Supporting Information

Down- and Up-Conversion Luminescent Carbon Dots Fluid: Inkjet Printing and Gel Glasses Fabrication

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1. FT-IR spectra.

Compared to TEPA, two typical IR signals appear in CDsF, which could be identified as C=ONR vibration at 1658 cm^{-1} and CON-HR vibration at 3296 cm^{-1}, confirming the occurrence of acylation reaction. When doped in silica glass, the C=ONR vibrations are slightly shift to 1654.9 of 0.1wt.% doped silica glass and 1647.2 of 15wt.% doped silica glass. Moreover, with the increasing of loading frictions, the peaks at 895nm which are the vibration of residual Si-OH groups gradually become weak. This could be ascribed to the effects of hydrogen bonds in rigid matrix.[1] The typical IR vibrations are summarized in the following table.

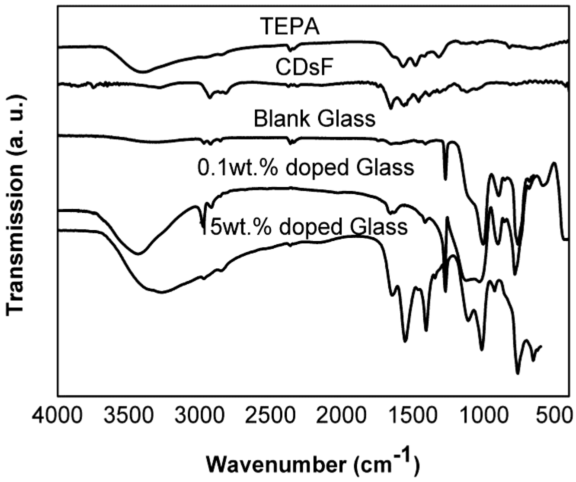

Figure S1 FT-IR spectra of TEPA, CDsF, blank glass and CDsF doped glass.

<table>
<tr><td>IR</td><td>TEPA</td><td>CDsF</td><td>0.1wt.% CDsF Gel glass</td><td>15 wt.% CDsF Gel glass</td><td>Blank gel glass</td></tr>
<tr><td>Si-O-R(st)</td><td>---</td><td>---</td><td>1004.5</td><td>1014.6</td><td>1030.0</td></tr>
<tr><td>Si-OH(st)</td><td>---</td><td>---</td><td>895.0</td><td>921.9</td><td>900.8</td></tr>
<tr><td>CH_2N-H(ä)</td><td>1460.1</td><td>1460.1</td><td>1458.2</td><td>1404.2</td><td>---</td></tr>
<tr><td>(C=O-)N-H(ä)</td><td>1564.3</td><td>1564.3</td><td>1560.4</td><td>1554.6</td><td>---</td></tr>
<tr><td>C=O(st)NR</td><td></td><td>1658.2</td><td>1654.9</td><td>1647.2</td><td>---</td></tr>
<tr><td>N-H(st)</td><td>3403.8</td><td>3296.3</td><td rowspan="2">3314</td><td rowspan="2">3271.2</td><td>---</td></tr>
<tr><td>Si-OH(st)</td><td>---</td><td>---</td><td>3435.2</td></tr>
</table>

2. XRD pattern of CDsF.

A broad diffraction peak located at around at 2θ=20° suggesting CDsF is amorphous in nature (Figure S2).

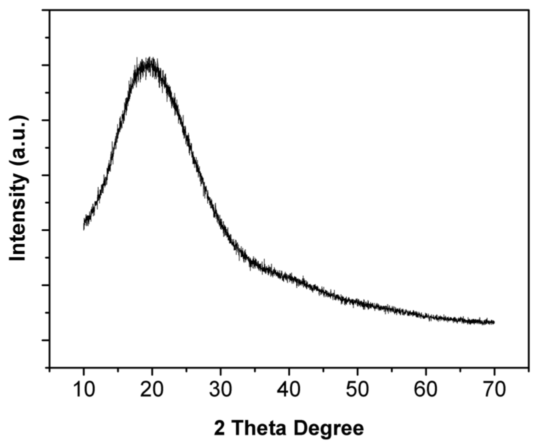

Figure S2 Powder XRD pattern of CDsF.

