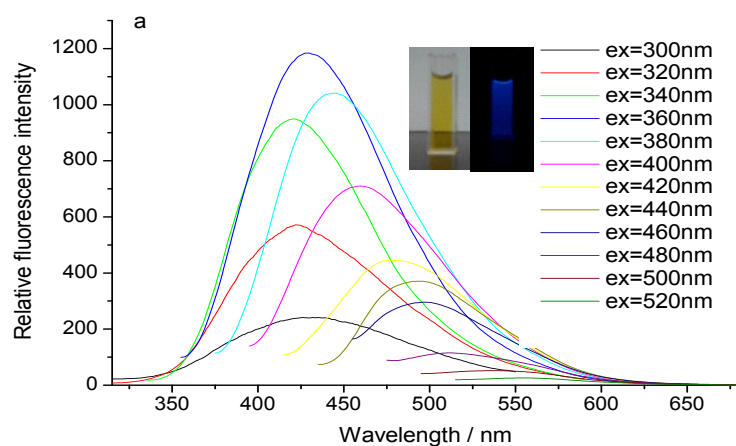
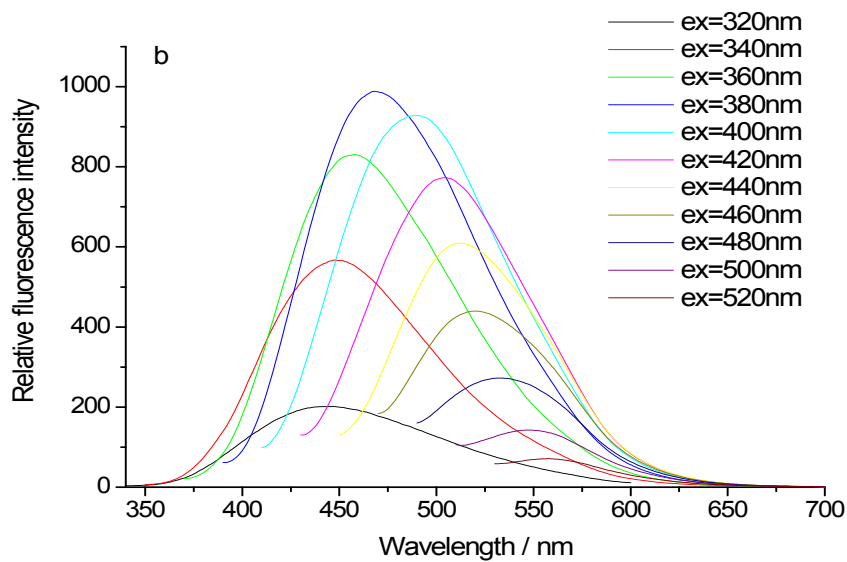
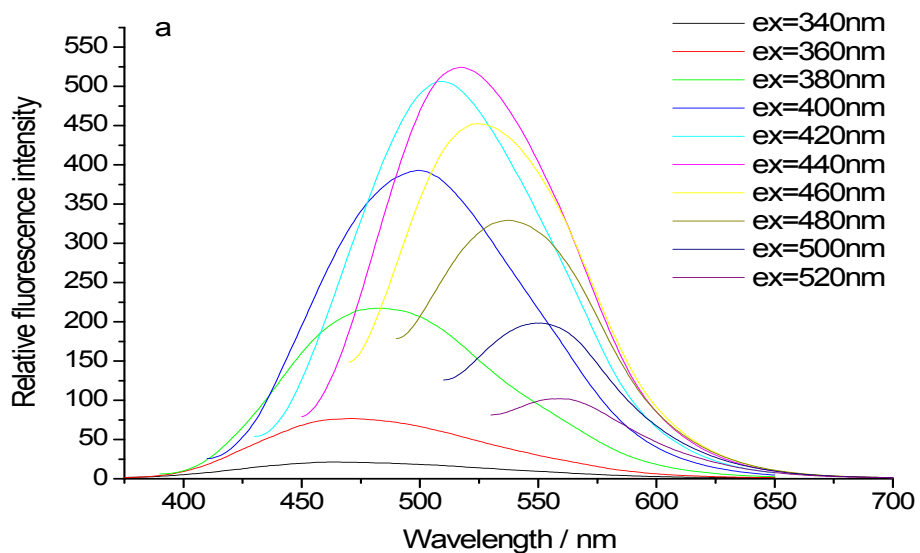


Figure S7 ↓ Fluorescence emission spectra of Milk-CDs (a-2h, b-3h, c-5h) prepared at different times excitation at different wavelength.



