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Electronic Supplementary Information (ESI)

Surface-mounted carbon quantum dots onto photonic crystal generating dual structural-fluorescent color rendering

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Content

Methods and materials

XRD patterns were obtained by a Bruker-AXS D8 Advance X-ray diffractometer under Cu Kα radiation (λ=1.5406 Å). SEM images were obtained by a GeminiSEM 300 scanning electron microscope. HRTEM image was obtained by a Tecnai G2 F20 transmission electron microscope. FTIR spectrums were obtained by a Bruker INVENIO FTIR Spectrometer. XPS spectroscopys were obtained by a PHI QUANTERA II X-ray Photoelectron Spectrometer. Ultraviolet-Visible (UV-Vis) spectrum was obtained by a EVOLUTION220 Ultraviolet-visible Spectrophotometer. Fluorescence spectrums were obtained by CARY ECLIPSE fluorospectrophotometer. The time-resolved fluorescence lifetime was measured on a Delta Flex modular fluorescence lifetime system. Acetone, H_2SO_4 and 30%H_2O_2 were purchased from Sinopharm Chemical Reagent Co. $Zn(CH_3COOH)_2{\cdot}2H_2O$, Citric Acid (CA) and Polyethyleneimine (PEI, Mw=1800, 99%) were purchased from Heowns Biochem Technologies, in Tianjin. 2-Methylimidazole (2-MiM) was purchased from Bidepharm. Methanol, anhydrous ethanol were purchased from Titan in Shanghai. Acetic acid was purchased from Macklin. Isopropyl alcohol (IPA) was purchased from Nanjing Chemical Reagent Co., Ltd. Tetrabutyl titanate (TBT) was purchased from Meryer.

Experimental Scetion

Preparation of TiO_2 solution

First, two solutions, A and B, were prepared: solution A was prepared by adding 8 ml of TBT and 4 ml of IPA to a 100 ml blue-capped bottle; solution B was prepared by adding 8 ml of IPA, 0.42 ml of deionized water and 34 μl of CH_3COOH to a 50 ml beaker. The two solutions were stirred separately for 10 min, and then the B solution was slowly dripped into the continuously stirred A solution using a dispensing funnel (about 20 min). Finally, 13 ml of IPA was added to the mixed solution and sealed and stirred at room temperature for about 12 h to obtain a colorless and transparent TiO_2 solution.

The hydrolytic reaction of n-Butyl titanate (TBT) under acidic conditions (CH_3COOH as a chelating agent to control the rate of hydrolysis) in isopropanol (IPA) medium is stepwise:

$$Ti(O{-}C_4H_9)_4 + H_2O \rightarrow Ti(O{-}C_4H_9)_2(OH) + C_4H_9OH \quad (1)$$

$$Ti(O{-}C_4H_9)_3(OH) + H_2O \rightarrow Ti(O{-}C_4H_9)_2(OH)_2 + C_4H_9OH \quad (2)$$

$$Ti(O{-}C_4H_9)_2(OH)_2 + H_2O \rightarrow Ti(O{-}C_4H_9)(OH)_3 + C_4H_9OH \quad (3)$$

$$Ti(O{-}C_4H_9)(OH)_3 + H_2O \rightarrow Ti(OH)_4 + C_4H_9OH \quad (4)$$

Synthesis of ZIF-8 nanoparticles

0.876 g of $Zn(CH_3COOH)_2{\cdot}2H_2O$ and 6.56 g of 2-MiM were dissolved in 80 mL of methanol, respectively. After sufficient stirring for 20 min, the $Zn(CH_3COOH)_2{\cdot}2H_2O$ solution was added to the 2-MiM solution and stirred at room temperature for 30 min. Then it was centrifuged at 10000 rpm/min for 15 min, washed with methanol and acetone for three times, respectively, and finally dried at 40 ℃ overnight.

Synthesis of PEI-capped CQDs

CA (0.384 g) and PEI (3.6 g) were dissolved in 90 ml of deionized water, stirred for 3 minutes, and the transparent mixture was transferred to a hydrothermal kettle for 20 h in an oven at 180℃. The result is a light yellow transparent solution, indicating the formation of CQDs, without any additional separation or purification procedures.

Cleaning of Silicon Wafers

Silicon wafers (20 mm×20 mm×0.75 mm) were cleaned with ethanol and deionized water in the ultrasonic cleaners for ten minutes at least, followed by a thirty-minute immersion in Piranha solution (H_2SO_4 : H_2O_2, V : V = 7:3). After thorough rinsing three times with DI, the silicon wafers were dried with nitrogen.

