Synthesis of flower-like α -Fe₂O₃ and its application in wastewater treatment*

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Abstract: The removal of arsenic from aqueous solution is crucial to human health and environmental pollution. Herein, flower-like α -Fe₂O₃ nanostructures were synthesized via a template-free microwave-assisted solvothermal technique, and were applied as adsorbents for the removal of arsenic (As(V)) from aqueous solutions. The results indicated that the synthesized flower-like α -Fe₂O₃ showed excellent sorption properties and had a maximum sorption capacity of 47.64 mg/g for As(V). Meanwhile, the experimental results of photodegradation of methylene blue (MB) indicated that the as-synthesized flower-like α -Fe₂O₃ exhibited very high photocatalytic performance for the photodegradation of MB and that the as-obtained flower-like α -Fe₂O₃ nanostructures were suitable materials in wastewater treatment.

Key words: Flower-like α -Fe₂O₃, Arsenate, Sorption, Methylene blue (MB), Photodegradation

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1 Introduction

Environmental pollution of soils and water is a worldwide problem. Common pollutants include organic compounds, such as different kinds of dyes, and heavy metal ions. Dyes are widely used as coloring agents in cosmetics, food, leather, textile, printing, and plastics. Because of their resistance to elimination and degradation, the dyes can remain in aqueous solution for a long time, and dyes and their metabolic byproducts will be mutagenic and cancer-

ogenic (Jović-Jovičić *et al.*, 2010; Koswojo *et al.*, 2010; Li *et al.*, 2011; Zhang *et al.*, 2013a; 2014). Many techniques such as membrane filtration, biological treatments, sorption, coagulation, flocculation, and advanced oxidation, are used for the treatment of dye-polluted wastewater (Barron-Zambrano *et al.*, 2010; Zermane *et al.*, 2010; Zhang *et al.*, 2013b). Heavy metal ions, such as arsenate ions, are very carcinogenic, harmful, and toxic to human beings (Wu *et al.*, 2013). Arsenic contaminated waters are dangerous to human health because of arsenic's presence in drinking water or food through uptake by plants (Xu *et al.*, 2013). Many people are at risk and tens of thousands suffer from diseases, such as lung and liver cancer, neuropathy, and skin diseases, because they drink water with a high concentration of arsenic (Mohan and Pittman, 2007; Violante *et al.*, 2009). From this, one can see that the elimination of

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arsenic from water is significant for human health and environmental protection.

Fabricating suitable nanomaterials with high surface area is a smart method to eliminate pollutants from aqueous solutions because nanomaterials with high specific surface area can adsorb pollutants, by providing more available sites for binding them and thereby improving sorption/degradation. Micro/nano structured materials, constructed by regularly integrating nanoparticles to microscale materials, have superior ability to remove pollutants compared with nanosized and micro-sized materials alone. Generally, micro/nano structured materials have the advantages of high activity, large specific surface area, low tendency to agglomerate, and good ease of recovery. Hematite (α -Fe₂O₃) nanosized materials with different kinds of structures have been synthesized, such as single-crystal nanorings, single-crystal nanorods, and symmetrical dendritic structures. Among these materials, the flower-like α -Fe₂O₃ composed of hierarchically nanosized building blocks is one of the best because of its high specific surface areas (Yang *et al.*, 2006; Hu *et al.*, 2007a; Jia *et al.*, 2008; Li *et al.*, 2009; Zhong and Cao, 2010; Sivula *et al.*, 2010; Sun *et al.*, 2010; Wang *et al.*, 2011; Zhang *et al.*, 2013c).

We developed a surfactant-free solvothermal method to synthesize flower-like α -Fe₂O₃ composed of 1D hierarchical mesoporous nanoplates. Its specific surface area is about 80 m²/g, which is higher than those of most hierarchical structures. The advantage of the synthesized material was evidenced from the sorption of arsenate on the as-synthesized sample. As a common material, the hematite material is widely used in the fields of photocatalysis, lithium ion batteries, and sorption (Hu *et al.*, 2007b; Das *et al.*, 2009; Kim *et al.*, 2010). In this study, some controlled experiments on photocatalytic reduction of methylene blue (MB) using the flower-like α -Fe₂O₃ as catalyst were also investigated. The experimental results showed possible applications of the as-synthesized material in sorption fields and electron transfer channels as catalyst in real applications.

