Supplementary Information

A novel ternary MQDs/NCDs/TiO_2 nanocomposite collaborated with activated persulfate for efficient RhB degradation under visible light irradiation

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Content

Content 1. Thermogravimetric analysis of as-prepared NCDs/TiO_2

Thermogravimetric analysis (TGA) was used to determine the amount of NCDs loaded on TiO_2 nanosheets. As shown in the Fig.S1, the 5.93% weight loss in pure TiO_2 was mainly ascribed to the evaporation of adsorbed water, the decomposition of surface-attached water, -OH group and remaining organic compound, while more weight loss observed in NCDs/TiO_2 nanocomposites could result from the combustion of NCDs. As a result, the mass percentage of NCDs in as-prepared three samples was 1.05%, 1.48% and 1.96%, respectively.

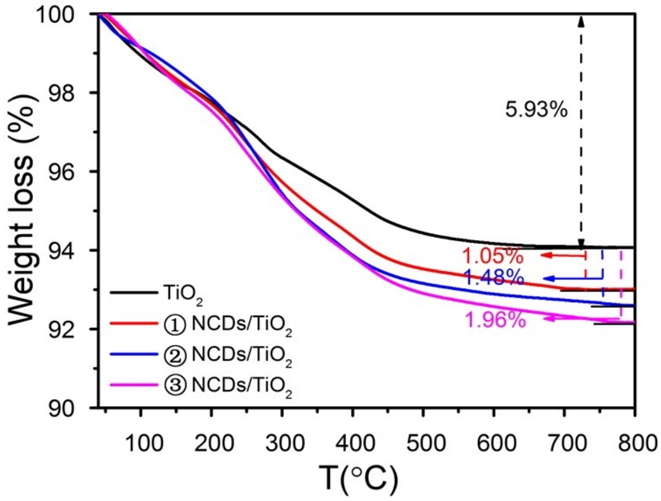

Fig. S1 TGA curves of TiO_2 nanosheets and NCDs/TiO_2 with different NCDs content.

Content 2. Exploration of optimum loading amount of quantum dots on MQDs/NCDs/TiO_2 nanocomposites

During the synthesis process of MQDs/NCDs/TiO_2 nanocomposites, NCDs were first loaded on TiO_2 nanosheets. The photocatalytic activity of NCDs/TiO_2 with different amounts of NCDs was evaluated toward RhB degradation to find the optimum content of NCDs. The change tendency of degradation rate of RhB over NCDs/TiO_2 nanocomposites are shown in Fig. S2a and 1.5%NCDs/TiO_2 displays the highest catalytic degradation activity. The decrease of photocatalytic activity with further increasing of NCDs amount is probably because excessive NCDs will partially become the recombination center of photogenerated electron-holes, which is disadvantageous to photocatalytic degradation. On this basis, different amount of MQDs was further loaded on 1.5%NCDs/TiO_2 nanocomposites. Similarly, the photocatalytic performance of MQDS/NCDs/TiO_2 increases at first with the increase of MQDs content (Fig. S2b). When the loading of MQDs was 1.5%, 1.5%MQDs/1.5%NCDs/TiO_2 exhibited the highest photocatalytic activity. However, further increasing amount of MQDs brings about a decrease of photocatalytic activity. This result may be ascribed to the shielding effect of overcharged MQDs which will hinder the light absorption of NCDs/TiO_2.

