

Supporting Information

Synthesis of Carbogenic Quantum Dots With Direct White-Light Emitting

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Experimental Part

Materials

Citric acid and lithium nitrate were purchased from Alfa Aesar GmbH, Poly(ethylene glycol) average M.W. 1500 was purchased from Acros Organics, all other solvents were purchased from Sigma-Aldrich. All chemicals were used as received without any further purification. Ultra pure water (Milli-Q water) was used in all experiments.

Synthesis

The synthesis of carbogenic dots includes two steps. Firstly, 0.5 g citric acid and 2.5 g lithium nitrate were mixed together. The mixture is placed in an alumina boat inside a tube furnace. The furnace temperature was increased to 280°C in 30 min and the

sample was annealed at this temperature for 2 h, and cooled to ambient temperature naturally. The whole process was protected under argon atmosphere (99%). For characterization and further surface passivation, the obtained product was dialyzed against ultrapure water (Milli-Q) overnight to remove the lithium nitrate. Subsequently, 10 ml of the obtained, purified sample, 20 ml toluene and 0.5 g poly(ethylene glycol) (PEG₁₅₀₀) were mixed in a round bottom flask. The mixture was heated to 130°C for 72 h, the continuously evaporating water was separated by a water segregator. After that, the toluene was evaporated and the product dispersed into ultra pure water (Milli-Q). The homogeneous light-yellow and photoluminescent functionalized carbogenic dots were finally obtained by dialysis of the suspension against ultra pure water (Milli-Q) with a cellulose ester membrane bag (Mw =3500) to remove excess PEG₁₅₀₀.

Characterization Part

Atomic force microscopy (AFM) images were recorded with a Dimension 3100CL in tapping mode. AFM samples were prepared by drop casting as-prepared samples onto freshly cleaved mica surfaces, and dried under room temperature. High-resolution TEM images were taken on a JEOL JEM-2010F microscope (JEOL, Japan) at an acceleration voltage of 200 kV. The specimen were prepared by drop casting the sample dispersion onto a carbon-coated 300 mesh copper grid, followed by drying under room temperature. X-ray powder diffraction patterns were recorded using a D/MAX-2550 diffract meter (Rigaku, Japan), with a Cu Ka ($\lambda=1.54178\text{\AA}$) radiation source. The Elemental Analysis was measured at the Institut für Organische Chemie

der Johannes Gutenberg-Universität Mainz. FT-IR spectra were recorded on a Nicolet 730 FT-IR spectrometer. Fluorescence spectra were measured on a J&M Fluoreszenzspektrometer 3095SL. UV spectra were recorded on a PERKIN ELMER Lambda 900 spectrometer. The FCDs film was prepared by spin coating the FCDs solution onto a thin glass cover slip (Concentration: about 1×10^{-6} g/L, rotation speed: 800 rpm, Time: 60 s). The emission spectrum of the FCDs film was obtained by confocal microscopy. 407 nm laser light provided by a laser diode (HAMAMATSU PICOSECOND LIGHT PULSER) was used for excitation. A 200 \times , 1.4 NA, oil immersion microscope objective (Plan-Apo, Nikon GmbH) was used to focus the illumination beam on to the sample. The fluorescence was collected with a CCD spectrograph (Andor, Shamrock SR-303i). A 405 nm notch filter and a 420nm long pass filter were used to remove any residual 405 nm light from entering the CCD.

1. XRD of CDs

A broad diffraction peak located at $2\theta=25^\circ$ was observed in the XRD spectrum (Fig. S1), which indicates an amorphous nature.