2 Experiments

2.1 Preparation of α -Fe₂O₃

All the reagents, including ferric chloride (FeCl₃·6H₂O), urea, and glycol, were purchased from

Tianjin Damao Chemical Reagent Co. Ltd., China and used without any further purification. In a typical step, 7.5 mmol of urea and 5 mmol of FeCl₃·6H₂O were dissolved in 100 ml of glycol, then 40 ml of mixed solution was decanted into a Teflon-lined autoclave. The autoclave was sealed and then placed in a microwave oven which was heated to 160 °C for 8 h under microwave heating. Then the sample was cooled to room temperature, and the precipitated α -Fe₂O₃ was achieved by centrifugation, then washed with ethanol, and finally dried at 60 °C for 6 h in vacuum. The dried powder was heated in a muffle furnace to 500 °C at a heating rate of 5 °C/min and then kept at 500 °C for 10 min. After the muffle furnace was cooled to room temperature, the red α -Fe₂O₃ hierarchical product was obtained.

2.2 Characterizations

The X-ray diffraction (XRD) pattern was measured from a D/Max-rB equipped with a rotation anode using Cu K α radiation ($\lambda=0.15418$ nm). The XRD device was operated at 200 mA and 40 kV. The microstructures and morphology of α -Fe₂O₃ were characterized by transmission electron microscopy (TEM) and field emission-scanning electron microscopy (FE-SEM). The N₂-Barrett-Emmett-Teller (BET) surface area was calculated from N₂ adsorption-desorption isotherms at 77 K with a Micromeritics ASAP 2010 system. X-ray photoelectron spectroscopy (XPS) analysis was conducted in a VG Scientific ESCALAB Mark II spectrometer.

2.3 Experimental process

A batch method was used to measure arsenic (As(V)) sorption. The suspensions of α -Fe₂O₃ and a known volume of As(V) solutions were mixed in polyethylene centrifuge tubes. The pH was revised to the desired values by adding 0.1 or 1.0 mol/L HCl or NaOH. After sorption equilibrium, the solid phase was separated by centrifugation at 10000 r/min for 30 min. The distribution coefficient (K_d) and the sorption percent (%) were calculated from

$$\text{Sorption percent} = \frac{C_0 - C_e}{C_0} \times 100\%, \quad (1)$$

$$K_d = \frac{C_0 - C_e}{C_0} \frac{V}{m}, \quad (2)$$

where m (g) is the mass of solid, V (ml) is the solution volume, C_0 is the initial concentration (mg/L), and C_e is the equilibrium concentration (mg/L).

MB was used as the probe molecule to estimate the photocatalytic activity of α -Fe₂O₃ under UV or visible light irradiation. The visible light photocatalytic experiments were conducted in a glass bottle (100 ml) under ambient conditions using a 125 W mercury lamp as the illuminating source. It was about 5 cm away from one side of the glass bottle, which was surrounded by a circulating water jacket to avoid the temperature increasing. A cutoff filter was used to eliminate radiations beyond 380 nm and below 200 nm. During the experiments, the temperature of the MB solution was maintained at (24±1) °C and the pH was 5.3. 1.0 mg of MB was dispersed in 100 ml water to achieve a 10 mg/L MB aqueous solution. That solution was exposed to the simulated light with continuous magnetic stirring for 240 min with all other lights eliminated. During the irradiation process, 4 ml aliquot was pipetted at a given interval time and filtered to remove the catalysts and the concentration of MB was analyzed on a Shimadzu UV-2550 spectrophotometer. For the durability measurements of flower-like α -Fe₂O₃, five consecutive cycles were carried out. Dark sorption experiments were also carried out to understand the sorption of MB on flower-like α -Fe₂O₃ nanostructures.

