Supporting information

A facile synthesis of MoS_2/soluble g-C_3N_4 /CdS ternary composite for high efficiency photocatalytic hydrogen production

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1. XRD patterns of series of Lg-C_3N_4/CdS samples treated by different time

XRD patterns of series of Lg-C_3N_4/CdS samples treated by different time were determined and demonstrated in Fig. S1.

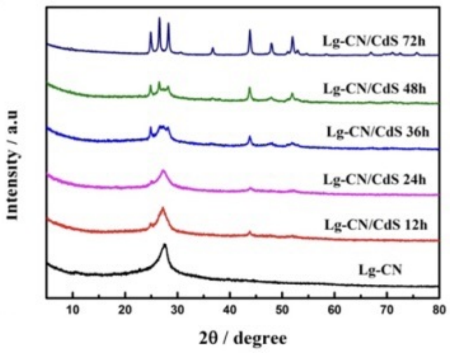

Fig. S1 XRD patterns of series of Lg-C_3N_4/CdS samples treated by different time

The XRD patterns of the series of Lg-C_3N_4/CdS samples treated for different times reveal important information about the formation and changes in the crystalline phases of CdS and soluble g-C_3N_4. In Fig. S1, the diffraction peaks of CdS become stronger and more prominent with increasing treatment time. This indicates the progressive crystallization and growth of CdS nanoparticles during the hydrothermal process. The enhanced intensity of the CdS peaks suggests an increase in the crystallinity and particle size of CdS, which can be attributed to the prolonged reaction time. On the other hand, the diffraction peaks corresponding to Lg-C_3N_4 become weaker as the treatment time extends, which suggests a decrease in the crystallinity or concentration of Lg-C_3N_4 in the composite structure. The weakening diffraction peaks indicate possible structural changes or degradation of Lg-C_3N_4 during the hydrothermal process. The gradual formation of both CdS and soluble g-C_3N_4 during the hydrothermal process is confirmed by the changing intensities of their respective diffraction peaks. The increasing intensity of CdS peaks and decreasing intensity of Lg-C_3N_4 peaks indicate the simultaneous synthesis and transformation of these components within the composite.

2. TEM, HRTEM images and XRD patterns of NaCl-treated and untreated MoS_2

TEM, HRTEM images and XRD patterns of NaCl-treated and untreated MoS_2 were determined and compared with each other (Fig. S2)

The TEM and HRTEM results are shown in Fig. S2. In Fig. S2, the nanosheets of NaCl-treated MoS_2 are observed to be smaller and thinner compared to untreated MoS_2, which suggests that the presence of NaCl during the synthesis process inhibits the growth of MoS_2 grains and restricts the layer thickness. The smaller and thinner nanosheets have a higher surface area-to-volume ratio, which promotes the exposure of more active sites, including the highly catalytically active edge sites. The HRTEM analysis provides a more detailed view of the crystal structure. The high-resolution images reveal the lattice arrangement of MoS_2. In NaCl-treated MoS_2, the presence of physical barriers restricts the growth of MoS_2 layers, resulting in fewer stacked layers and a higher prevalence of exposed edges. This leads to the formation of more edge active sites, which are known to exhibit enhanced catalytic activity for the hydrogen evolution reaction. All this will result in an enhanced hydrogen evolution activity.

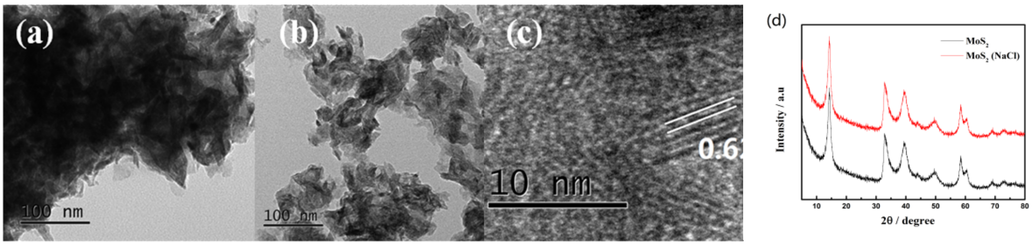

Fig. S2 TEM, HRTEM images and XRD pattern (d) of pure MoS_2 (b-c) and MoS_2 treated with NaCl (d-e)

3. XPS spectra of 9%MoS_2/20% soluble g-C_3N_4/CdS

XPS spectra of the 9% MoS_2/20% soluble g-C_3N_4/CdS ternary composite and after four consecutive hydrogen production cycles were determined and the results were listed in Fig. S3.