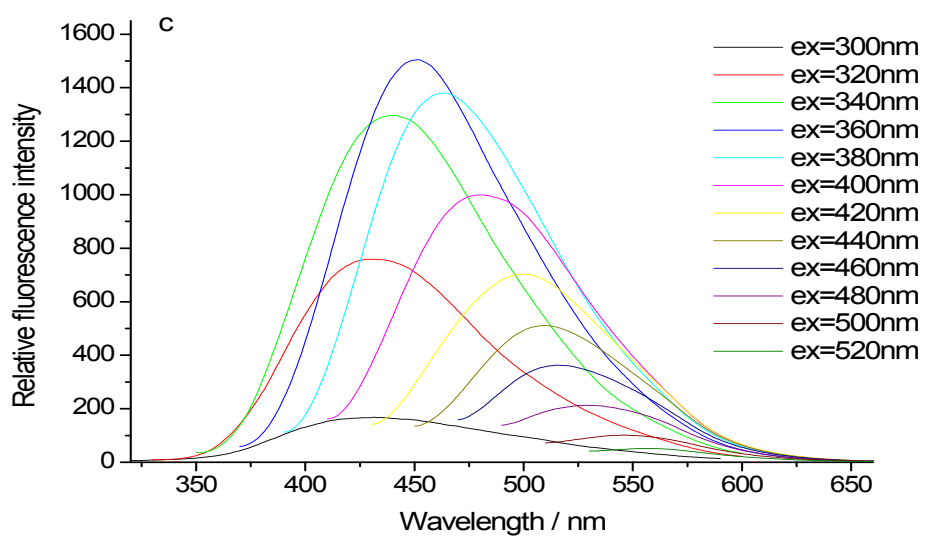


Figure S8 ↓ Up-conversion FL properties of CDs. FL emission spectra for the CDs dispersed in water at excitation wavelengths from 600 nm to 880 nm. (a) S doped CDs; (b) N doped CDs

