Fabrication of CdS/Ti3C2/g-C3N4NS Z-Scheme Composites with Enhanced Visible-Light-Driven Photocatalytic Activity

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Abstract

The Ti$_3$C$_2$ and g-$C_3$N$_4$NS were obtained first, and the CdS/Ti$_3$C$_2$/g-$C_3$N$_4$NS Z-scheme composites were prepared via a facile hydrothermal synthesis and their photocatalytic properties were investigated. The g-$C_3$N$_4$NS with a high surface area displayed higher adsorption and degradation capacity. Compared with Ti$_3$C$_2$/g-$C_3$N$_4$NS and CdS, the optimal ternary composites exhibited significantly enhanced visible light (vis) photocatalytic activity. The Fabrication of CdS/Ti$_3$C$_2$/g-$C_3$N$_4$NS Z-scheme heterostructure not only enhanced vis absorption, but also improved the separation ability of the photoinduced e$^-$-h$^+$ pairs and the redox ability of the catalyst, thereby leading to the improvement of visible-light-driven photocatalytic activity. This finding provides new insights into the construction of high efficiency Z-scheme heterostructure photocatalyst.

Introduction

With the development of industry, water pollution has become a serious problem. Photocatalysis has attracted much attention in resolving water pollution (Xu et al. 2019; Sun et al. 2020). The two-dimensional (2D) layered materials have been widely studied due to their special physical and chemical properties (Zhang et al. 2015; Feng et al. 2018; Low et al. 2018). Ti$_3$C$_2$ MXene is a promising 2D-layered photocatalyst material due to its fast electron transfer capability and rich surface properties (Zhang et al. 2018). However, fast charge recombination in Ti$_3$C$_2$ catalysts limits its further application. Ti$_3$C$_2$ has abundant surface functional groups and can form Schottky junction with some semiconductor materials, which can promote the separation of photogenerated e$^-$-h$^+$ pairs (Gao et al. 2015; Zhou et al. 2017; Ai et al. 2019; Xiao et al. 2020).

Graphitic carbon nitride (g-$C_3$N$_4$) as a nontoxic and accessible semiconductor material, was widely applied in the field of photocatalysis (Koyyada et al. 2021; Ibrahim and Gondal 2021). Furthermore, g-$C_3$N$_4$ nanosheets (g-$C_3$N$_4$NS) were obtained by treating g-$C_3$N$_4$, and their photocatalytic degradation properties were further improved (Dong et al. 2017; Wu et al. 2019). CdS is an excellent vis-sensitive photocatalyst (Zhou et al. 2015; Zhang et al. 2016). However, the photocatalytic degradation effect of CdS was limited due to the problems of fast recombination of the photoexcited carriers and the photocorrosion (Peng et al. 2019; Zou et al. 2020). The CdS was combined with other semiconductor materials to form composites, which can effectively inhibit the recombination of the photoinduced e$^-$-h$^+$ pairs and improve the photocatalytic degradation performance (Kang et al. 2017; Ran et al. 2017; Peng et al. 2019; Zou et al. 2020).

In addition, the formation of Z-scheme heterojunction in the composite catalyst can also efficiently improve the photocatalytic activity (Zhao et al. 2019). Successful ternary Z-scheme photocatalysts generally utilize noble metals as electron transfer components. Recently, some studies found that the preparation of ternary Z-scheme heterostructure composites using Ti$_3$C$_2$ as electron transfer medium can improve the photocatalytic degradation of pollutants (Ai et al. 2019; Li et al. 2019; Ding et al. 2019; Sun et
al. 2020). To further improve visible-light-driven photocatalytic activity, it is still a great challenge to develop novel Z-scheme heterostructure photocatalysts with high efficiency and stability using Ti$_3$C$_2$ as a charge transport medium via a simple method.

Herein, the g-C$_3$N$_4$NS and Ti$_3$C$_2$ were obtained using urea and Ti$_3$AlC$_2$ as raw materials, respectively, then a 2D-layered CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS Z-scheme photocatalysts were prepared via a facile hydrothermal synthesis. The photocatalytic activity of as-prepared ternary composites was investigated under vis irradiation using orange II as an organic pollutant. This study may provide useful insights into utilizing Ti$_3$C$_2$ as the mediator for controlling the transfer of photogenerated carriers in Z-scheme photocatalysis.