3 Results and discussion

3.1 Characterization of flower-like α -Fe₂O₃ nanostructures

The nanostructures and morphologies of the flower-like α -Fe₂O₃ were illuminated by FE-SEM. The lower magnification of FE-SEM image (Fig. 1a) showed the multiple flower-like α -Fe₂O₃ nanostructures, which maintained well-preserved hierarchical nanostructures with diameters of 1–2 μ m. A representative flower-like nanostructure is shown in the magnified FE-SEM image (Fig. 1b), which indicates that the exterior of the flower-like hierarchical nanostructure was composed of multiple randomly assembled irregular-shaped sheets with a thickness of about 30 nm, as well as loose and cross-linked interiors.

More detailed information of flower-like α -Fe₂O₃ nanocrystals was provided by TEM. A repre-

sentative TEM image of the as-obtained material at a low magnification (Fig. 1c) illustrates that the α -Fe₂O₃ consisted of many randomly thin nanosheets. Fig. 1d displays a high-magnification TEM image of a flower-like α -Fe₂O₃ hierarchical nanostructure, indicating that the structures of the flower-like α -Fe₂O₃ were very loose, and the nanosheets were composed of irregular-shaped nanoparticles. Some pale areas between the dark nanoparticles indicate porous nanostructures of the nanosheets. The high resolution TEM (HR-TEM) image of the flower-like α -Fe₂O₃ hierarchical nanostructures (the inset of Fig. 1d) shows the lattice image obtained at the edge of the sample. The (012) d spacing of the α -Fe₂O₃ was found from the typical lattice fringe spacing (0.370 nm), clearly indicating that the nanostructures consisted of single crystalline nanoparticles.

Fig. 2 shows the corresponding powder XRD pattern of flower-like α -Fe₂O₃ nanostructures. The diffraction peaks could be indexed to pure α -Fe₂O₃ (JCPDS No. 80-2377). The intense peaks in the XRD pattern indicate that the flower-like α -Fe₂O₃ nanostructures were well crystallized. Moreover, no impurity peaks were found in the XRD pattern, pointing to the high purity of the α -Fe₂O₃.

The N₂ adsorption-desorption isotherms (Fig. 3) were measured to calculate the specific surface area and pore volume of as-obtained flower-like α -Fe₂O₃ hierarchical structures. The pore size distribution showed that the average pore of the α -Fe₂O₃ was

Fig. 1 SEM images of flower-like α -Fe₂O₃ nanostructures (a) Lower magnification; (b) Higher magnification; (c) TEM image of flower-like α -Fe₂O₃ nanostructures; (d) Higher magnification images of flower-like α -Fe₂O₃ nanostructure (the inset is the corresponding HR-TEM image)

Fig. 2 XRD pattern of flower-like α -Fe₂O₃

Fig. 3 N₂ adsorption-desorption isotherm (a) and pore size distribution (b) of the flower-like α -Fe₂O₃ nanostructures

about 4–50 nm. The BET specific surface area obtained from the N₂ adsorption was 80 m²/g, which was larger than that of the commercial α -Fe₂O₃ structures (17 m²/g) (not given in Fig. 3). The porous framework and large surface area of the flower-like α -Fe₂O₃ hierarchical structure provide a more efficient transport pathway to the interior voids, which is useful for possible applications in real wastewater treatment.

3.2 As(V) sorption

3.2.1 Time-dependent sorption

The sorption of As(V) on flower-like α -Fe₂O₃ nanostructures as a function of contact time was investigated. As shown in Fig. 4a, the sorption of As(V) on α -Fe₂O₃ occurred quickly and 8 h of contact time was enough to achieve equilibrium. The fast As(V) sorption at the beginning of the contact time was attributed to the rapid diffusion of As(V) from the aqueous solution to the external surfaces of α -Fe₂O₃. Then the sorption achieved equilibrium. From the above results, 24 h was chosen in the following sorption experiments.