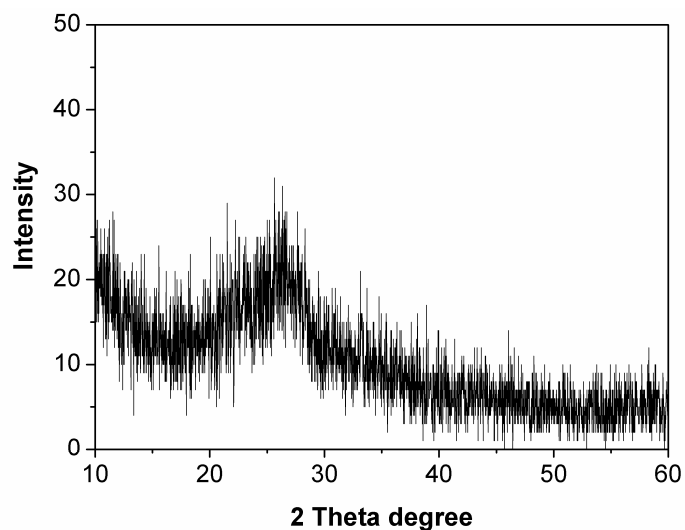


Fig. S1 Powder XRD pattern of the Carbogenic dots.

2. The absorption and emission of CDs

The absorption and emission spectra of CDs in aqueous solution (Figure S2) are comparable to those previously reported for carbogenic dots. The emission peaks shift to longer wavelengths with increasing excitation wavelength. The strongest emission was observed for an excitation at 360 nm.

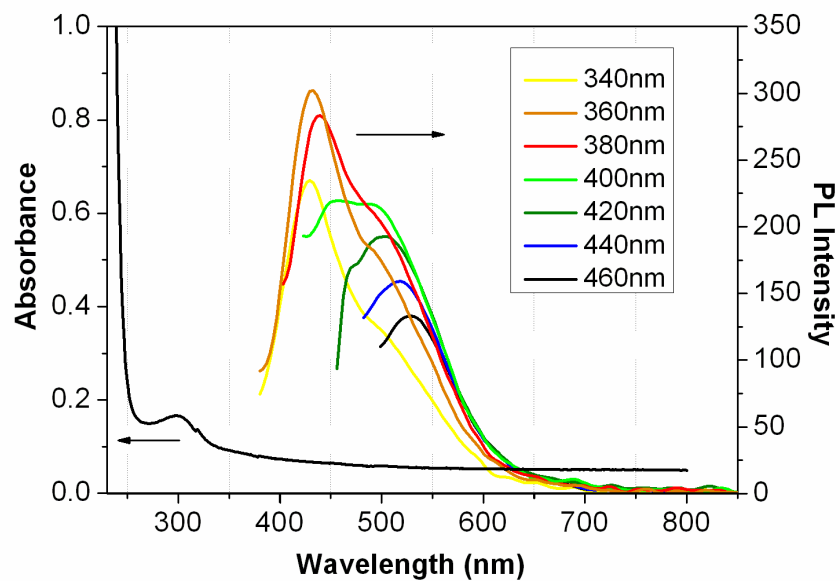


Fig. S2 UV/Vis absorption and photoluminescence emission spectra of CDs in water.

3. Quantum Yield (QY) Measurements.¹

Quinine sulfate in 0.1 M H₂SO₄ (literature quantum yield 0.54 at 360 nm) was chosen as a standard. The quantum yield of CDs (in water) and FCDs (in ethanol) was calculated according to:

¹ Lakowicz, J. R. *Principles of Fluorescence Spectroscopy*, 2nd Ed., 1999, Kluwer Academic/Plenum Publishers, New York.

$$\varphi_x = \varphi_{std} \left[\frac{I_x}{A_x} \right] \left[\frac{A_{std}}{I_{std}} \right] \left[\frac{\eta_x}{\eta_{std}} \right]^2$$

Where φ is the quantum yield, I is the measured integrated emission intensity, η is the refractive index, and A is the optical density. The subscript “*std*” refers to the reference fluorophore of known quantum yield. In order to minimize re-absorption effects, absorption in the 10 mm fluorescence cuvette was kept below 0.10 at the excitation wavelength (360 nm).

