Supporting Information

One-step synthesis of self-quenching-resistant carbon dots phosphors and their application in fingerprint identification and anti-counterfeiting

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Experimental Section

Materials

Malic acid and levofloxacin were supplied by Sinopharm Chemical Reagent Co. Ltd., China, and used as received. The ultrapure water was obtained from Milli-Q Direct Water Purification System.

Preparation of FNCDs phosphors

Firstly, 0.5g MA and 0.5g Lev were added to 10 mL ultrapure water in a glass beaker, and the ultrasonic treatment was applied to prepare a homogeneous solution. The solution was then heated using a microwave (800W) for 5 min, where the color has changed from transparent colorless to a yellow-green and finally dark brown solid. By applying ultrasonic treatment, the solids were dispersed in water and purified using a dialysis bag (1000 Da). Finally, the liquid was transferred into plastic container and freeze-dried to obtain FNCDs solids (Scheme 1).

Characterization

The morphology of FNCDs was examined using a FEI Tecnai G2 F20 transmission electron microscopy. The crystallinity of the solid phosphors was measured using D/MAX 2500 diffractometer using CuKα1 radiation (1.54 Å) in the 2θ range of 10°-40° (Neotoku Corp., Japan). The functional groups were analyzed by a FIR8900 Fourier transform infrared spectrometer (FT-IR), and an Escalab 250Xi XPS from Thermo Scientific were applied to investigate the chemical structure and compositions of FNCDs. The X-ray Photoelectron Spectroscopy (XPS) spectra were carried out on K-Alpha (Thermo Scientific). The Raman spectrometer was measured on Horiba scientific-LabRAM HR evolution. The dynamic light scattering (DLS) of FNCDs in water was measured using a Malvern Nano-ZS90.

For the optical analysis, the UV-visible spectra of FNCDs solution were recorded on a Hitachi U-4100 spectrophotometer, while the UV-visible reflection spectrum of FNCDs phosphors was measured with Hitachi UH4150 Spectrophotometer. The photoluminescence (PL) spectra for FNCDs in solution and solids with excitation wavelength varies from 260 nm to 400 nm were collected using Hitachi F-7000 fluorescence spectrometer. For stability analysis, the thermal gravimetric analysis (TGA) of solid phosphors was carried out with NETZSCH-STA449C. The fluorescence decay lifetimes for both FNCDs solution and solids were measured on a FLSP920 from Edinburgh Instrument. Meantime, the PL quantum yield (QY) measurement was carried out with calibrated integrating sphere equipped on the FLSP920 spectrometer. A gel permeation chromatography (ViscotekM302-050) was used to determine the molecular weight of FNCDs. The nuclear magnetic resonance spectra were collected using Avance Spectrometer 600 MHz (Bruker, Germany) with DMSO-d6 as solvent.

Visualization of latent fingerprints

In order to collect latent fingerprints using the as-prepared fluorescence nanomaterials, FNCDs was firstly grounded into small particles for powder dusting. The fingerprints of the desired fingers were supplied by one volunteer, who was asked to touch the designed substrates (such as glass, plastic bags, and aluminum foil) to leave the latent fingerprints. Then, the grounded powers were dusting on the surfaces and the excess solids were removed using a soft brush. In around 10 s, the images of fingerprints under UV lamp (365 nm) can be collected easily using a mobile phone (as seen in Scheme 1).

Preparation of anti-counterfeiting patterns

To explore the further application of FNCDs in anti-counterfeiting, the fluorescent ink was prepared through dissolving FNCDs in ultrapure water (1.0 mg/mL) using ultrasonic treatment. Ten Arabic numbers, three English letters (YSU, shorter name for Yanshan University), and three symbols of musical instruments were drawn on filter papers through painting brushes. The filter papers were naturally dried in around 10 min, after which the images of each filter paper under sunlight and UV lamp (365 nm) were taken using a normal mobile phone.