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3. Dynamic light scattering measurements of the CDsF.

The average size of the CDsF is acquired based on the measurement of dynamic light scattering (Figure S3). The result demonstrates CDsF suspension in water have a narrow size distribution with a mean diameter around 11 nm with a standard deviation of 0.8 nm.

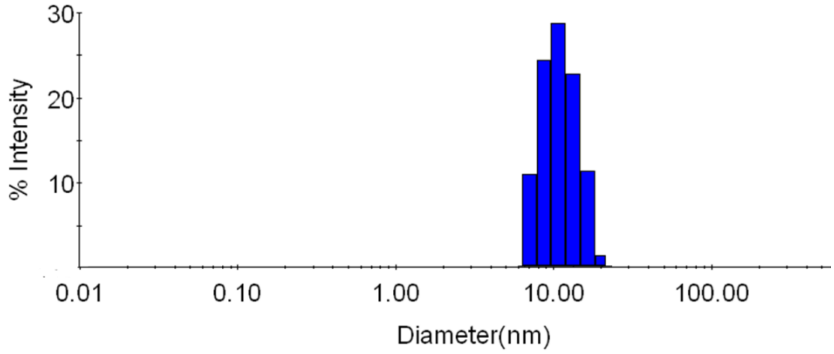

Figure S3 Size distribution histogram obtained from the dynamic light scattering measurement of the CDsF in water.

4. Optical property of CDsF.

Figure S4 shows the absorption and emission spectra of CDsF in water. An obvious absorption feature centered at 360 nm is observed in the UV-Vis absorption spectrum. As the excitation wavelength increases, the maximum emission band shifts to longer wavelength.

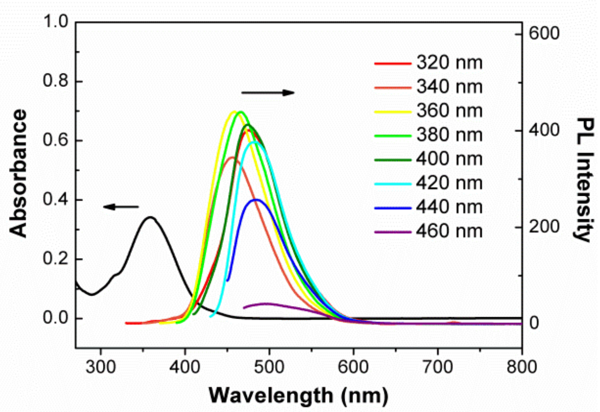

Figure S4 The absorption and photoluminescence spectra of the CDsF in water

5. Morphology of crude CDsF and CDs outside the membrane.

Figure S5 shows TEM images of the crude CDsF and CDs outside the membrane. It can be observed that the crude CDsF include two parts of CDs, the majority is around 10 nm, and the other is around 1 nm (Figure S5A), after dialyzing the smaller particles go out of the membrane with unreacted TEPA (Figure S5B).

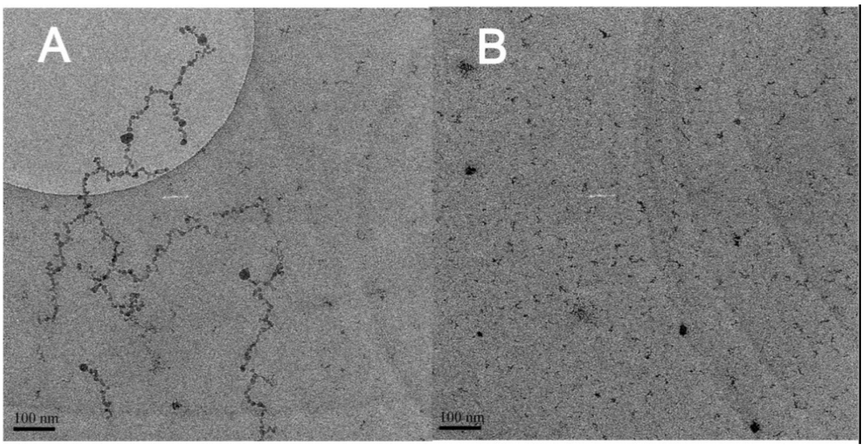

Figure S5 TEM images of crude CDsF (A) and the CDs outside the membrane (B).