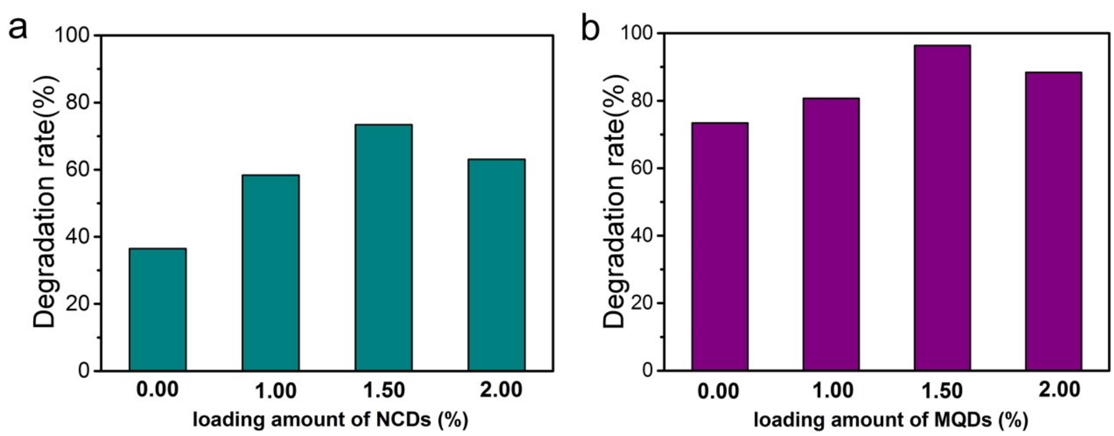

Fig. S2 (a) The degradation rate of RhB by NCDs/TiO_2 nanocomposites loaded with different amounts of NCDs, (b) the degradation rate of RhB by MQDs/NCDs/TiO_2 nanocomposites loaded with 1.5% NCDs and different amounts of MQDs.

Content 3. The HRTEM image of NCDs and MQDs

The HRTEM image of NCDs and MQDs is shown in Fig. S3a and Fig. S3b, respectively. It can be observed that NCDs and MQDs are both spherical and with the dimensions less than 10 nm.

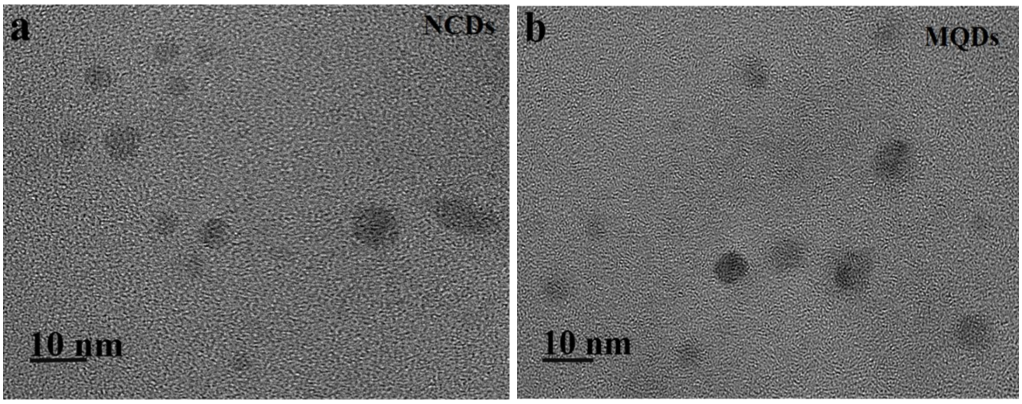

Fig. S3 HRTEM image of (a) NCDs and (b) MQDs samples.

Content 4. The energy dispersive spectroscopy pattern and elements mapping of as-prepared sample

The energy dispersive spectroscopy (EDS) pattern and elements mapping of sample shows that the six elements of Ti, C, N, O, Mo and S were dispersed in MQDs/NCDs/TiO_2 nanocomposites, which further demonstrates that NCDs and MQDs were well distributed on TiO_2 nanosheets.