**Experimental Section**

**Materials**

Ti$_3$AlC$_2$, HF, CdCl$_2$, Na$_2$S, Urea, HCl, orange II, p-benzoquinone (BZQ), tertbutanol (TBA), ethylenediaminetetracetic acid (EDTA), 5.5-dimethyl-1pyrroline Noxide (DMPO), were used. The deionized water (DI) was used to prepare all the solutions.

**Preparation of Ti$_3$C$_2$ and g-C$_3$N$_4$NS**

Ti$_3$C$_2$ was obtained by exfoliating the Al layers from Ti$_3$AlC$_2$ with 40 wt% HF at 30°C for 25 h. The precipitates were then filtered, washed with DI, and dried in the oven for 10 h.

Synthesis of the g-C$_3$N$_4$NS: the urea was calcined at 500° C for 6 h to obtain a g-C$_3$N$_4$ bulk material, and 0.24g of g-C$_3$N$_4$ was added to 60 mL 6M HCl, and treated with ultrasound for 30 min. The mixture was transferred to an autoclave (100mL) and then heated at 110 °C for 7h. The precipitates were centrifuged, washed, and dried at 60°C for 12h in a vacuum oven.

**Preparation of Ti$_3$C$_2$/g-C$_3$N$_4$NSand CdS/g-C$_3$N$_4$NS composites**

0.5g of Ti$_3$C$_2$ (CdS) and 0.6g of g-C$_3$N$_4$NS samples were added to 50 mL DI under stirring, respectively. The two mixtures were then mixed and sonicated for 1 h. Subsequently, the suspension was heated at 80 °C in a water bath until the solvent was evaporated. The products (Ti$_3$C$_2$/g-C$_3$N$_4$NS and CdS/g-C$_3$N$_4$NS ) were then dried at 60 °C for 12h in a vacuum oven.

**Fabrication of CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS composites**

The obtained Ti$_3$C$_2$/g-C$_3$N$_4$NS (0.5 g) was dispersed in 60 mL of CdCl$_2$ solution and further stirred for 15 min, and certain amounts of Na$_2$S were then added to the mixture solution under stirring. Subsequently, the mixture was transferred to an autoclave (100mL) and then heated at 200 °C for 6h. After the hydrothermal treatment, the precipitates were centrifuged, washed, and then dried at 85 °C for 12 h. The
obtained CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS composites by controlling the mass ratio of CdS and Ti$_3$C$_2$/g-C$_3$N$_4$NS of 2:1, 3:1, 4:1, and 5:1 were denoted as CTN-2:1, CTN-3:1, CTN-4:1, and CTN-5:1, respectively.

**Measurement of photocatalytic activity**

The photocatalyst (0.04 g) was dispersed in an orange solution (100 mL, 20mg/L) at pH 3, and stirred in a dark room for 1h. The 300W Xe lamp was selected as light source. All experimental runs were performed at 20 °C under continuous stirring. During the process of light irradiation, 5 mL suspension were taken out and centrifuged. The concentrations of orange were determined using a UV–vis spectrometer (UV-8000) at 486nm.

**Characterization** The characterization and performance of photocatalyst are summarized in the Supporting Information (Table S1).

**Results And Discussion**

**Structures and morphologies of samples**

Figure 1 displays the XRD patterns of the as-prepared samples. In Fig. 1a, the peaks at 2θ of 8.84°, 18.4°, 27.5°, and 60.7° correspond to (002), (004), (006), and (110) crystal planes of Ti$_3$C$_2$ (Xu et al. 2018; Cai et al. 2018), respectively. In Fig. 1b, the diffraction peaks of the Ti$_3$C$_2$ and g-C$_3$N$_4$NS were presented (Xu et al. 2019). As shown in Fig. 1c–f, the CdS with cubic phase (JCPDS No 80 – 0019) is obtained in addition to Ti$_3$C$_2$ and g-C$_3$N$_4$NS phases.