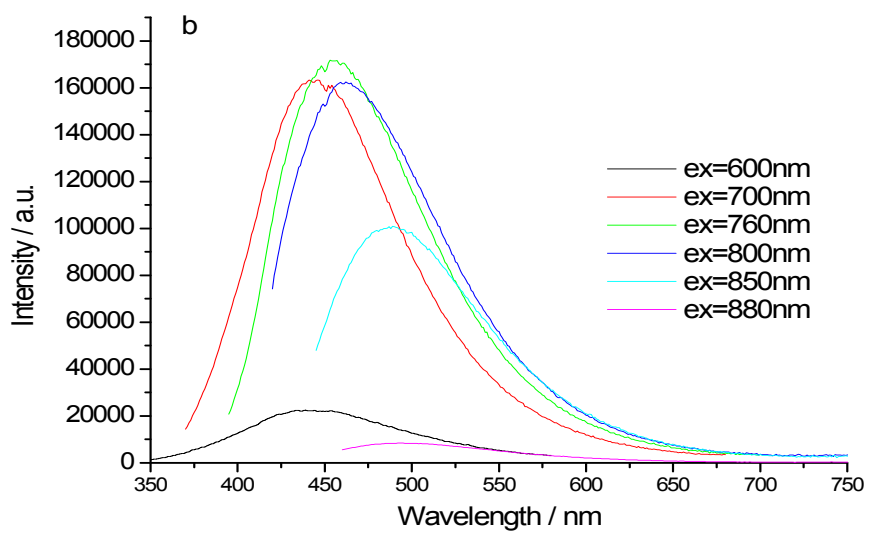
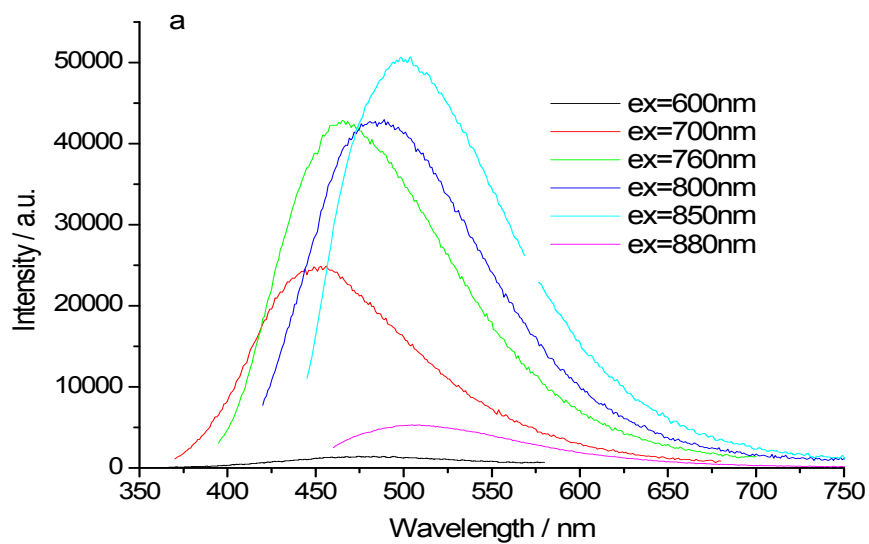
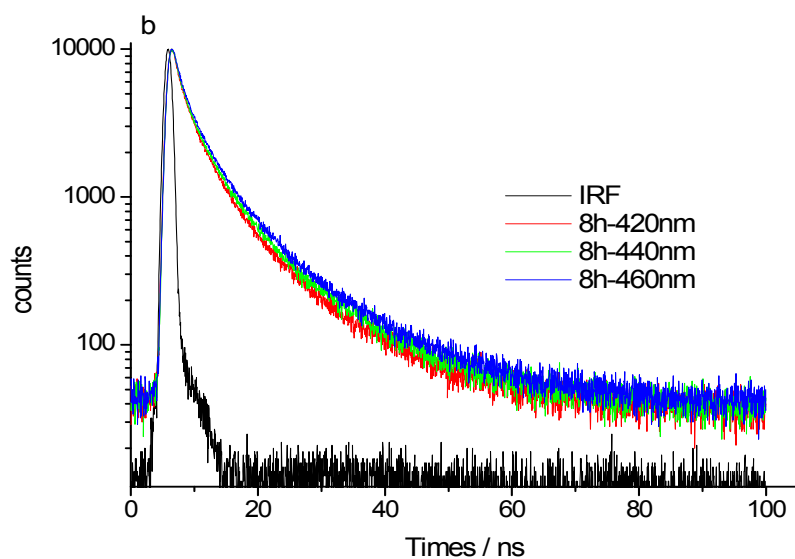
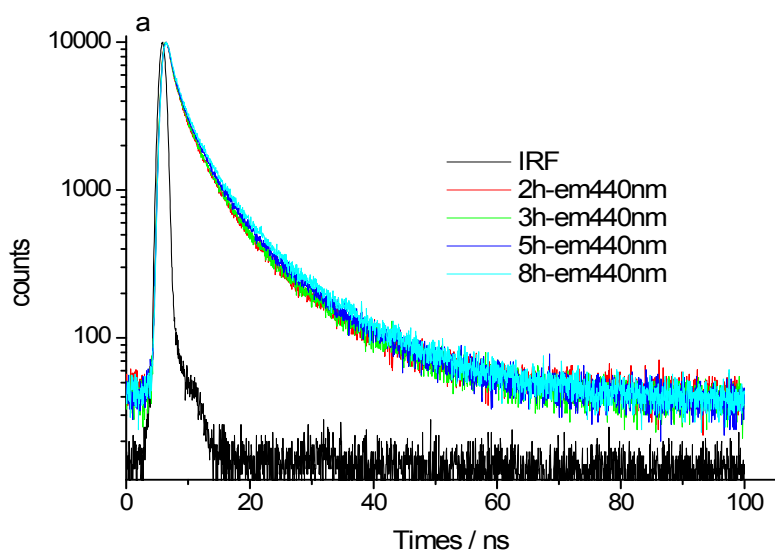


Figure S9 ↓ The decay curves of CDs in water (a) Milk-CDs (2, 3, 5, 8h); (b) Milk-CDs (8h); (c) S doped CDs; (d) N doped CDs; excited at 360 nm.