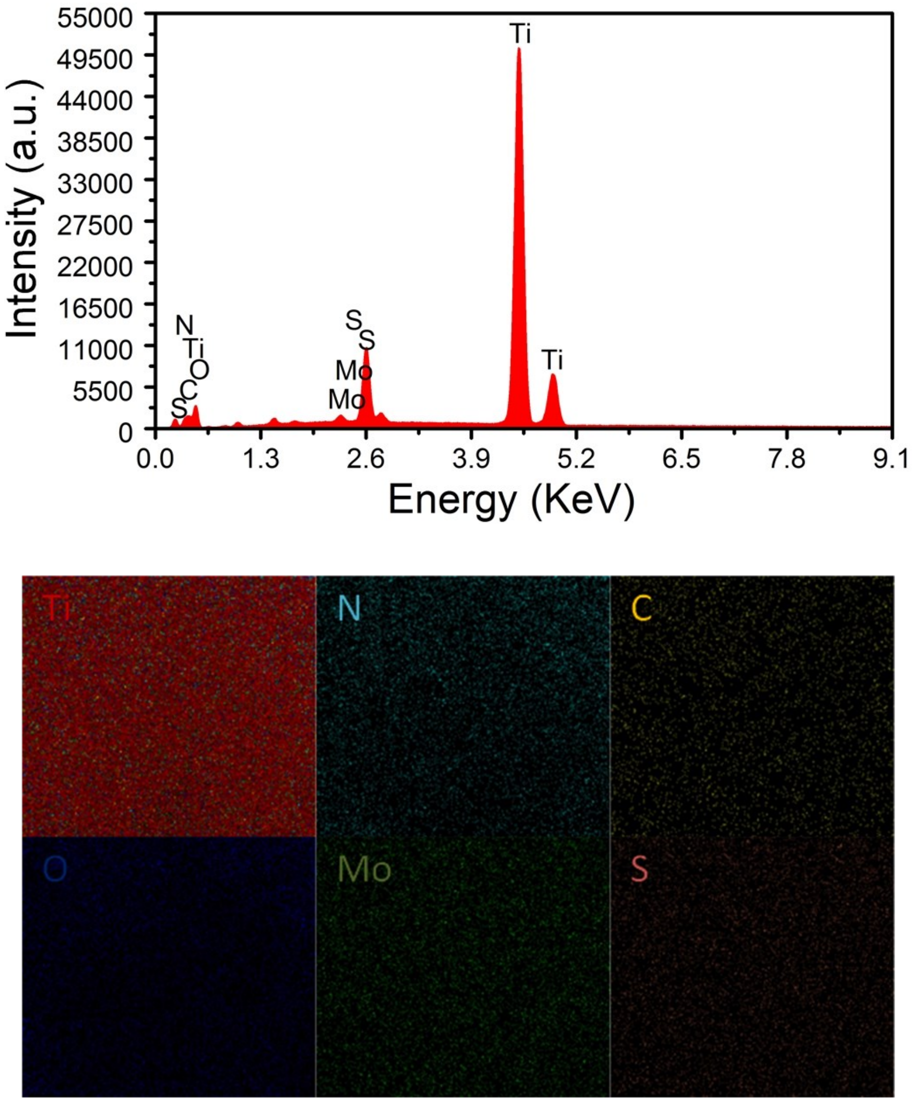

Fig. S4 EDS pattern of MQDs/NCDs/TiO_2 nanocomposites and the corresponding elements mapping for Ti, N, C, O, Mo, and S.

Content 5. The specific surface area, average pore size and pore volume of three samples

The specific surface area, average pore size and pore volume of three samples were listed in Table S1.

Table S1 Summary of specific surface area, average pore size and pore volume of TiO_2, NCDs/TiO_2 and MQDs/NCDs/TiO_2 samples.

Samples	Specific surface area (m^2/g)	Average pore size (nm)	Pore volume (cm^3/g)
TiO_2	126.13	17.87	0.049
NCDs/TiO_2	116.71	17.01	0.045
MQDs/NCDs/TiO_2	101.48	16.29	0.039

Content 6. Comparison of photocatalytic performance for MQDs/NCDs/TiO_2 nanocomposites with similar materials

In this work, we compared nanocomposites with previously reported TiO_2-based photocatalyst and the results listed in Table S2. The photocatalytic performance can be influenced by some factors, such as the power of light source, the dose of catalysts and pollutants, degradation time and so on. Compared with first three photocatalysts in Table S2, the degradation efficiency of MQDs/NCDs/TiO_2 are the highest. Although the degradation efficiency of MQDs/NCDs/TiO_2 is slightly lower than that of the latter two catalysts, the degradation time and the power of light source are quite short and low. Thus, the MQDs/NCDs/TiO_2 nanocomposites exhibit excellent photocatalytic activity even without persulfate addition under visible light.