Supporting Figures

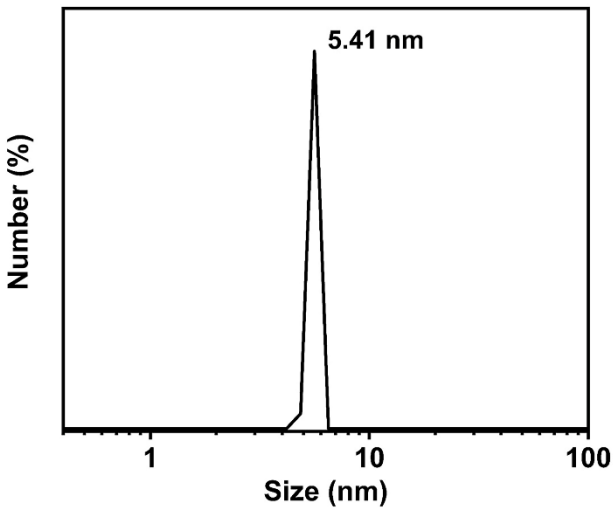

Fig. S1 Size distribution by DLS

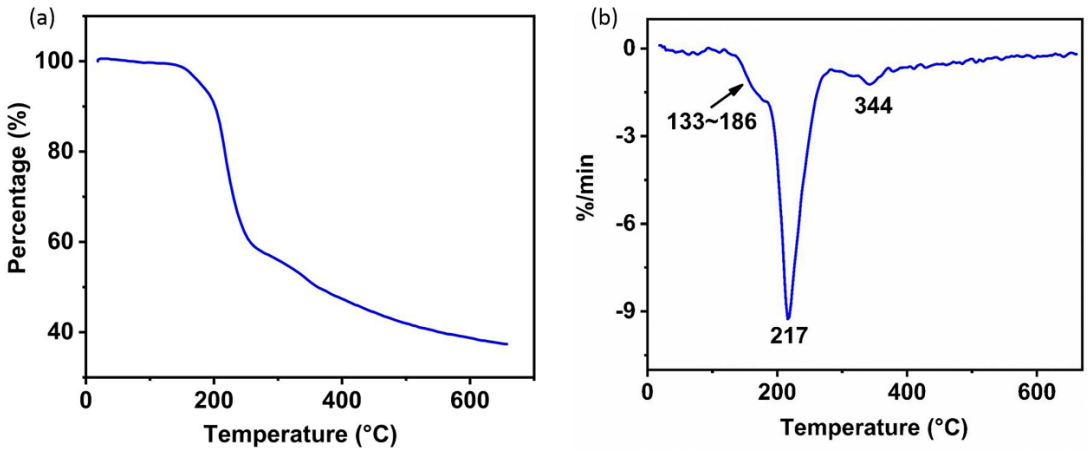

Fig. S2. TGA and DTA curves of FNCDs

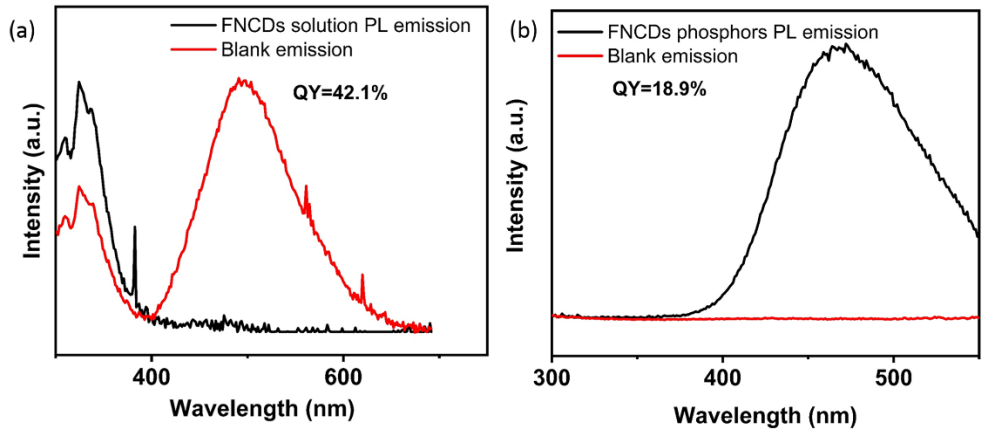

Fig. S3 The absolute quantum yield of FNCDs in both solution (a) and solids (b) excited at 280nm.