6. Optical property of obtained products.

Figure S6 shows the absorption and emission spectra of crude CDsF, CDs outside the membrane and purified CDsF in water. It is noted that they all have a similar absorption band centered around 360 nm, on excitation at the absorption band of 360 nm, similar emission spectra centered at 450 nm with full width at half maximum (FWHM) around 80 nm are observed. The quantum yield (excitation at 360 nm) of crude CDsF, purified CDsF and membrane outside CDs in water is 13%, 17% and 7% respectively.

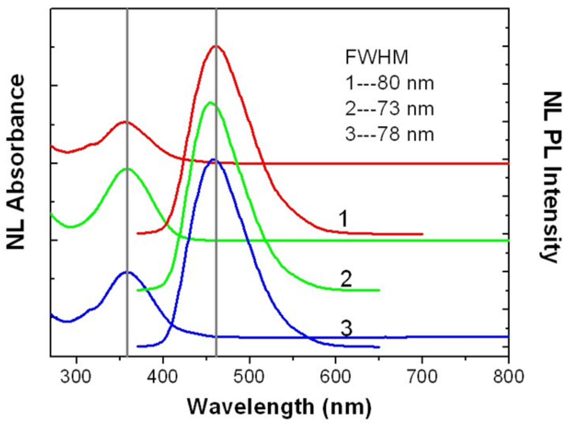

Figure S6 The absorption and photoluminescence emission spectra (λ_{ex}=360 nm) of crude CDsF (1), CDs outside the membrane (2) and purified CDsF (3) in water.

7. Emission of CDsF at different temperature.

As illustrates in Figure S7, the emission of CDsF is dependent on the temperature. When increasing the temperature from 25 ^{o}C to 90 ^{o}C, the emission intensity is decreased systematically. When the temperature goes back to 25 ^{o}C, the emission intensity can be recovered without peak shift.

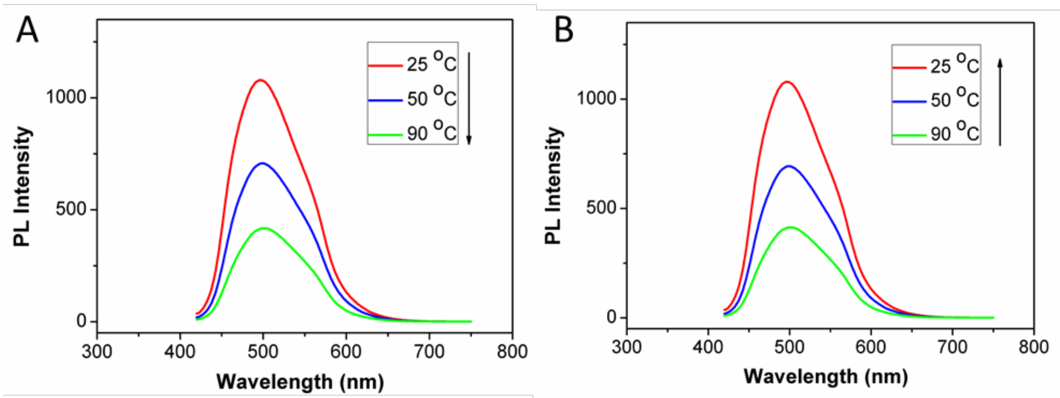

Figure S7 The emission spectra of CDsF from 25 ^{o}C to 90 ^{o}C (A) and from 90 ^{o}C to 25 ^{o}C (B).