A pseudo-second-order rate equation was applied to simulate the sorption of As(V) on α -Fe₂O₃ (Li et al., 2011):

$$\frac{t}{q_t} = \frac{1}{2k'q_e^2} + \frac{1}{q_e}t, \quad (3)$$

where q_t (mg/g) is the amount of As(V) adsorbed on α -Fe₂O₃ at time t (h), q_e is the amount of As(V) adsorbed per weight of α -Fe₂O₃ (mg/g) after equilibrium, and k' (g/(mg·h)) is the rate constant of the pseudo-second-order kinetics. The k' (12.86 g/(mg·h)) and q_e (14.47 mg/g) values are calculated from the slope and intercept of the linear plot of t/q_t vs. t (Fig. 4). The correlation coefficient (R^2) of the linear plot is 0.99 (very close to 1), indicating that the kinetic sorption of As(V) on α -Fe₂O₃ is a pseudo-second-order rate model.

3.2.2 Effect of pH

The pH of the As(V) solution is an important factor influencing As(V) sorption. The impact of pH on As(V) sorption by flower-like α -Fe₂O₃ nanostructures at pH 1.0–12.0 is shown in Fig. 4c. As(V) sorption on α -Fe₂O₃ maintains about 94% at pH 1.0–4.4 and then decreases quickly at pH 4.4–8.0. At pH > 8.0, As(V) sorption decreases slightly with increasing pH. The zero point charge (pH_{ZPC}) of α -Fe₂O₃ and the species of As(V) are the main parameters controlling the sorption of As(V) on α -Fe₂O₃. As shown in Fig. 5a, the pH_{ZPC} of α -Fe₂O₃ is about 4.4. The major As(V) species in different pH ranges are also included in Fig. 5b. As the solution pH increases from an acidic region to an alkaline region, As(V)

ions in solution exist mainly as H_3AsO_4 at $\text{pH} < 2.2$ ($\text{p}K_{\text{a}1}$), H_2AsO_4^- at $\text{pH} 2.2\text{--}6.98$ ($\text{p}K_{\text{a}2}$), HAsO_4^{2-} at $\text{pH} 6.98\text{--}11.5$ ($\text{p}K_{\text{a}3}$), and AsO_4^{3-} at $\text{pH} > 11.5$ (Zhu *et al.*, 2009; Chang *et al.*, 2010). When the pH is below the isoelectric point of $\alpha\text{-Fe}_2\text{O}_3$, the surface of $\alpha\text{-Fe}_2\text{O}_3$ will be positively charged and favorable for As(V) sorption. As(V) ions are easily adsorbed on the $\alpha\text{-Fe}_2\text{O}_3$ hierarchical microspheres surface in the low pH range due to strong electrostatic attraction between As(V) and $\alpha\text{-Fe}_2\text{O}_3$. As pH increases, the

$\alpha\text{-Fe}_2\text{O}_3$ surface becomes less positively charged, and the interaction between $\alpha\text{-Fe}_2\text{O}_3$ and As(V) becomes less and changes to a repulsive force at $\text{pH} > \text{pH}_{\text{zpc}}$, resulting in a significant decrease of As(V) sorption. The relationship of the electrostatic force between As(V) ions and $\alpha\text{-Fe}_2\text{O}_3$ explains the influence of pH on As(V) sorption. This has been well described in previous studies concerning As(V) sorption on other adsorbents (Zhu *et al.*, 2009; Chang *et al.*, 2010; Sheng *et al.*, 2012).

Fig. 4 As(V) sorption on flower-like $\alpha\text{-Fe}_2\text{O}_3$ nanostructures

(a) Effect of time ($m/V=0.6$ g/L, $\text{pH}=5.0$); (b) Pseudo-second-order kinetics for the sorption of As(V) on flower-like $\alpha\text{-Fe}_2\text{O}_3$ nanostructures ($m/V=0.6$ g/L, $\text{pH}=5.0$); (c) Effect of pH ($m/V=0.6$ g/L); (d) Sorption isotherms of As(V) on flower-like $\alpha\text{-Fe}_2\text{O}_3$ nanostructures ($m/V=0.6$ g/L, $\text{pH}=5.0$)