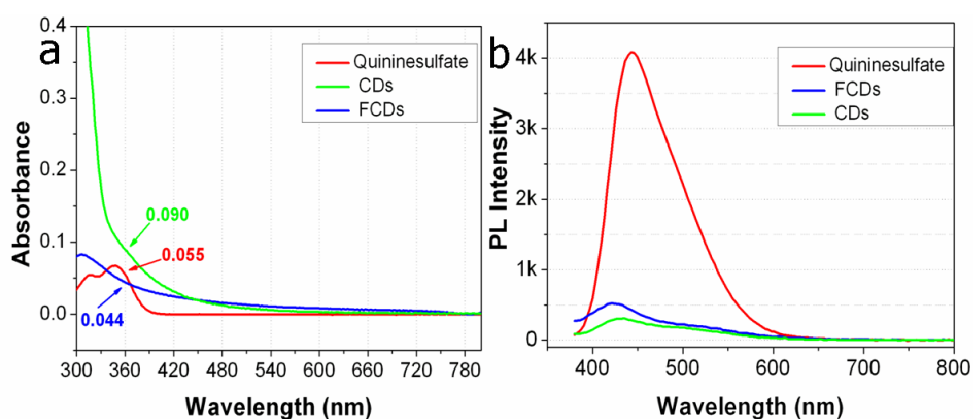


Fig. S3 Absorption (a) and PL (b) spectra of Quinine sulfate, CDs and FCDs.

4. Dispersibility of FCDs

The FCDs are highly dispersible in a range of solvents with negligible emission peak shift when excited at 360 nm, see Fig. S4.

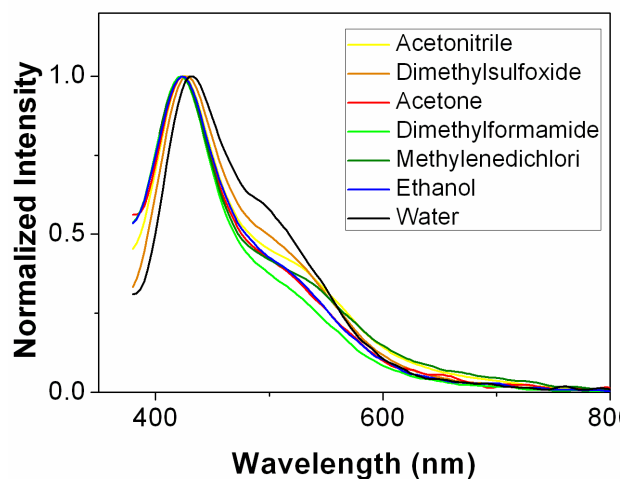


Fig. S4 photoluminescence of FCDs in different solvents excited at 360nm.

5. Effect of the solution pH on the PL intensity.

The FCDs are stable in a wide range of pH values (pH 5–9) with only a slight decrease when the solution in the strong basic or acid condition, furthermore, the PL emission peak did not shift with varying pH, see Fig. S5.

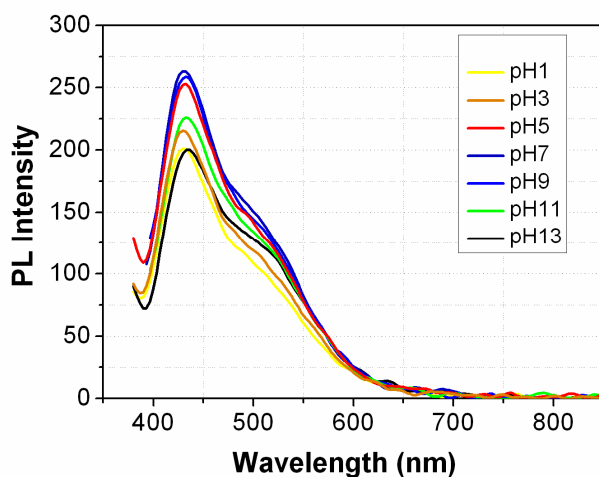


Fig. S5 PL intensity of the FCDs in different pH excited at 360 nm.