Fig. 2 shows the Raman spectra of the samples. In Fig.2a, the Raman peaks located at 325.5 cm$^{-1}$ (A1g mode) corresponds to the out-of-plane stretching vibrations of Ti and C (Hu et al. 2015), and the peaks at 1456 and 1519 cm$^{-1}$ can be attributed to the D-band and G-band of Ti$_3$C$_2$ (Naguib et al. 2014). In Fig.2b, the typical peaks at 301.1 and 600.2 cm$^{-1}$ are assigned to the first-order LO Raman peak and second-order LO phonon vibrational mode of cubic CdS (Rengaraj et al. 2011), respectively. In Fig.2 c, the peak at 474cm$^{-1}$ is referred as the Raman signal of g-C$_3$N$_4$NS(Sutar et al. 2020). As shown in Fig.2d, the Raman peaks of Ti$_3$C$_2$, g-C$_3$N$_4$NS and CdS are shown, respectively. The XRD and Raman results verify that the ternary composites are composed of Ti$_3$C$_2$, g-C$_3$N$_4$NS and CdS.

FigureS1 shows the morphologies of g-C$_3$N$_4$ and g-C$_3$N$_4$NS. g-C$_3$N$_4$ shows an irregularly wrinkled morphology, and the prepared g-C$_3$N$_4$NS presents a thin sheet shape. Figure 3 presents the morphologies of the Ti$_3$C$_2$, Ti$_3$C$_2$/g-C$_3$N$_4$NS and CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS samples. The prepared Ti$_3$C$_2$ exhibits a 2D-layered morphology (Fig. 3a). In Fig. 3b, the g-C$_3$N$_4$NS is tightly coated around the Ti$_3$C$_2$, forming a rough surface. A rough surface facilitates the transmission of photogenerated carriers (Zhang et al. 2020). As shown in Fig. 3c-f, the SEM images of CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS composites show that the CdS particles are deposited and tightly attached on the interlayer and surface of Ti$_3$C$_2$/g-C$_3$N$_4$NS. With the further increase
in CdS amount, the interlayer of the composite occupies a large amount of CdS particles, and the 2D-layered structure of the ternary composite is weakened (Fig. 3f). The EDX spectra and the corresponding elemental mapping were carried out for the CTC-4:1 sample (Fig. S2). Ti, C, N, S, and Cd elements are uniform distributed in the composite.

The HRTEM image of CTC-4:1 is shown in Fig. 4. The lattice spacings of 0.250nm and 0.336nm correspond to the (006) and (111) crystal facets in Ti$_3$C$_2$ and CdS (Cao et al. 2013; Ding et al. 2019), respectively. The g-C$_3$N$_4$NS with low crystallinity do not show obvious lattice fringes (Wang et al. 2019). A compact and continuous interface exists among Ti$_3$C$_2$, CdS, and g-C$_3$N$_4$NS, which can provide efficient separation and diffusion of photoinduced carriers (Kang et al. 2017).

**Xps Analysis Of Samples**

Figure 4 shows the XPS spectra of the CTN-4:1 and CdS. The XPS survey spectrum indicates that the CTN-4:1 is composed of Ti, C, N, S, and Cd elements (Fig. S3).

In the Ti2p XPS spectrum of CTN-4:1 (Fig. 5A), the peaks at around 454.7, 458.7 and 463.9 eV are attributed to the Ti-C, Ti2p3/2 and Ti2p1/2 in Ti$_3$C$_2$ (Yang et al. 2018; He et al. 2020). For the C1s spectrum (Fig. 5B), the peaks at approximately 286.26 eV can correspond to C–Ti on the CTN-4:1 surface (Peng et al. 2017), while the peaks at 284.6 and 288.36 eV are attributed to the C-C and C-N = C bonds in g-C$_3$N$_4$NS (Diao et al. 2020).

The S2p and Cd3d XPS spectra of CTN-4:1 and CdS were compared. In the S2p and Cd3d spectra of CTN-4:1, peaks at 161.9 and 163.2 eV can be correspond to S2p$_{1/2}$ and S2p$_{3/2}$ of S$^{2+}$ (Ai et al. 2019) (Fig. 5C), and the peaks at 412.3 and 405.5 eV can be ascribed to Cd3d$_{3/2}$ and Cd3d$_{5/2}$ of Cd$^{2+}$ (Ai et al. 2019) (Fig. 5D). Compared with CdS, the binding energies of S2p and Cd3d in the CTN-4:1 show a shift to the right, suggesting the strong interactions between CdS and Ti$_3$C$_2$/g-C$_3$N$_4$NS, forming a heterojunction composite (Wang et al. 2018; Wang et al. 2019).