Table S2 Comparison of photocatalytic performance for MQDs/NCDs/TiO_2 nanocomposites with similar materials

Photocatalysts	Light source	Pollutant	Degradation time (min)	Degradation efficiency	Ref
$CQDs/Fe_2O_3/TiO_2$ (50 mg)	Xe lamp (300 W)	MB (100 mL, 20 mg/L)	180	86.5 %	S1
$CQDs/TiO_2$/ $g\text{-}C_3N_4$ (50 mg)	Xe lamp (350 W)	Enrofloxacin (50 mL, 4 mg/L)	60	91.6 %	S2
MQDs/graphene/ TiO_2 (40 mg)	Xe lamp (150 W)	RhB (80 mL, 10 mg/L)	80	80 %	S3
MoS_2/TiO_2/HMFs (400 mg)	Halogen lamp (500 W)	RhB (32 mL, 20 mg/L)	140	98.7 %	S4
C-Dots/$Ag_6Si_2O_7/TiO_2$ (100 mg)	LED lamp (300 W)	RhB （250 mL，8 mg/L)	120	99.8 %	S5
MQDs/NCDs/TiO_2 （100 mg）	Xe lamp (150 W)	RhB (100 mL, 10 mg/L)	80	96.4 %	This work

Reference:

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S2. Y. Su, P. Chen, F. Wang, Q. Zhang, T. Chen, Y. Wang, K. Yao, W. Lv and G. Liu, Decoration of $TiO_2/g\text{-}C_3N_4$ Z-scheme by carbon dots as a novel photocatalyst with improved visible-light photocatalytic performance for the degradation of enrofloxacin. *RSC Adv*., 2017, **7**, 34096-34103.

S3. W. Gao, M. Wang, C. Ran and L. Li, Facile one-pot synthesis of MoS_2 quantum dots-graphene-TiO_2 composites for highly enhanced photocatalytic properties. *Chem. Commun*., 2015, **51**, 1709-1712.

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S5. S. Feizpoor, A. Habibi-Yangjeh, D. Seifzadeh, S. Ghosh, Combining carbon dots and $Ag_6Si_2O_7$ nanoparticles with TiO_2: Visible-light-driven photocatalysts with efficient performance for removal of pollutants. *Sep. Purif. Technol.,* 2020, **248**, 116928-116938.

Content 7. Band-gap energy and Valence-band XPS spectra of NCDs

The band-gap and LUMO position of NCDs was determined from the plots of $(\alpha h\nu)^{n/2}$ versus band-gap energy and valence-band XPS spectrum. As shown in Fig. S5a and Fig. S5b, the band-gap of NCDs is about 1.78 eV and the HOMO position is at 0.31 eV. Based on this, the LUMO position can be calculated to be -1.47 eV.

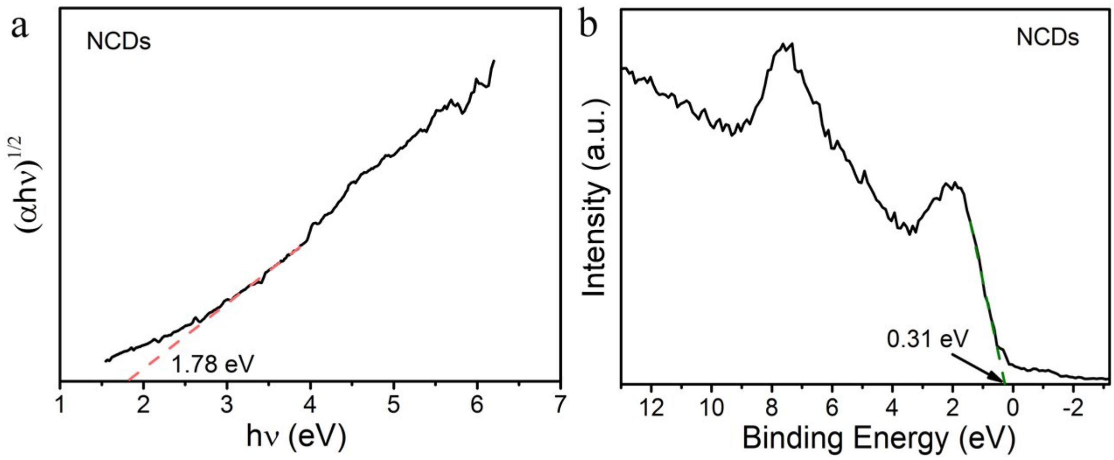

Fig. S5 (a) Band-gap energy and (b) valence-band XPS spectrum of NCDs