Fig. 5 Zeta potential of $\alpha\text{-Fe}_2\text{O}_3$ (a) and speciation diagram of arsenate (b)

TOT: the total concentration of consumed protons in the titration process

3.2.3 Sorption isotherms

The sorption isotherms of As(V) on flower-like α -Fe₂O₃ nanostructures are shown in Fig. 4d. The Freundlich (Li *et al.*, 2011) and Langmuir (Sheng *et al.*, 2012) models are used to simulate As(V) interaction on α -Fe₂O₃. The Freundlich model is described by

$$q_e = k_F C_e^n, \quad (4)$$

and the Langmuir model can be expressed as

$$q_e = \frac{b q_{\max} C_e}{1 + b C_e}, \quad (5)$$

where k_F (mg¹⁻ⁿ·Lⁿ/g) represents the sorption capacity when the metal ion equilibrium concentration equals to 1 and n represents the degree of dependence of sorption with equilibrium concentration, C_e is the equilibrium concentration of As(V) in the supernatant (mg/L), $q_{\max}$ is the maximum sorption capacity of As(V) per weight of α -Fe₂O₃ (mg/g), and b represents the Langmuir sorption constant (L/mg). The Freundlich constant k is correlated to the relative sorption capacity of As(V) (mg/g), and $1/n$ is the sorption intensity.

The sorption results were regressively modeled by the Langmuir and Freundlich models. The parameters are listed in Table 1. The higher R value of the Langmuir model indicated that the sorption isotherms were better simulated by the Langmuir model than that by the Freundlich model. The calculated value of $q_{\max}$ was 47.62 mg/g for α -Fe₂O₃, indicating that flower-like α -Fe₂O₃ nanostructures had excellent sorption properties. The Freundlich constant n is found to be 0.53 ($n < 1$), indicating a favorable process of As(V) sorption on α -Fe₂O₃.

Table 1 Langmuir and Freundlich isotherm parameters for As(V) sorption on flower-like α -Fe₂O₃

Langmuir			Freundlich		
$q_{\max}$ (mg/g)	b (L/mg)	R^2	k_F (mg ¹⁻ⁿ ·L ⁿ /g)	n	R^2
47.64	0.28	0.99	11.36	0.52	0.96

To investigate the sorption mechanism further, as-saturated flower-like α -Fe₂O₃ nanostructures were

prepared. As(V) ions were excited predominately as NaH₂AsO₄ in aqueous solutions at pH=4.4. The surface of flower-like α -Fe₂O₃ was positively charged. Thereby, the electrostatic attraction between the positively charged α -Fe₂O₃ samples and the negatively charged As(V) ions was the main driving force binding the As(V) ions onto the α -Fe₂O₃. The sorption mainly occurred on the surface of α -Fe₂O₃ nanostructures. XPS technique was applied to characterize the surface states of α -Fe₂O₃ after As(V) sorption. Fig. 6a shows the full-range XPS spectra of α -Fe₂O₃ nanostructures after As(V) sorption. It displays the binding energies for C 1s, O 1s, As 3d, Fe 2p, and As 2p. As shown in Fig. 6a, As(V) element was found in the XPS spectrum. The element mapping indicated that As(V) was evenly distributed on α -Fe₂O₃ nanostructures. As(V) appeared after As(V) was adsorbed on α -Fe₂O₃. The As 3d spectrum after As(V) sorption showed peaks at 45.2 eV and 1327.4 eV, which were attributed to As(V)-O bonding. Fig. 6d displays the Fe 2p spectrum after As(V) sorption, and no peaks were changed, indicating that the structure of α -Fe₂O₃ was not changed after As(V) sorption.

From the results mentioned above, the sorption mechanism of As(V) on the flower-like α -Fe₂O₃ nanostructures was electrostatic attraction between α -Fe₂O₃ and H₂AsO₄⁻ species. Electrostatic force played a critical role in sorption.