**Bet Analysis Of Samples**

The Nitrogen adsorption-desorption isotherms of as-prepared samples are shown in Fig. S4. The specific surface area and pore volume values of all samples are summarized in Table 1. The surface area and pore volume values of obtained g-C$_3$N$_4$NS are evidently higher than that of g-C$_3$N$_4$. In contrast to the Ti$_3$C$_2$/g-C$_3$N$_4$NS, the CdS-loaded ternary composites increase the surface area and pore volume values. Among the ternary composites, the CTN-4:1 sample presents the largest surface area, which may provide more reactive active sites for photocatalytic degradation (Elfiad et al. 2018).
Table 1
Surface area and pore volume of the samples

| Sample          | Surface area (m²/g) | Pore volume (cm³/g) |
|-----------------|---------------------|---------------------|
| g-C₃N₄         | 45.09               | 0.22                |
| g-C₃N₄NS       | 70.72               | 0.53                |
| CdS            | 54.83               | 0.30                |
| Ti₃C₂          | 6.501               | 0.04                |
| Ti₃C₂/g-C₃N₄NS| 46.28               | 0.22                |
| CTN-2:1        | 51.29               | 0.24                |
| CTN-3:1        | 52.99               | 0.26                |
| CTN-4:1        | 48.89               | 0.25                |
| CTN-5:1        |                     |                     |

Photocatalytic Activity Of As-prepared Samples

Photocatalytic degradation of orange II

In Fig. S5, the adsorption and degradation curves of orange II exhibit that g-C₃N₄NS has higher adsorption and degradation performances than that of g-C₃N₄, which agrees well with the BET analysis. Figure 6A presents the degradation efficiency (DE) of orange II using different samples as the photocatalysts. And the reaction rate constants in different catalyst systems were calculated by the pseudo-first-order model (Fig. 6B) and listed in Table 2. Ti₃C₂ and CdS show low degradation effect on orange II. Compared with Ti₃C₂/g-C₃N₄NS, the CdS-loaded ternary composites show enhanced photocatalytic degradation activity. Among the ternary composites, the CTN-4:1 exhibits the highest photocatalytic activity. The UV–vis spectral variation of orange II solution with different treatment times in the CTN-4:1 system is exhibited in Fig. 6C. It is clear that the typical adsorption peak of orange II at 486 nm decreased rapidly with the time increasing. Simultaneously, the color of the filtered solution changes from deep to colorless, indicating the degradation of orange II. The TOC removal efficiency of orange II in the CTN-4:1 system is about 76 % at 60 min, indicating that orange II can be effectively mineralized (Fig. S6A). After subsequent reactions under identical conditions, the CTN-4:1 still maintains high catalytic performance after four cycles (Fig. S6B). In Fig. S6C, no evident difference is found for the structure of CTN-4:1 before and after the photocatalytic reaction, which indicates excellent reusability and stability.

Analysis Of Photocatalytic Mechanism
Figure 7A and Fig. S7A present the UV–vis absorption spectra of the samples. Ti$_3$C$_2$ shows no obvious absorption edge. Compared with the CdS and Ti$_3$C$_2$/g-C$_3$N$_4$NS, all CdS-loaded ternary composites can cause an appropriate shift to long wavelengths. The (ahv)$^{1/2}$ versus hv plots of the samples are presented in Fig. 7B and Fig. S7B. The band-gap energy ($E_g$) values of g-C$_3$N$_4$ and g-C$_3$N$_4$NS are calculated to be 2.87, 2.77eV, respectively. The $E_g$ of obtained g-C$_3$N$_4$NS is lower than that of g-C$_3$N$_4$. And the $E_g$ values of other corresponding samples are summarized in Table 2. Compared with the CdS and Ti$_3$C$_2$/g-C$_3$N$_4$NS, the $E_g$ values of the CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS composites decrease. Among the ternary composites, the CTN-4:1 has the lowest band-gap energy, which is beneficial improve the absorption of visible light.

| Samples          | Reaction rate constant (min$^{-1}$) | Band-gap energy (eV) |
|------------------|-------------------------------------|-----------------------|
| Ti$_3$C$_2$      | 3.8×10$^{-3}$                      | 0.50                  |
| CdS              | 3.9×10$^{-3}$                      | 2.27                  |
| Ti$_3$C$_2$/g-C$_3$N$_4$NS | 1.3×10$^{-2}$                  | 2.50                  |
| CTN-2:1          | 1.6×10$^{-2}$                      | 1.85                  |
| CTN3:1           | 2.3×10$^{-2}$                      | 1.82                  |
| CTN-4:1          | 4.2×10$^{-2}$                      | 1.76                  |
| CTN-5:1          | 1.7×10$^{-2}$                      | 1.89                  |

