

Facile one-pot preparation of cadmium sulfide quantum dots with good photocatalytic activities under stabilization of polar amino acids

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ABSTRACT

In the present study, through a facile one-pot strategy, the stable cadmium sulfide (CdS) quantum dots were prepared successfully using two different polar amino acids including aspartate and glutamate as additives. The as-prepared CdS quantum dots exhibited unique absorption and photoluminescence properties in visible light region. From the results, the CdS quantum dots could photocatalytically

source ($\lambda=1.5406 \text{ \AA}$). The UV-visible absorption and photoluminescence (PL) spectra were recorded on Lambda-17 UV-vis and Cary Eclipse fluorescence spectrophotometers, respectively.

For the photocatalytic activity evaluation, 24 mL of CdS aqueous suspension (1.25 mg/mL) was mixed with 6 mL of rhodamine B (RhB) aqueous solution (250 ppm). The system was stirred in dark for 1 h to establish adsorption/desorption equilibrium. Then the system was exposed to 500 W xenon lamp for photocatalysis reaction under moderate stirring. At regular intervals, the suspension was taken from the vessel and centrifuged. The content of RhB in the supernatant was determined by UV-vis spectroscopy at 554 nm. For comparison, the photocatalytic activities of the bulk CdS and the commercially available TiO_2 (Degussa P25) were also determined.

The formation of $\cdot\text{OH}$ on the photo-irradiated CdS QDs' surface was detected by fluorimetric assay using terephthalic acid (TPA) as a fluorescent probe under photocatalytic conditions except the replacement of RhB with TPA [2,12,13]. The photo-irradiated suspension was taken from the vessel and centrifuged. Then the supernatant was excited by 315 nm irradiation and the photoluminescent intensity at 425 nm was detected.

In order to further confirm the $\cdot\text{OH}$ mediation effect on the photocatalytic degradation of RhB, additional Vitamin C aqueous solution was introduced into the photocatalytic reaction suspension to perform the photocatalytic degradation of RhB under the photocatalytic conditions.

3. Results and discussion

Fig. 1a shows the XRD patterns of the CdS QDs. From the figure, the Asp-CdS and Glu-CdS exhibit similar XRD patterns. The three peaks at 26.77° , 44.06° and 52.13° are assigned to (111), (220) and (311) planes of the cubic CdS phase (JCPDF 75-0581), respectively. The broadness of the diffraction peaks can be attributed to the small sizes of the QDs. Fig. 1b and c presents the TEM images of the CdS QDs. From the figure, both the Asp-CdS and Glu-CdS exhibit the spherical morphology. From Fig. 1d and e, the QDs exhibit narrow particle size distributions. The mean diameter of the Asp-CdS is 5.25 nm, slightly smaller than that of the Glu-CdS (5.54 nm).

The optical properties of the CdS QDs including the UV-visible absorption and PL spectra were determined and the results are shown in Fig. 2a and b. From Fig. 2a, the CdS QDs exhibit the very broad absorption bands from 200 to 550 nm, indicating the relatively strong photo absorption properties. In addition, from the PL spectra of the AAs-QDs shown in Fig. 2b, the CdS QDs exhibit strong green emission near 528 nm when excited by 202 nm irradiation, which can be attributed to the recombination of the charge carriers within the surface states [14].

On account of the good photo absorption properties, the photocatalytic activities of the CdS QDs on the degradation of RhB under visible light irradiation were evaluated. From the results (Fig. 3a), after exposed to visible light for 110 min, the photodegradation efficiencies of the Asp-CdS and Glu-CdS on RhB are 98.98% and 99.04%, respectively, much high than those of the bulk CdS (15.68%) and the commercial P25 (3.11%), also better than our previous results [10,11]. Furthermore, the recycling properties of the CdS QDs for the photocatalytic reaction were evaluated. From the results (Fig. 3b and c), the photocatalytic activities of the AAs-QDs do not show apparent loss after five cycles of the photocatalytic reaction, revealing their excellent recycling stability. These suggest that the CdS QDs can be reused for many times to degrade the organic pollutants under visible light irradiation, exhibiting the important potentials for practical and long-term applications.

From previous studies, the active oxygen species such as $\cdot\text{OH}$ played critical roles in the photocatalytic degradation of organic

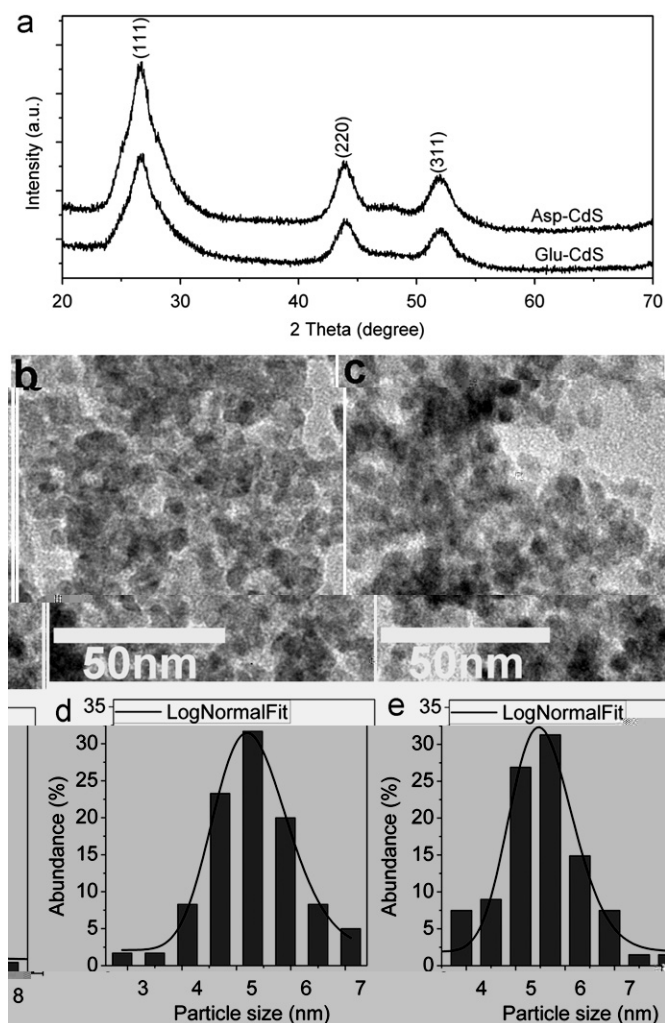
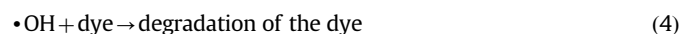
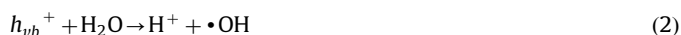