8. Inkjet printing of CDsF inks by piezoelectric printer.

Figure S8A is the pattern with 10 wt.% CDsF in water, it is almost invisible under day light, however, under the UV light, a bright graph is observed (Figure S8B). Figure S8C is the pattern with 30 wt.% CDsF in water, we can roughly see the profile in day light, under the UV light, a much brighter graph is exhibited (Figure S8D). Photo-stability of Figure S8D was evaluated under daylight after 6 months later Figure S8E and under 10 hours 36 W UV lamp Figure S8F.

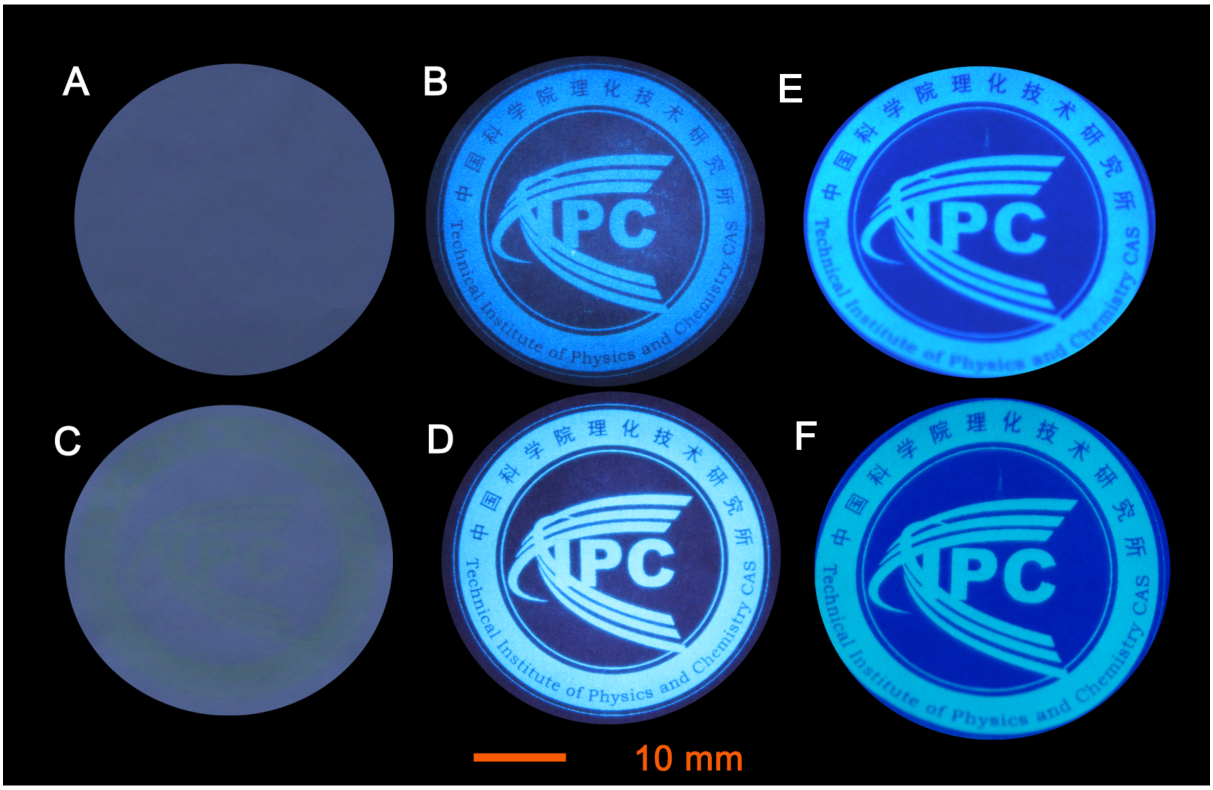

Figure S8 Optical photographs of inkjet-printed images of a logo on weighing paper with CDsF ink (10 wt.% in water) in day light (A) and under UV light (B). And with CDsF ink (30 wt.% in water) in day light (C) and under UV light (D). Photo-stability evaluation of the same sample with Figure S8D under daylight after 6 months later (E) and under 10 hours 36 W UV lamp (F).