The PL spectra and transient photocurrent responses of the samples were shown in Fig. 8 (A and B) and Fig.S8 (A and B). The CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS composites show lower PL intensity and higher photocurrent density compared with Ti$_3$C$_2$/g-C$_3$N$_4$NS and CdS. Among all samples, CTN-4:1 exhibits the lowest PL intensity and maximum photocurrent intensity, indicating its higher separation efficiency of the photoinduced e–h$^+$ pairs (Liu et al. 2020). As seen in Fig. 8C, by contrast, CTN-4:1 exhibits the smaller impedance radius, indicating the higher charge transfer and separation ability (He et al. 2019). The formation of heterojunction in ternary composites can promote the transfer and separation of photoinduced carries, which leads to the enhancement of photocatalytic activity.

Figure 9A shows the trapping experiments for the CTN-4:1 degradation system using BZQ, EDTA, and TBA as the scavengers of •O$_2^-$, h$^+$, and •OH species, respectively. The DEs of orange II decrease after the addition of the scavengers, indicating that the •O$_2^-$, h$^+$, and •OH species are formed, and •O$_2^-$ and h$^+$ species are the main active species in the degradation system. Meanwhile, the EPR spectra of DMPO-
•O$_2^-$ in the CdS, Ti$_3$C$_2$/g-C$_3$N$_4$NS and CTN-4:1 degradation systems were determined under vis irradiation. As shown in Fig. 9B, the six characteristic peaks corresponding to DMPO–•O$_2^-$ are detected in the CTN-4:1 degradation system. The generation efficiency of •O$_2^-$ in the CTN-4:1 system is slightly higher than those of CdS and Ti$_3$C$_2$/g-C$_3$N$_4$NS. On the other hand, the characteristic signal peaks of DMPO–•OH signals can also be observed for the CTN-4:1 system (Fig.S9). Under vis irradiation, CTN-4:1 degradation system can promote the production of active species and effectively degrade orange II.

As shown in Fig. S10A, compared with CdS/g-C$_3$N$_4$NS sample, CTN-4:1 catalysis has higher photocatalytic activity for degradation of orange II under the same conditions. The trapping experiments for the CdS/g-C$_3$N$_4$NS system show that both •O$_2^-$ and h$^+$ are the major active species during the degradation process (Fig.S10B). As presented in Fig. S10C, the generation efficiency of •O$_2^-$ in the CdS/g-C$_3$N$_4$NS system is lower than that of CTN-4:1. From Fig.S9 we can see that the •OH radicals are basically not produced for the CdS/g-C$_3$N$_4$NS degradation system. The formation of CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS Z-scheme heterojunction composites using Ti$_3$C$_2$ as a charge transport bridge, can improve the redox capacity of photocatalysis and promote the production of the active species.

Figure S11 shows the Mott-Schottky plots of the g-C$_3$N$_4$NS, Ti$_3$C$_2$, and CdS. The slopes of the lines are all positive, implying that the samples belong to n-type semiconductor. The flat potential (E$_fb$) of g-C$_3$N$_4$NS, Ti$_3$C$_2$, and CdS are estimated to be -1.11, -0.22, and -0.47 V vs.Ag/AgCl (0.22 V vs. NHE), respectively. Normally, conduction band (E$_{CB}$) of an n-type semiconductor was about 0.1eV more negative than its E$_fb$(Sun et al. 2014; Ma et al. 2018). Thus, the E$_{CB}$ values of g-C$_3$N$_4$NS, Ti$_3$C$_2$, and CdS are estimated to be about -0.99, -0.10, -0.35 V vs.NHE, respectively. According to the band-gap energies of samples, the valence band (E$_{VB}$) values of g-C$_3$N$_4$NS, Ti$_3$C$_2$, and CdS are calculated to be 1.78, 0.40, 1.92 V vs.NHE, respectively.