The absolute quantum yield of FNCDs in solid-state and solution-state were measured using a steady/transient-state fluorescence spectrometer (FLS920) equipped with a calibrated integrating sphere. The QY value of FNCDs solids was determined as 18.9% with BaSO4 as the reference, while the QY of FNCDs solution was measured as 42.1% with water as the blank.

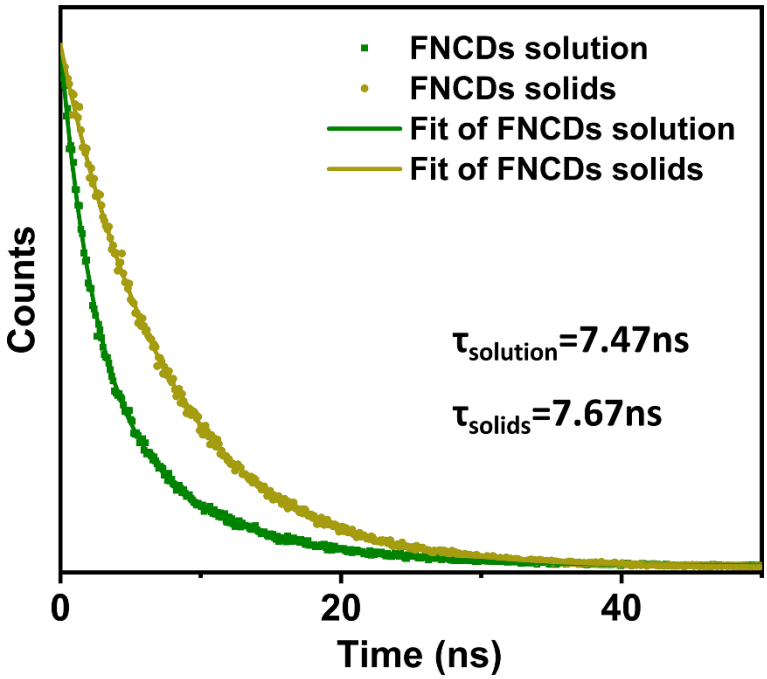

Fig. S4 Decay curves of FNCDs in solution and solids