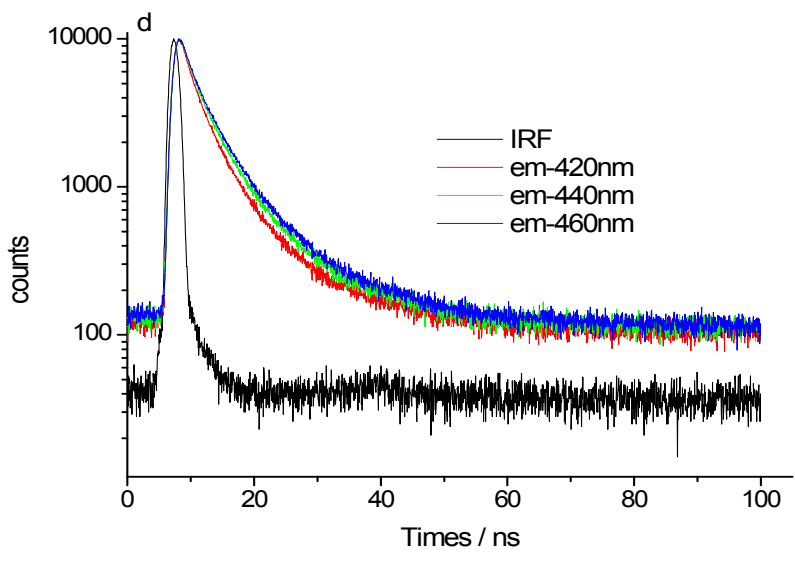
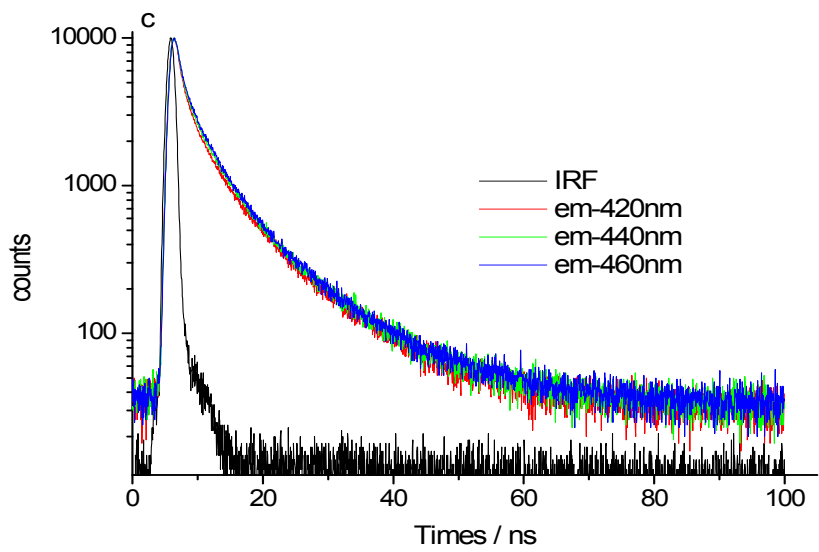


Table S1 ↓ Photophysical Properties of Milk-CDs and Carrots-CDs. The fluorescence quantum yield (FLQY) at different reaction time.

Sample	2h	3h	5h	8h
Milk-CDs	5.86%	6.75%	7.27%	7.55%
Carrots-CDs	4.39%	4.91%	5.18%	5.55%

Table S2 ↓ Elemental analysis of Milk-CDs, S doped CDs and N doped CDs.

sample	C (%)	H (%)	O (%)	N (%)	S (%)
Milk-CDs	62.50	8.379	24.45	3.92	0.751
S doped CDs	46.83	8.150	29.37	8.22	7.428
N doped CDs	33.70	7.143	37.28	20.88	1.002

Table S3 ↓Photophysical properties of CDs (reaction time-8h). The fluorescence quantum yield (FLQY) at different excitation wavelength.