9. Inkjet printing of CDsF ink by thermal inkjet printer.

The CDsF with a concentration as high as 85 wt.% can be printed. As show below, the printed images can be clearly observed under daylight, when exposing to UV light, strong fluorescence was exhibited.

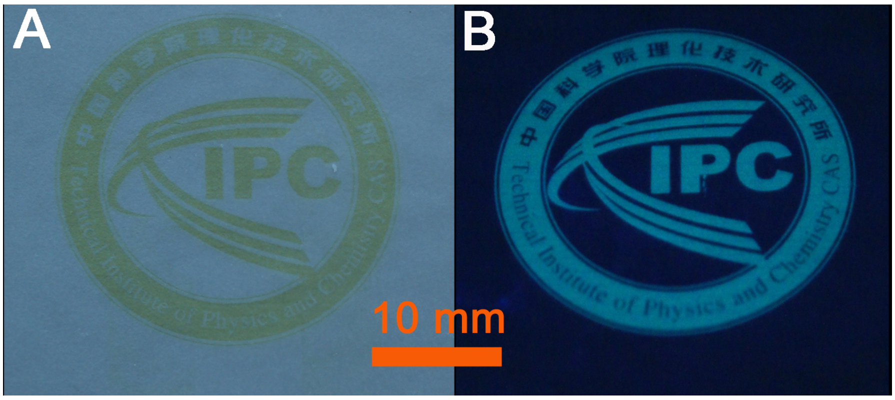

Figure S9 The image was printed with 85 wt.% CDsF with thermal inkjet printer. (A) under daylight; (B) under UV light.

10. CDsF doped Silica Glass.

Figure 10 A shows the sol-gel derived organically modified silicate glasses doped with different amount of CDsF. As the loading fractions increase, the color of the glass getting dark, however, it is clear that the glasses are no obvious agglomeration, phase separation and crack. Under the excitation of UV light (Figure 10B), and 800 nm laser (Figure 10C) strong emissions are observed by naked eyes.

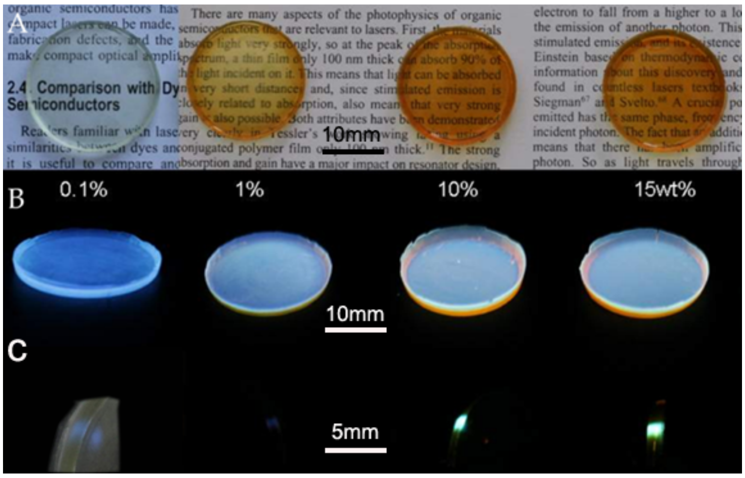

Figure S10 Optical photographs of different amount of CDsF doped organic silica glass in day light (A), under UV light (B) and 800 nm laser (C).

Reference:
1. Kubo, M.; Takimoto, C.; Minami, Y.; Uno, T.; Itoh, T.; Shoyama, M. Incorporation of π-Conjugated Polymer into Silica: Preparation of Poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene]/Silica and Poly(3-hexylthiophene)/Silica Composites. *Macromolecules* **2005**, *38*, 7314–7320.