According to the above analysis, the plausible photocatalytic degradation mechanism of the CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS catalyst is depicted in Scheme 1. Under vis irradiation, e−−h$^+$ pairs can be generated on the CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS Z-scheme composite. The E$_{CB}$ of CdS (-0.35 V vs. NHE) is more negative than that of Ti$_3$C$_2$ (-0.10 V vs. NHE), and the photoinduced electrons in CdS can be transferred to Ti$_3$C$_2$. The E$_{VB}$ of g-C$_3$N$_4$NS (1.78V vs. NHE) is higher than that of Ti$_3$C$_2$ (0.40 V vs. NHE). The photogenerated holes in g-C$_3$N$_4$NS can migrate to the Ti$_3$C$_2$. As a result, the photogenerated carriers can be effectively separated by the Z-scheme heterostructure. Meanwhile, the E$_{CB}$ of g-C$_3$N$_4$NS (-0.99 V vs. NHE) is more negative than the potential of superoxide radicals (-0.046 V) (Kandi et al. 2017), and the dissolved O$_2$ can combine with the electrons in the E$_{CB}$ of g-C$_3$N$_4$NS to produce •O$_2^-$ in the photodegradation process. In acidic degradation system, some of •O$_2^-$ radicals may also combine with H$^+$ to produce •OH (Cai et al. 2018). At the same time, the holes are accumulated in the E$_{VB}$ of CdS. The CdS/Ti$_3$C$_2$/ g-C$_3$N$_4$NS degradation system can produce additional active species, resulting in high catalytic degradation efficiency of orange II under vis irradiation.
Conclusions

In this work, a novel CdS/Ti$_3$C$_2$/g-C$_3$N$_4$NS Z-scheme composites with enhanced vis photocatalytic activity were prepared. In contrast to g-C$_3$N$_4$, obtained g-C$_3$N$_4$NS sample showed improved adsorption and photocatalytic degradation performances. It is found that the CdS/Ti$_3$C$_2$/ g-C$_3$N$_4$NS Z-scheme heterojunction composites formed by using Ti$_3$C$_2$ as a charge transport bridge could improve the vis absorption, enhance the separation ability of the photoexcited carriers, and improve the redox capacity of the composite and promote the production of active species ($\cdot$O$_2^-$, h$^+$, and $\cdot$OH), thus enhancing the photocatalytic degradation efficiency of orange II. Among them, the CTN-4:1 sample exhibited the highest vis photocatalytic activity. This study would provide useful insights into utilizing Ti$_3$C$_2$ as the electron mediator in Z-scheme photocatalysis.

Declarations

Authors’ contributions Ranran Zhang: Data curation, Writing-Original draft preparation. Jiaying Jin: Investigation, Writing-Reviewing and Editing. Lumeng Jia: Writing-Reviewing and Editing. Bo Shi: Software, Validation, Project administration, Resources, Supervision. Rufen Chen: ConceptualizationIdeas, Methodology, Formulation of overarching research goals and aims. Investigation, Project administration, Resources, Supervision, Writing-review & editing.

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Consent for publication Not applicable.

Competing interests The authors declare no competing interests

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**Figures**

![XRD patterns of samples](image)

**Figure 1**

XRD patterns of samples (a: Ti3C2, b: Ti3C2/g-C3N4NS, c: CTN-2:1, d: CTN-3:1, e: CTN-4:1, and f: CTN-5:1)
Figure 2

Raman spectra of samples (a: Ti$_3$C$_2$, b: CdS, c: g-C$_3$N$_4$, and d: CTN-4:1).
Figure 3

SEM images of samples (a: Ti3C2, b: Ti3C2/g-C3N4NS, c: CTC-2:1, d: CTC-3:1, e: CTC-4:1, and f: CTC-5:1)
Figure 4

HRTEM image of CTN-4:1
Figure 5

XPS spectra of the CTN-4:1 composite (A: Ti2p, B: C1s); S2p (C) and Cd3d (D) spectra of CTN-4:1 and CdS
Figure 6

(A) Degradation curves of orange II in the different catalyst systems and (B) the corresponding first-order plots. (C) The UV–vis spectra change of orange II solution in the CTN-4:1 system.
Figure 7

(A) UV–vis absorption spectra, (B) band-gap energy of the samples (a: Ti3C2, b: CdS, c: Ti3C2 / g-C3N4NS, d: CTN-2:1, e: CTN-3:1, f: CTN-4:1, and g: CTN-5:1)
Figure 8

(A) PL spectra, (B) transient photocurrent responses and (C) EIS spectra of the samples
Figure 9

(A) Reactive species trapping experiments for the CTN-4:1 degradation system. (B) ESR spectra of DMPO-•O2− in different systems.

Supplementary Files

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