Fig. 1. (a) XRD patterns of the CdS QDs. (b) TEM images of the Asp-CdS and (c) Glu-CdS QDs. (d) Particle size distributions of the Asp-CdS and (e) Glu-CdS QDs.

pollutants [10,11]. Therefore, using TPA as fluorescent probe, the photo-generated $\cdot\text{OH}$ formed on the photo-illuminated QDs' surface was measured to evaluate the degradation mechanism of RhB. From Fig. 3d, with the prolongation of the irradiation time, the PL intensities increase gradually, indicating the consecutive formation of $\cdot\text{OH}$ during the irradiation. Based on the results, the photocatalytic degradation mechanism of RhB is proposed. Firstly, the photons with the energy higher than that of the QDs' band gap are absorbed onto the QDs' surface. This results in the excitation of the electrons from valence band (ν) to conduction band (σ), which can produce the holes (\cdot^+) at the valence band edge and the electrons (\cdot^-) in the conduction band of the QDs (Eq. (1)). Subsequently, \cdot^+ and \cdot^- can react with water or hydroxyl groups and generate the highly reactive $\cdot\text{OH}$ (Eqs. (2) and (3)). Finally, $\cdot\text{OH}$ can react with RhB molecules adsorbed on the QDs' surface to exert the degradation reaction (Eq. (4)).



Additionally, this photodegradation mechanism was further confirmed with the aid of Vitamin C, an important $\cdot\text{OH}$ scavenger.

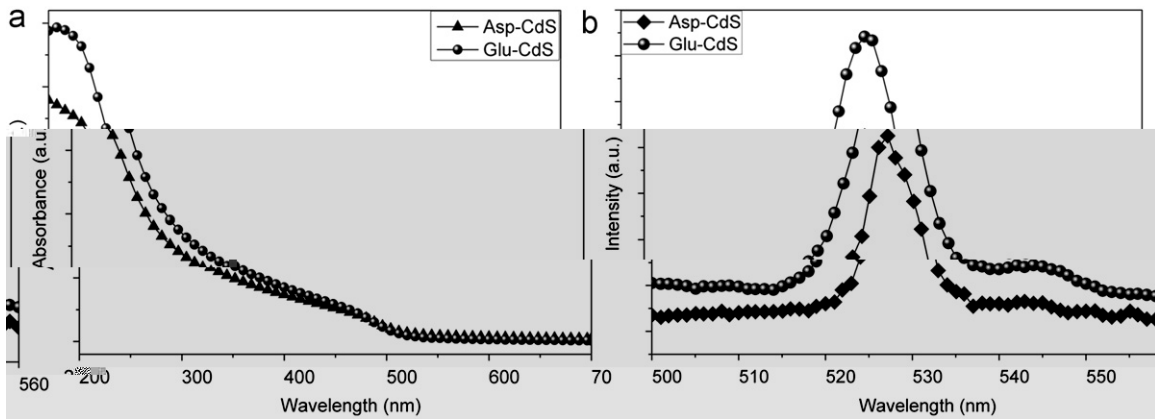


Fig. 2. (a) UV-vis and (b) PL spectra of the CdS QDs.



Fig. 3. (a) Photocatalytic degradation of RhB in the presence of the CdS QDs. (b) The recycling of the Asp-CdS and (c) Glu-CdS on the photocatalytic degradation of RhB. (d) The PL intensities at 426 nm against irradiation time for TPA on the CdS QDs. Inset: the photodegradation of RhB in the presence of Glu-QDs and Glu-QDs+Vitamin C.

From the result shown in the inset of Fig. 3d, the photocatalytic degradation of RhB in the presence of the mixture of Vitamin C and Glu-QDs decreases significantly, which can be attributed to the scavenging of photo-generated $\cdot\text{OH}$ by Vitamin C. This further confirms that the photocatalytic degradation of RhB by the QDs is really mediated by the photo-generated $\cdot\text{OH}$.

4. Conclusions

In summary, the stable CdS QDs were successfully prepared using polar AAs Asp and Glu as additives. Through the mediation of photo-generated $\cdot\text{OH}$, the CdS QDs exhibited strong photocatalytic activities and good recycling stability to degrade the organic dyes under visible light irradiation, suggesting the potential application in the efficient treatment of the organic pollutants under visible light irradiation.

Acknowledgments

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