Supporting Figures

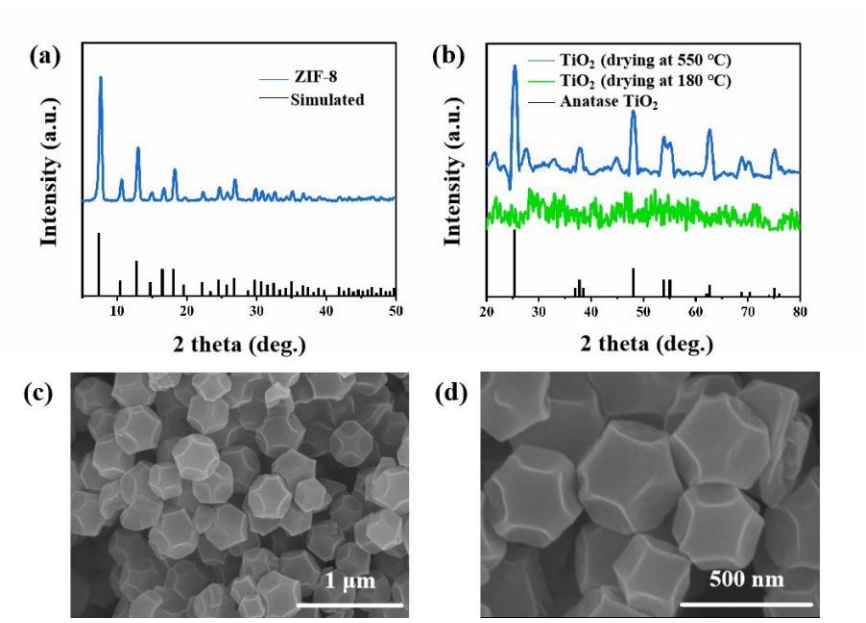

Fig. S1 PXRD spectra of (a) ZIF-8 and (b) TiO_2 (Anatase TiO_2, JCPDS card NO.21-1272); (c-d) SEM images of ZIF-8 nanoparticle

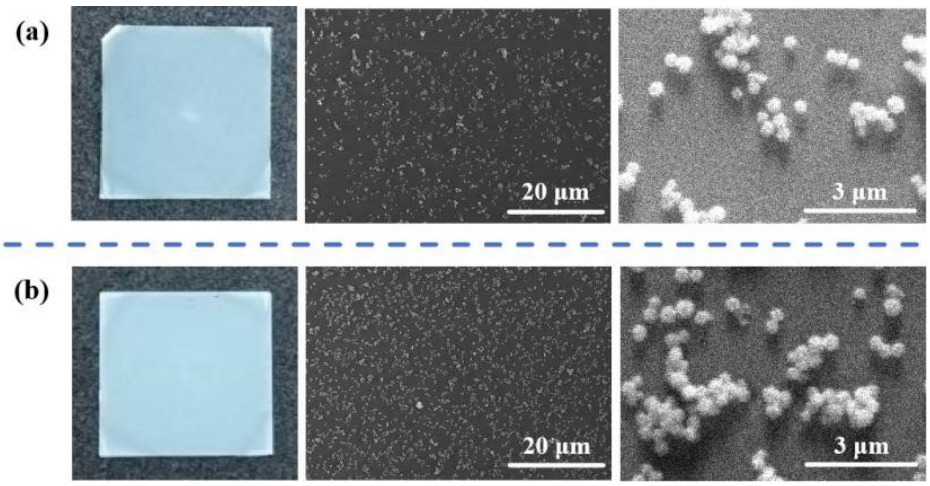

Fig S2. Photos and SEM images of ZIF-8 layers obtained by spin-coating with ZIF-8 suspensions (a) $C_{ZIF\text{-}8}$ = 4 mg/ml; (b) $C_{ZIF\text{-}8}$ = 8 mg/ml.