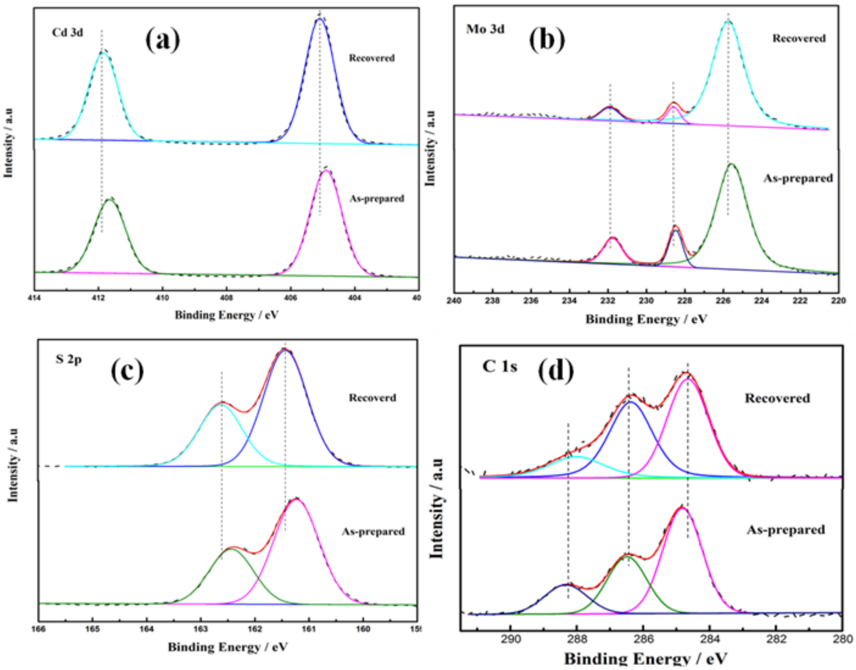

Fig. S3 High resolution XPS spectra of (a) Cd, (b) Mo, (c) S, and (d) C for 9% MoS_2/20% soluble g-C_3N_4/CdS as-prepared and recovered after the cycling experiment

As shown in Fig. S3, the observed slight shifts to higher binding energies in the peaks of Cd 3d, Mo 3d, and S 2p after four cycles of hydrogen production reaction, which indicate potential changes in the electronic properties and chemical states of the elements in the ternary composite catalyst. Specifically, the slight increase in binding energy for the Cd 3d peaks suggests that cadmium (Cd) remain in the form of Cd^{2+} ions throughout the photocatalytic hydrogen production process. Before the photocatalytic hydrogen production, the binding energy values of Cd $3d_{5/2}$ and Cd $3d_{3/2}$ were 404.9 eV and 411.7 eV, respectively. After four rounds of photocatalytic hydrogenevolution experiments, the binding energy values only increased 0.2 eV. This small shift suggests that the electronic environment surrounding the Cd ions remains relatively stable, indicating that Cd is primarily present as Cd^{2+} ions.

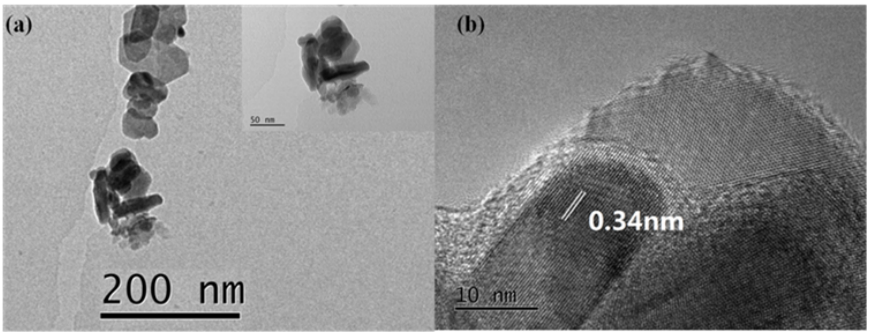

Fig. S4 TEM and HRTEM images of 9% MoS_2/20% soluble g-C_3N_4/CdS after the 4-cycle test

In the photocatalytic experiment, Cd is prone to light corrosion. Therefore, the TEM and HRTEM of 9% MoS_2/20% soluble g-C_3N_4/CdS ternary composite and after four consecutive hydrogen production cycles were determined and compared, the result are shown in Fig. S4. The results depicted in Fig. S4, showing that the particle size, exposed crystal plane, and shape of the target ternary composite catalyst sample remained relatively unchanged after four rounds of photocatalytic hydrogen production experiments, indicate that the ternary photocatalyst possesses good stability during the photocatalytic reaction. This stability is crucial for ensuring consistent catalytic performance and long-term durability.