Effect of Ti Species Dosage on the Photocatalytic Performance of $HNbMoO_6$

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Abstract: A series of Ti species pillared $HNbMoO_6$ composites with different Ti/Mo ratios were prepared via an intercalation–pillaring route. The results showed that the effects of Ti species dosage on its disperse state, the interaction model, spectral response characteristic and photocatalytic performance were significant. When the Ti/Mo ratio was less than 1, Ti species were uniformly dispersed on the interlayer of $HNbMoO_6$, and presented the obvious interaction with the host laminates. The narrower band gap and more excellent photocatalytic performance of T1-$HNbMoO_6$ were derived from the obvious synergistic effect between the host and the guest.

Keywords: Interaction, Synergistic effect, Photocatalytic degradation.

1. Introduction

With the rapid development of science and technology, the requirements for materials are more and more rigorous. The materials constructed by only one component can hardly meet human demands. In recent years, the composite materials become a current topic in the materials science because they colligate the advantages of each component during in the design process.

As one of the component, the layered transition metal composite oxides offer huge potential application in the field of building composite photocatalytic materials due to the diversity of the composition, structure and so on. Among them, the layered Nb-based composite oxide, such as layered titanoniobate, niobium tungstate and niobium molybdate [1-3], can be employed to build the functional composite materials by intercalation, pillaring, exfoliation or assembling, and they all present many outstanding advantages in the photocatalytic field.

In the present study, $HNbMoO_6$ is acted as the host materials to build the novel composite materials with the Ti species. The as-prepared samples were characterized by means of XRD, SEM, EDS, Raman and UV-vis DRS. Their photocatalytic performances are evaluated through methylene blue (MB) degradation reaction. The Ti species dispersion state, the interaction between Ti species and $HNbMoO_6$, and the photocatalytic performances were investigated with the different Ti/Mo ratios. The interaction model and the synergistic effect model between the host $HNbMoO_6$ and the guest Ti species were proposed.

2. Experimental (or Theoretical)

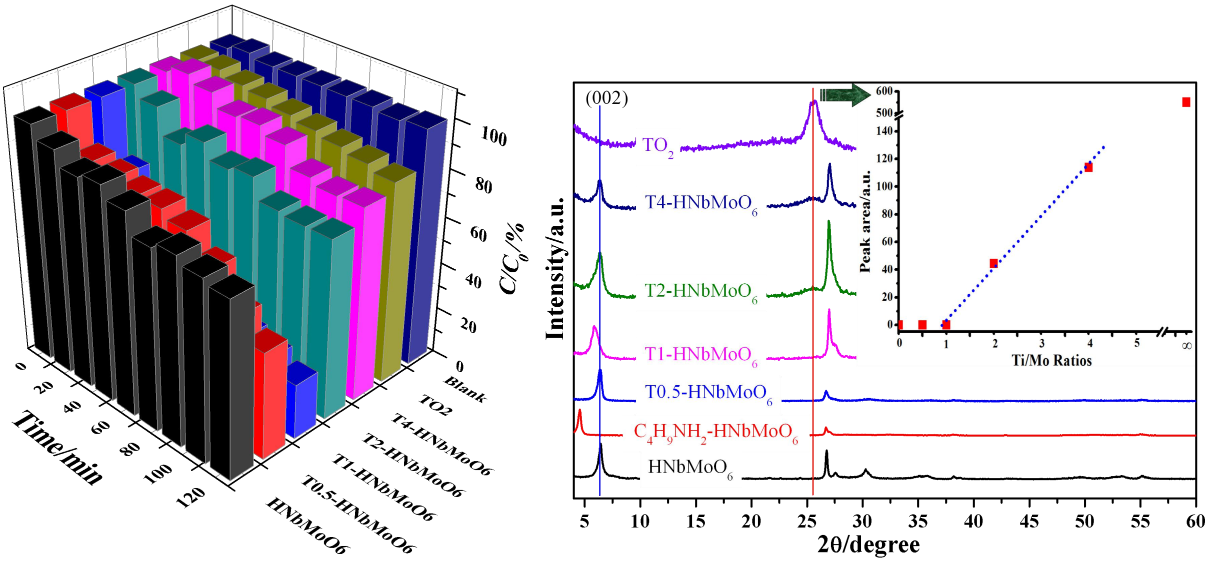
Ti species pillared $HNbMoO_6$ with the different Ti/Mo ratios (0.5, 1, 2 and 4) were prepared by inserting Ti species into $C_4H_9NH_2$-$HNbMoO_6$ which was obtained by stirring $HNbMoO_6$ (4 g) in 200 ml of 20 vol.% n-$C_4H_9NH_2$/n-heptane mixed solution under reflux at 323 K for 72 h. After calcination at 573 K for 3 h, the products were designated as T0.5-$HNbMoO_6$, T1-$HNbMoO_6$, T2-$HNbMoO_6$ and T4-$HNbMoO_6$, respectively.