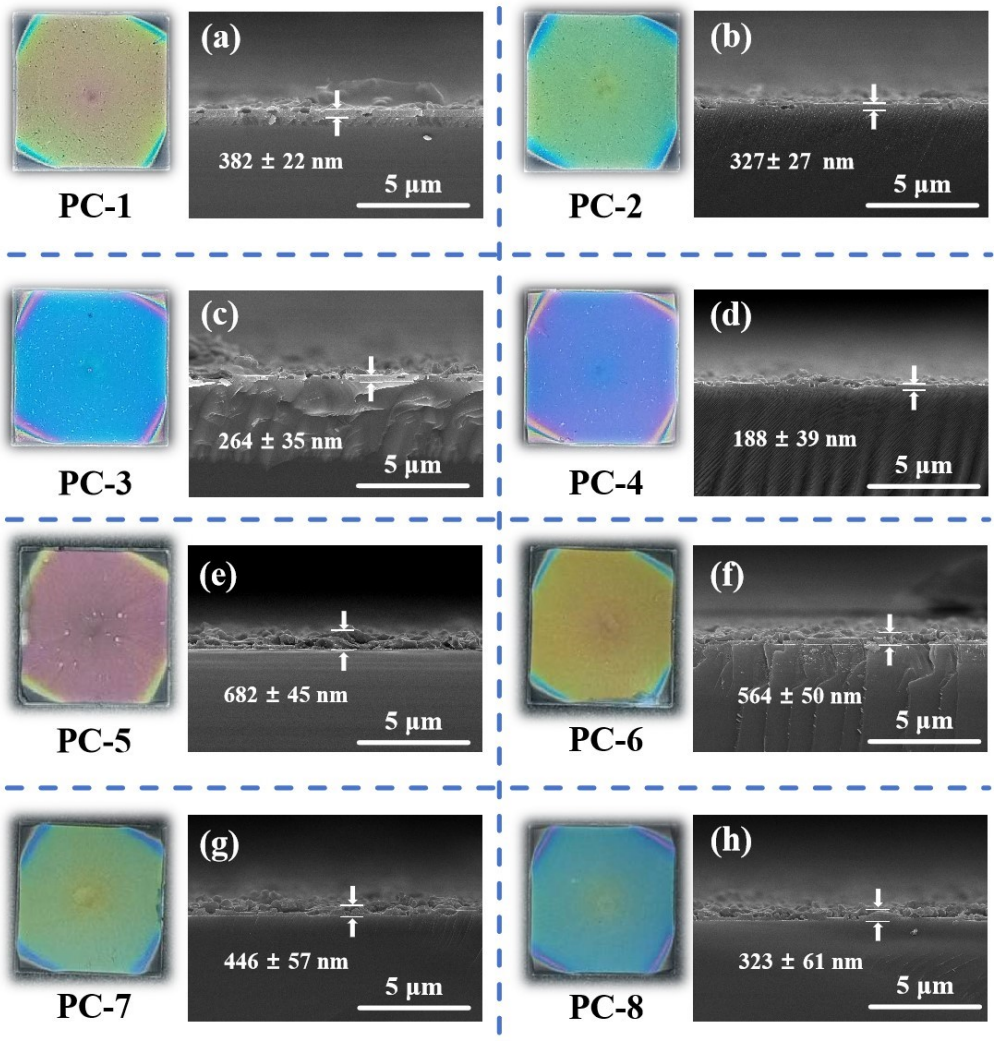

Fig S3. SEM images of cross sections of ZIF-8/TiO_2 1D PCs

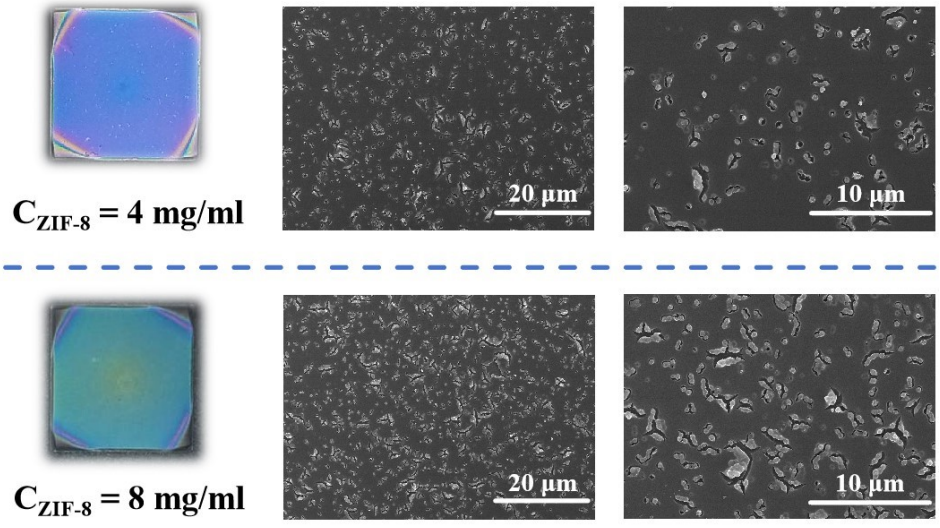

Fig S4. SEM images of top view of ZIF-8/TiO_2 1D PCs

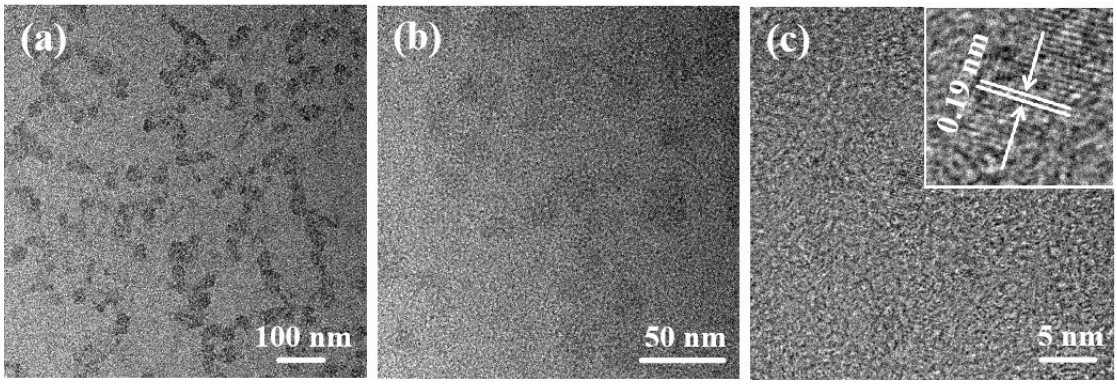

Fig S5. HRTEM images of PEI-capped CQDs

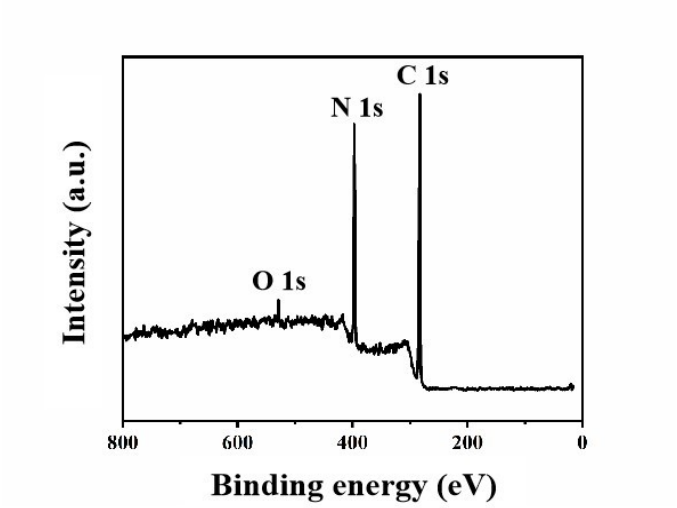

Fig S6. XPS spectra of PEI-capped CQDs