Sample	$\lambda_{\text{ex}}=320\text{nm}$	$\lambda_{\text{ex}}=340\text{nm}$	$\lambda_{\text{ex}}=360\text{nm}$	$\lambda_{\text{ex}}=380\text{nm}$
Milk-CDs	1.85%	9.62%	9.68%	7.07%
S dopedCDs	7.42%	8.82%	10.38%	6.58%
N doped CDs	13.52%	15.04%	15.39%	11.52%

Table S4 ↓ Photophysical Properties of Milk-CDs when excitation at 360nm in water. Decay times τ_1 , τ_2 , τ_3 and average life time τ_A , and the relative amplitude (%).

Compound	Preparation Time	Monitored Emission Wavelength/nm	τ_1 /ns	τ_2 /ns	τ_3 /ns	τ_A	χ^2
Milk-CDs	2h	420	0.80 (22.78%)	3.26 (47.69%)	10.38 (29.53%)	4.69	1.112
		440	0.80 (20.68%)	3.28 (46.97%)	10.56 (32.34%)	5.16	1.013
		460	0.80 (19.07%)	3.38 (45.44%)	10.76 (35.50%)	5.37	1.050
	3h	420	0.72 (20.10%)	3.10 (48.74%)	10.26 (31.16%)	5.05	1.042
		440	0.81 (20.29%)	3.36 (47.50%)	11.03 (32.21%)	5.43	1.079
		460	0.85 (18.80%)	3.46 (45.74%)	10.96 (35.46%)	5.49	1.043
	5h	420	0.86 (20.37%)	3.46 (49.21%)	11.17 (30.42%)	5.09	1.057
		440	0.86 (19.22%)	3.49 (47.34%)	11.27 (33.44%)	5.64	1.036
		460	0.97 (19.30%)	3.72 (45.02%)	11.46 (35.08%)	6.15	1.124
	8h	420	0.84 (17.96%)	3.42 (48.52%)	11.05 (33.53%)	5.54	1.144
		440	0.95 (19.29%)	3.75 (47.01%)	11.74 (33.70%)	5.90	1.043
		460	1.01 (18.58%)	3.92 (46.17%)	12.04 (35.25%)	6.07	1.017

Photophysical Properties of the Milk-CDs (8h), S doped CDs and N doped CDs when excitation at 360nm in water. Decay times τ_1 , τ_2 , τ_3 and average life time τ_A , and the relative amplitude (%).

Compound	Reaction Time	Monitored Emission Wavelength /nm	τ_1 /ns	τ_2 /ns	τ_3 /ns	τ_A	χ^2
Milk-CDs	8h	420	0.84 (17.96%)	3.42 (48.52%)	11.05 (33.53%)	5.54	1.144
		440	0.95 (19.29%)	3.75 (47.01%)	11.74 (33.70%)	5.90	1.043
		460	1.01 (18.58%)	3.92 (46.17%)	12.04 (35.25%)	6.07	1.017
S doped CDs	8h	420	0.64 (25.00%)	3.14 (36.63%)	10.23 (38.37%)	5.07	1.022
		440	0.75 (25.09%)	3.63 (39.86%)	10.87 (35.05%)	5.47	1.020
		460	0.68 (21.62%)	3.47 (42.03%)	10.55 (36.35%)	5.29	0.991
N doped CDs	8h	420	1.32 (22.12%)	3.97 (56.32%)	11.54 (21.56%)	5.20	1.039
		440	1.21 (15.70%)	3.84 (54.17%)	10.33 (30.14%)	5.53	1.020
		460	1.22 (14.00%)	4.08 (55.12%)	10.78 (30.88%)	5.85	1.014

Table S5 ↓ Photophysical Properties of CDs when excitation at 330 nm in water. Decay times τ_1 , τ_2 , τ_3 and average life time τ_A , and the relative

amplitude (%)

