A highly recoverable photocatalyst synthesized via a biomimetic approach

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Abstract: In this study, a highly recoverable TiO_2/carbon-clay photocatalyst was prepared by immobilizing TiO_2 on strong adsorbent (clay) via a bio-mimetic coating strategy and followed by a carbonization process. Superior separability of TiO_2/carbon-clay was achieved by simple gravity sedimentation. The obtained TiO_2/carbon-clay composites possessed a maximum adsorption capacity of 95.4 mg/g and showed improved photocatalytic activity than pure TiO_2. This TiO_2/carbon-clay composites also exhibited excellent durability and no apparent reduction of photocatalytic activity was observed after 5 cycles reuse.

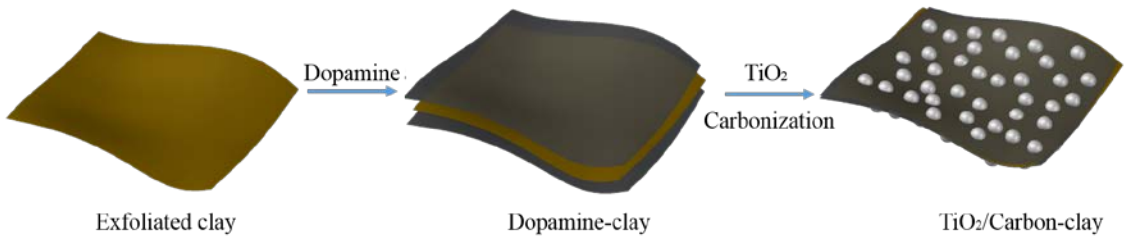
Keywords: biomimetic coating, highly recoverable, clay.

1. Introduction

Among the diverse techniques for removing coloured compounds from water, physical adsorption is widely used because of its simplicity of operation.[1] Natural clay, as a typical physical adsorbent, has been widely used for its high adsorption capacity. It is reported that the adsorption property of clay could exceed that of activated carbon under the same conditions.[2-3] However, all the adsorbents suffered from the limitation of reuse owing to their non-destructive nature. The technology of physical adsorption produces large amounts of sludge that has to be further regenerated or disposed of as a prescribed waste. Therefore, the regeneration of the used adsorbents is a critical step to achieve a cost-effective use of adsorbents for large-scale coloured compounds removal from environmental aqueous system.[4] In this study, for the first time, a simple biomimetic strategy was used to immobilize TiO_2 on exfoliated clay nanosheets to construct TiO_2/carbon-clay. The obtained TiO_2/carbon-clay showed good photocatalytic ability, excellent durability, strong absorbent capacity and highly recoverable performance against removing dye from water.

2. Experimental

Scheme 1 shows the preparation steps of TiO_2/carbon-clay (TiO_2/C-clay). Pristine clay (Na-montmorillonite) was exfoliated into nanosheets. Then a natural "super glue", polydopamine, was used to adhere TiO_2 onto the clay nanosheet to get TiO_2/dopamine-clay. The obtained TiO_2/dopamine-clay was calcinated at 600 °C to convert polydopamine into carbon to obtain the TiO_2/C-clay.



Scheme 1. Schematic description of preparation steps and structure of TiO_2/carbon-clay.

3. Results and discussion

Figure 1A shows that TiO_2 nanoparticles are successfully immobilized on the surface of clay nanosheets. Almost no free TiO_2 outside of the nanosheets was observed by TEM. TiO_2 nanoparticles appeared to exhibit strong interactions with the underlying clay nanosheets since sonication did not result in their dissociation. Figure 1B shows the X-ray diffraction pattern of the synthesized clay, TiO_2 and TiO_2/C-clay. TiO_2/C-clay has very similar XRD pattern with pure TiO_2. Both anatase and rutile peaks are observed in the composites with no diffraction peaks from clay, which proves clay remained as exfoliated nanosheets after the TiO_2 loading and carbonization process.