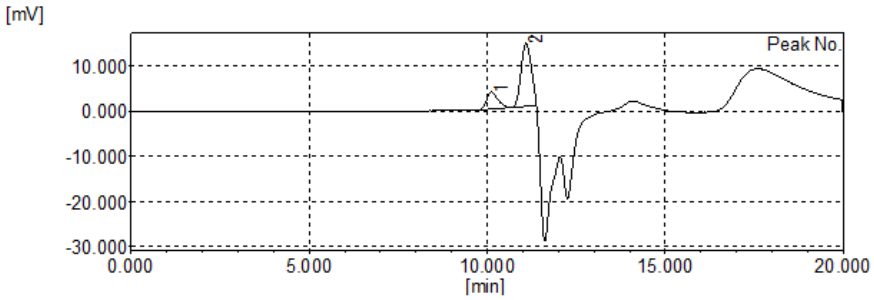

Fig. S5 GPC curves of FNCDs, M_w=587

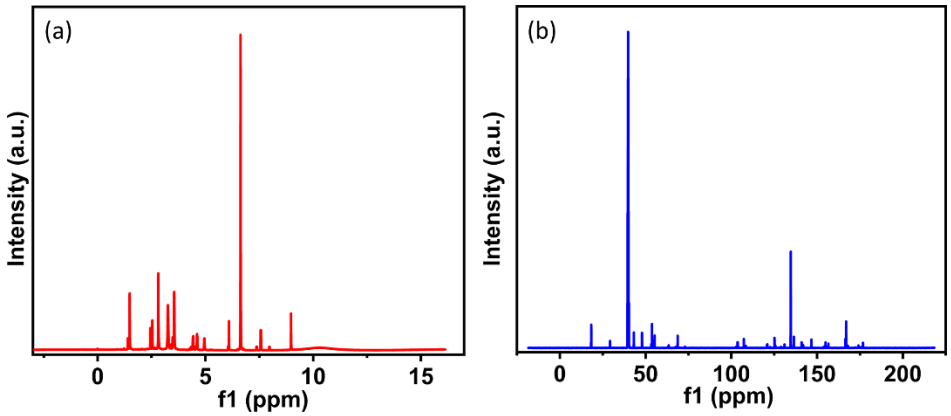

Fig. S6 (a) 600M Hz ^{1}H NMR spectrum of FNCDs; (b) ^{13}C NMR spectrum of FNCDs

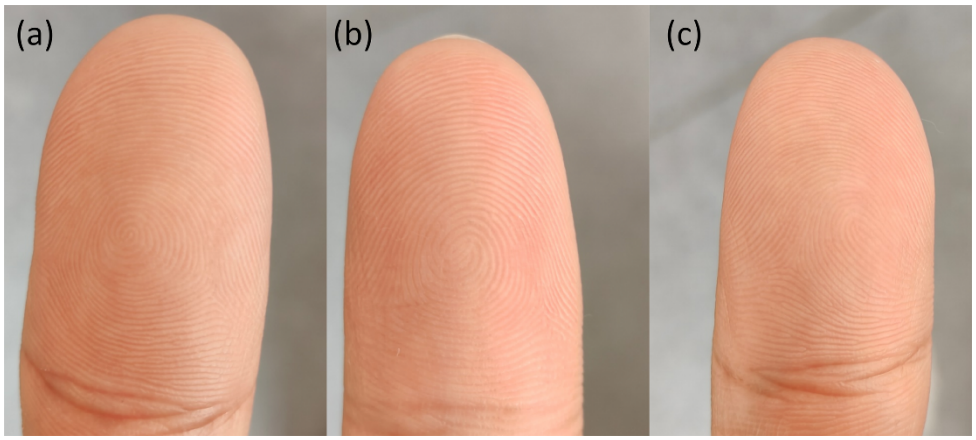

Fig. S7 Fingerprint pictures of the fingerprint provider

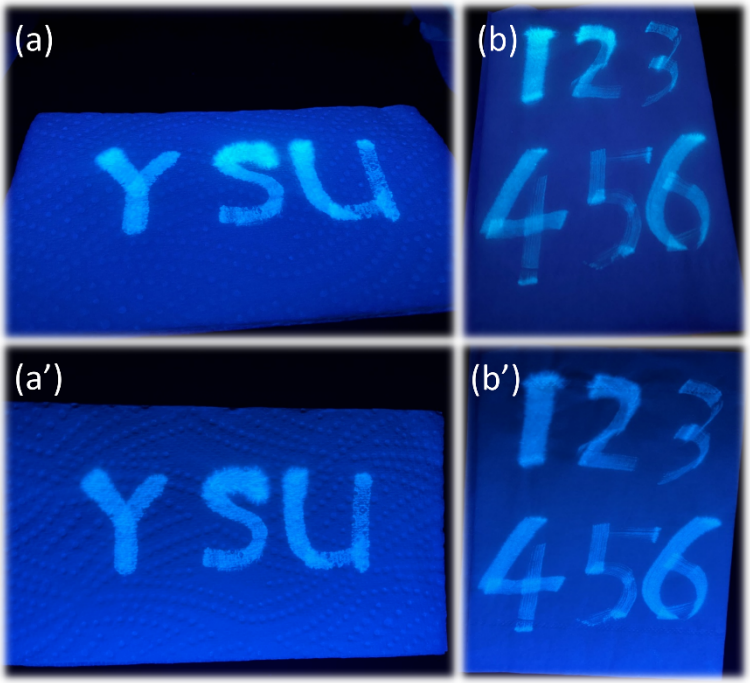

Fig. S8 Fluorescence images of FNCDs patterns on filter papers (a) and (b) fresh samples; (a') and (b') images after 20 days' storage