The photocatalytic activities of the as-prepared photocatalysts were evaluated by the photodegradation of methylene blue (MB) solution in a cylindrical quartz vessel under simulated sunlight at ambient temperature.

3. Results and discussion

The photocatalytic performances of the investigated samples under the simulated sunlight are showed in Fig. 1. As showed in Fig. 1, the order of photocatalytic performance under the simulated sunlight are T1-$HNbMoO_6$ > T0.5-$HNbMoO_6$ > $HNbMoO_6$ > T2-$HNbMoO_6$ > T4-$HNbMoO_6$ > TiO_2 > blank. Among them, T1-$HNbMoO_6$ composite exhibits a highest photocatalytic performance and 76.5% for MB is degraded after 120 min irradiation. However, only 54.6% of MB is degraded over T0.5-$HNbMoO_6$, and 10%-30% is degraded over $HNbMoO_6$, T2-$HNbMoO_6$, T4-$HNbMoO_6$ and TiO_2 under the same conditions. Why too much and too little Ti species on the surface of $HNbMoO_6$ are bad for the photocatalytic degradation of MB is an issue deserved to study.

In order to investigate clearly why Ti species dosage has a great influence on the photocatalytic performance of $HNbMoO_6$. The crystal structure, skeleton structure, surface structure and the spectral response characteristics of the as-prepared function materials were investigated.



Photocatalytic degradation curves of MB over the as-prepared samples (Fig. 1) and their XRD patterns (Fig. 2).

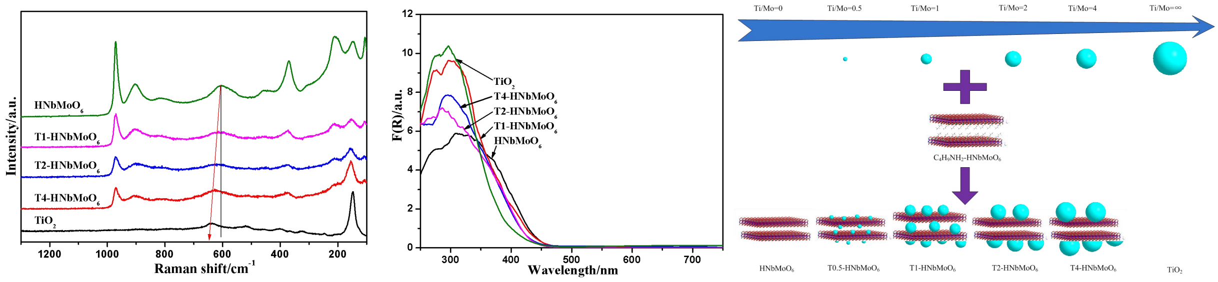


Fig. 3-5. LRS and UV-vis DRS of as-prepared samples and Structure and preparation diagram of T-HNbMoO6

Specific surface area of catalyst is one of the important factors to affect its adsorption and catalytic performance. In this study, the specific surface area of T1-$HNbMoO_6$ is 92.85 m^2/g, it is larger than T2-$HNbMoO_6$ and T4-$HNbMoO_6$, and it is 4 times than that of the host material. The larger specific surface area can provide more active adsorption sites and catalytic sites. Therefore, T1-$HNbMoO_6$ shows the best photocatalytic performance with the larger specific surface area in this study.

For the photocatalytic reaction, the bandgap engineering such as the band-gap energy and the band potential of conduction band and valence band play a decisive role. In this study, the band gap of T1-$HNbMoO_6$ is 2.78 eV and it is narrower than $HNbMoO_6$, T2-$HNbMoO_6$, T4-$HNbMoO_6$, and TiO_2. Therefore, T1-$HNbMoO_6$ shows the best photocatalytic performance with the narrower band gap in this study.

From the above, T1-$HNbMoO_6$ shows the best photocatalytic performance because its appropriate crystal structure, the larger specific surface area and the narrower band gap.

4. Conclusions

By an intercalation–pillaring route, a series of T-$HNbMoO_6$ composite materials were prepared successfully. The Ti species can be dispersed in the interlayer of $HNbMoO_6$ uniformly when the Ti/Mo ratio is less then 1. The interaction between the $HNbMoO_6$ and the dispersed Ti species is obvious in T-$HNbMoO_6$. The effects of Ti/Mo ratios on the dispersed state, interaction model and photocatalytic performance were meaningful. The photocatalytic performance for MB over T1-$HNbMoO_6$ is the most excellent due to the moderate crystal structure, the larger specific surface area and the narrower band gap.

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