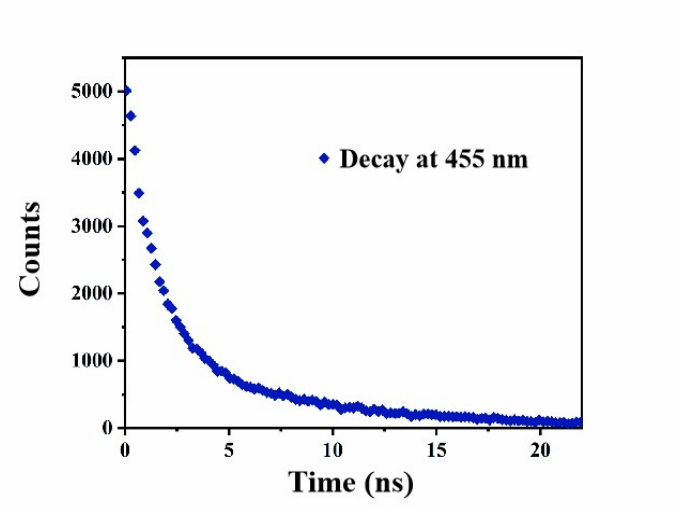

Fig S7. Time-resolved fluorescence decay of PEI-capped CQDs at 455 nm.

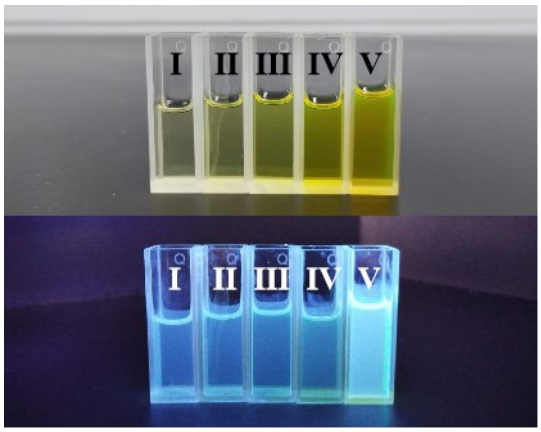

Fig S8. PL Intensity of CQDs dispersed in water at different concentrations: C_I=6.25%; C_{II}=12.5%; C_{III}=25%; C_{IV}=50%; C_V=100%.

Supporting References

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