3.3 Photocatalysis of MB

3.3.1 Degradation efficiency

The photocatalytic degradation of MB in four different treatment processes is displayed in Fig. 7a. It can be seen that only 62% of MB was degraded after 250 min of continuous visible light irradiation without any catalyst. In the presence of flower-like α -Fe₂O₃ nanostructures under the same conditions, almost all of the MB was photocatalytic degraded, suggesting excellent photocatalytic ability of flower-like α -Fe₂O₃ under visible light irradiation. When the test tube was placed in dark surroundings, almost no MB was degraded, indicating that the elimination of MB was mainly caused by photocatalytic degradation rather than adsorption. As comparison, the photocatalytic activity of commercial α -Fe₂O₃ was also studied. The results demonstrated that the flower-like

Fig. 6 Full-range XPS spectra of flower-like α - Fe_2O_3 nanostructures after As(V) sorption (a), As 2p XPS spectrum (b), As 3d XPS spectrum(c), and Fe 2p XPS spectrum (d)

Fig. 7 Photocatalysis of MB

(a) Comparison of change in degradation efficiency (%) as a function of irradiation time, $C_{[\text{MB}]_{\text{initial}}}=10 \text{ mg/L}$, $m/V=0.6 \text{ g/L}$; (b) Effect of photocatalyst dosage on MB degradation ($C_{[\text{MB}]_{\text{initial}}}=10 \text{ mg/L}$); (c) Effect of MB concentration on MB degradation ($m/V=0.6 \text{ g/L}$); (d) EIS changes of flower-like α - Fe_2O_3 and commercial α - Fe_2O_3 powder electrodes

α -Fe₂O₃ has higher photocatalytic ability than commercial α -Fe₂O₃.

3.3.2 Effect of photocatalyst dosage on MB degradation

Photocatalysis of MB (10 mg/L) was measured with four different catalyst contents ranging from 0.2 to 0.8 g/L. As can be seen from Fig. 7b, the photocatalytic degradation of MB increased with increasing catalyst content from 0.2 to 0.6 g/L. With increasing amount of catalyst, the quantity of photons and the MB adsorbed on α -Fe₂O₃ increased and consequently increased the MB degradation. However, the further increase in α -Fe₂O₃ concentration to 0.8 g/L resulted in a decrease of the efficiency of MB degradation. Consequently, higher concentrations of α -Fe₂O₃ revealed a passive effect on the photocatalytic degradation of MB. The available active sites increased with increasing amount of α -Fe₂O₃; however, the photoactivated volume of solution and the light penetration shrank (Chang *et al.*, 2010). It can also be attributed to the increased opacity of the suspension bringing a shielding effect and light scattering (Chang *et al.*, 2010). In addition, the decrease of degradation at higher catalyst concentrations may be due to the deactivation of activated MB molecules through conflict with ground state molecules (Chang *et al.*, 2010; Zhao *et al.*, 2012). Herein, the optimum concentration of catalyst was chosen as 0.6 g/L, to assure the absorption of light photons for efficient photomineralization and also to avoid unnecessary excess.

3.3.3 Effect of the initial concentration of MB

Fig. 7c shows the photocatalytic degradation of MB at different initial concentrations at a α -Fe₂O₃ content of 50 mg/L. One can see from Fig. 7c that the photodegradation efficiency decreases with increasing MB concentration. The degradation rate is related to the formation of free hydroxyl radicals on the surface of α -Fe₂O₃ and the reaction of free hydroxyl radicals with MB molecules. With increasing MB concentration, the probability of -OH radical reaction with MB molecules increases. The available active sites on the α -Fe₂O₃ surface are replaced or overlaid by MB molecules. The production of -OH radicals decreases as there are fewer available active sites for the regeneration of -OH radicals. Another important

reason is that the high MB concentration shadows the light, making it difficult for visible light to trigger the catalyst. Thereby, the concentration of hydroxyl free radicals decreases and the photocatalytic degradation decreases (Zhang *et al.*, 2013c).