Compound	Excitation Wavelength/nm	Monitored Emission Wavelength /nm	τ_1 /ns	τ_2 /ns	τ_3 /ns	τ_A	χ^2
Milk-CDs	330	420	0.84 (11.72%)	3.82 (31.42%)	10.87 (56.86%)	7.38	1.028
		440	1.19 (15.70%)	4.87 (35.54%)	11.93 (48.76%)	7.63	1.012
		460	1.06 (13.40%)	4.45 (37.01%)	12.00 (49.59%)	7.88	1.014
S doped CDs	330	420	0.78 (26.60%)	3.47 (34.65%)	10.03 (38.75%)	5.32	1.032
		440	0.77 (23.69%)	3.52 (36.90%)	10.45 (39.41%)	5.59	1.083
		460	0.83 (23.62%)	3.77 (39.16%)	10.75 (37.22%)	5.79	1.107
N doped CDs	330	420	1.08 (13.15%)	3.59 (44.51%)	9.84 (42.34%)	5.99	1.044
		440	1.23 (11.18%)	3.97 (40.57%)	10.06 (48.25%)	6.51	1.067
		460	1.51 (12.50%)	4.63 (40.91%)	10.34 (46.59%)	6.87	1.003

Photophysical Properties of CDs when excitation at 375 nm in water.

Decay times τ_1 , τ_2 , τ_3 and average life time τ_A , and the relative amplitude

(%)

Compound	Excitation Wavelength/nm	Monitored Emission Wavelength /nm	τ_1 /ns	τ_2 /ns	τ_3 /ns	τ_A	χ^2
Milk-CDs	375	420	0.33 (19.80%)	3.31 (41.77%)	12.41 (38.43%)	6.22	1.157
		440	0.36 (17.91%)	3.52 (42.00%)	13.06 (40.09%)	7.05	1.064
		460	0.38 (15.84%)	3.51 (40.57%)	12.58 (43.59%)	6.78	1.042
S doped CDs	375	420	0.30 (23.49%)	3.23 (35.49%)	10.53 (41.02%)	5.67	1.057
		440	0.28 (22.82%)	3.30 (38.84%)	10.59 (38.34%)	5.55	1.014
		460	0.39 (22.00%)	3.63 (45.02%)	11.45 (32.98%)	5.65	1.092
N doped CDs	375	420	0.48 (17.13%)	3.04 (55.06%)	9.32 (27.63%)	4.42	1.117
		440	0.52 (15.95%)	3.37 (55.14%)	10.36 (28.91%)	5.02	1.121
		460	0.43 (13.53%)	3.32 (49.91%)	9.74 (36.56%)	5.42	1.075

Table S6 ↓ Photophysical Properties of Carrot-CDs when excitation at 360nm in water. Decay times τ_1 , τ_2 and τ_3 , and the relative amplitude (%)

Compound	Preparation Time	Monitored Emission Wavelength/nm	τ_1 /ns	τ_2 /ns	τ_3 /ns
Carrot-CDs	2h	420	0.70 (28.09%)	2.77 (55.12%)	9.71 (16.79%)
		440	0.72 (25.29%)	2.77 (53.63%)	9.52 (21.08%)
		460	0.76 (24.30%)	3.06 (52.18%)	10.19 (23.52%)
	3h	420	0.68 (30.14%)	2.72 (54.22%)	9.35 (15.64%)
		440	0.75 (30.17%)	2.90 (52.02%)	9.75 (17.81%)
		460	0.74 (26.07%)	2.95 (50.92%)	9.31 (23.01%)
	5h	420	0.72 (31.29%)	2.61 (53.68%)	8.82 (15.03%)
		440	0.77 (30.88%)	2.72 (51.42%)	9.06 (17.71%)
		460	0.82 (29.04%)	3.01 (50.99%)	9.70 (19.97%)
	8h	420	0.75 (31.15%)	2.61 (53.39%)	9.07 (15.46%)
		440	0.80 (31.24%)	2.84 (52.12%)	10.04 (16.65%)
		460	0.87 (29.68%)	3.11 (49.96%)	10.44 (20.37%)