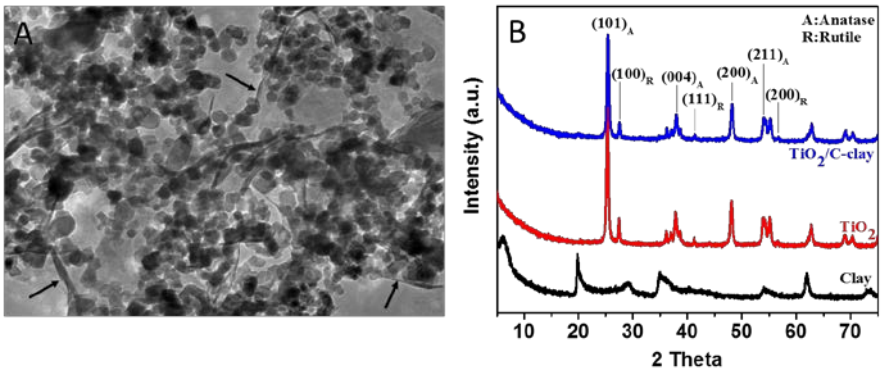


Figure 1. TEM images of TiO_2/C-clay composites (A) XRD of colloidal clay aggregates, TiO_2, and TiO_2/C-clay (B).

Figure 2A shows the relative change of the absorption peak intensity as a function of irradiation time, where C_0 and C is the initial and actual concentration of dye at different reaction times, respectively. It can be seen that the decrease of dye concentration was faster with the presence of TiO_2/C-clay than TiO_2. One of the reasons is that dye was adsorbed by TiO_2/C-clay more than by TiO_2 even before light-induced degradation. It's well known that easy recovery is important for photocatalysts usage in practice. It has been a great challenges to recovering photocatalyst from aqueous systems after usage. TiO_2/C-clay showed superior separability from water by simple gravitational settling. The optical images of TiO_2 and TiO_2/C-clay suspensions in water were taken at different sedimentation times as shown in Figure 2B and C. The concentrations of TiO_2/C-clay and TiO_2 were fixed at 1 mg/mL. TiO_2 nanoparticles dispersed well in water and settled very slowly. The supernatant was still turbid after 4 days of sedimentation and needed more than 1 week to become clear (Figure 2B). This is compared with fast settling behavior of TiO_2/C-clay composite. Most of the TiO_2/C-clay composites settled in 5 min and it became clear after 2 h (Figure 2C).

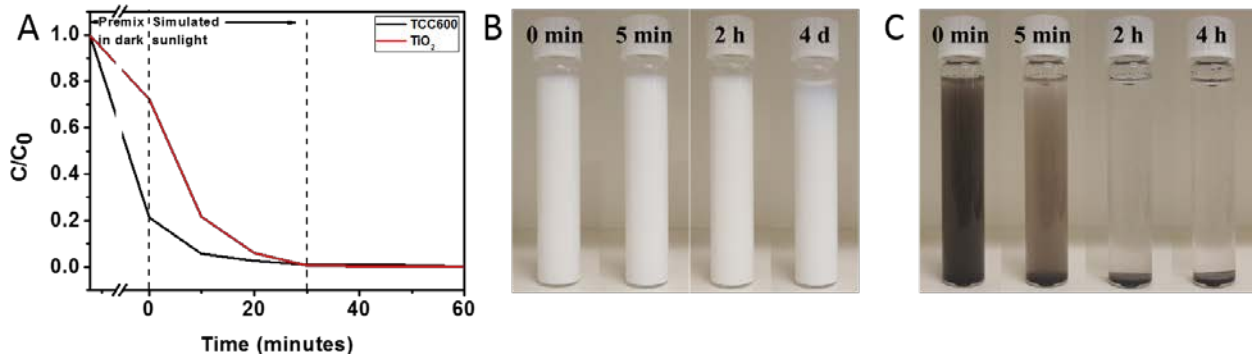


Figure 2. The photocatalytic performance of TiO_2/C-clay and TiO_2 against dye RhB (A), Photographs of the sedimentation of TiO_2 (B), and TiO_2/C-clay (C) in water with different settling times up to 4 days

4. Conclusions

An easily recycling photocatalysts was prepared by applying mussel-inspired coating strategy to immobilize TiO_2 on the surface of clay nanosheets. Compared with TiO_2, TiO_2/C-clay showed superior separability from water by simple gravitational settling. It also showed increased photocatalytic activity compared to TiO_2, robust reusability and excellent adsorptive ability against dye RhB. This work provides a simple, low-cost, scalable method for preparing TiO_2-clay composite, which open the possibilities for applying TiO_2 as an easy separation photocatalyst in real world environmental remediation.

References

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