3.3.4 Electrochemical impedance spectroscopy (EIS) changes of flower-like α -Fe₂O₃ nanostructures and the commercial α -Fe₂O₃ powder electrodes

Fig. 7d shows the EIS of the flower-like α -Fe₂O₃ nanostructures and the commercially available α -Fe₂O₃ samples. One can see that both samples have similar plots with one semicircle in the high frequency region and an inclined straight line in the low frequency. It is clear that the semicircle radius of the flower-like α -Fe₂O₃ sample is much smaller than that of a commercial α -Fe₂O₃ powder sample. It can be deduced that the flower-like α -Fe₂O₃ nanostructures improve the conductivity of the electrode. The designed hierarchical nanostructure is important for the enhancement of electron transport. The netlike substructures of the plates in the flower-like α -Fe₂O₃ material improve electron transport in the electron-transport channels. For the commercial α -Fe₂O₃ powder sample, the transfer of electrons is difficult because of contact resistance between the particles.

3.3.5 Reuse of photocatalyst

The reusability of the catalyst is important for efficiency. For an environmentally friendly approach, reusability is desired for it makes the process free of waste and also reduces its operational cost. To explore the reusability potential of the flower-like α -Fe₂O₃, it was recovered from the reaction mixture through filtration. The catalyst was then washed with distilled water and dried in an oven at 60 °C. The recovered catalyst was then reused for the degradation of MB under the same reaction conditions as mentioned above. The catalytic activity of α -Fe₂O₃ was tested for 5 cycles. As can be seen from Fig. 8, after being reused for 5 times, the α -Fe₂O₃ catalyst still preserved its photocatalytic behavior and the dye degradation efficiency was almost the same. This reusability of α -Fe₂O₃ is attributed to its stability and resistance to photocorrosion. Thus, because of the recyclable nature of α -Fe₂O₃, it can be used as an efficient catalyst for the degradation of dyes.

Fig. 8 Reusability of α -Fe₂O₃ catalyst for the degradation of MB for 5 cycles

4 Conclusions

Flower-like α -Fe₂O₃ nanostructures were synthesized using a low-cost solvothermal method. These flower-like α -Fe₂O₃ nanostructures had high specific surface area and abundant hydroxyl groups and showed high sorption capacity for As(V) ions. The sorption mechanism of As(V) on the flower-like α -Fe₂O₃ nanostructures was confirmed as an electrostatic force between α -Fe₂O₃ and As(V) species. The photocatalytic degradation of MB was dependent on the hierarchical flower-like α -Fe₂O₃ nanostructures. The initial MB concentration and the content of α -Fe₂O₃ affected the photocatalytic degradation of MB markedly. The remarkable improvement in sorption and photocatalytic degradation properties was attributed to the flower-like structures. To sum up, the as-synthesized flower-like structures are a benefit for real applications in the cleanup of wastewater pollution.

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中文摘要:

本文题目: 花状氧化铁的制备及其在废水处理中的应用

Synthesis of flower-like α -Fe₂O₃ and its application in wastewater treatment

研究目的: 研究花状氧化铁的制备并探讨其对砷的吸附性能和亚甲基蓝的催化性能。

创新要点: 1. 合成了花状氧化铁; 2. 发现 Langmuir 模型能更好地模拟砷的吸附过程; 3. 发现花状氧化铁对亚甲基蓝有很好的催化降解性能。

研究方法: 1. 使用扫描电镜、投射电镜、X 射线衍射和 BET 比表面及孔径分析仪对合成的花状氧化铁进行表征; 2. 采用静态实验法研究砷的吸附性能及亚甲基蓝的催化行为。

重要结论: 1. 采用一种低成本的溶剂热法合成了花状氧化铁; 2. 合成的花状氧化铁有着较大的比表面积并对砷有着很好的吸附性能, 并且吸附率随着 pH 的增加而降低。同时发现 Langmuir 模型能更好地模拟砷的吸附过程; 3. 亚甲基蓝的初始浓度和花状氧化铁的用量对催化性能影响较为明显, 花状氧化铁有较好的重复利用性; 4. 合成的花状氧化铁可以应用于大批废水的处理。

关键词组: 花状氧化铁; 砷; 吸附; 亚甲基蓝; 光降解