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Facile synthesis of gelatin modified attapulgite for the uptake of uranium from aqueous solution

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ABSTRACT

Gelatin modified attapulgite (ATT@Gel) with high adsorption capability for U(VI) was synthesized by plasma technique. The ATT and ATT@Gel composites were characterized by scanning electron microscope (SEM), X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), and thermogravimetric analysis (TGA). The characterization results indicated that ATT@Gel was synthesized successfully. The adsorption capability of ATT@Gel for U(VI) was studied by batch adsorption technique. Experiment results indicate that the modified gelatin on ATT surface can markedly improves the adsorption efficiency of ATT@Gel for U(VI).

1. Introduction

The behaviors of long-lived actinides in environmental has aroused great interest in radioactive waste management [1,2]. The migration and diffusion of actinides on the surface of minerals are of primary importance for its environmental behavior [3]. The fate of actinides in environment solution is mainly dominated by its adsorption and complexation on mineral surfaces [4–7]. Uranium, a typical actinide elements, exists as hexavalent uranyl (U(VI)) in environment solution. U(VI) can be retained and enriched in environment for a long time due to its long half-life (such as $^{238}Ut_{1/2} = 4.51 \times 10^9$ years) [8–10]. Therefore, it is very important to uptake uranium ions from environment solution. Attapulgite, a number of sepiolite families in mineralogy, its basic structural unit is 2: 1 layer type which is two layers of silicon oxide tetrahedraclip a layer of magnesium oxide octahedron. Si^{4+} is replaced by Al^{3+} on the surface of attapulgite and thereby its appears negative charge, which ensures it presents adsorption capability for trace heavy metal ions [11,12] and radionuclides (such as U(VI)) in environment solution [13]. However, the low adsorption capability of attapulgite greatly limits its application in the management of radioactive pollution. Amino groups are widely considered as effective chelating functional groups to separate various contaminants from solution because of their high reactivity [14–16]. Gelatin, a heterogeneous mixture of animal origin protein, contains abundant amounts of amino groups which can form strong complex with metal ions in solution. To further enhance the adsorption capability of attapulgite, attapulgite was modified with gelatin (denoted as ATT@Gel) in this work. Plasma technique was used in synthesis process because it is an environmental friendly and effective technique which can modify material surface without altering its bulk properties [17]. The energy of activated particles formed in plasma is much greater than chemical bond energy and can break chemical bonds to form active species on ATT surface. The active species would then react with the functional groups in gelatin, which result in the modification of gelatin on ATT surface. The prepared ATT@Gel composites were applied to uptake U(VI) from solution to evaluate its potential application in radioactive pollution management.

2. Experimental

2.1. Chemicals

All chemical reagents used in this paper were in analytic purity. The attapulgite (ATT) was received from Kai-Xi Co. China.

ATT@Gel was synthesized by plasma technique. Briefly, 1.0 g attapulgite was treated by nitrogen plasma (100 W) for 30 min the

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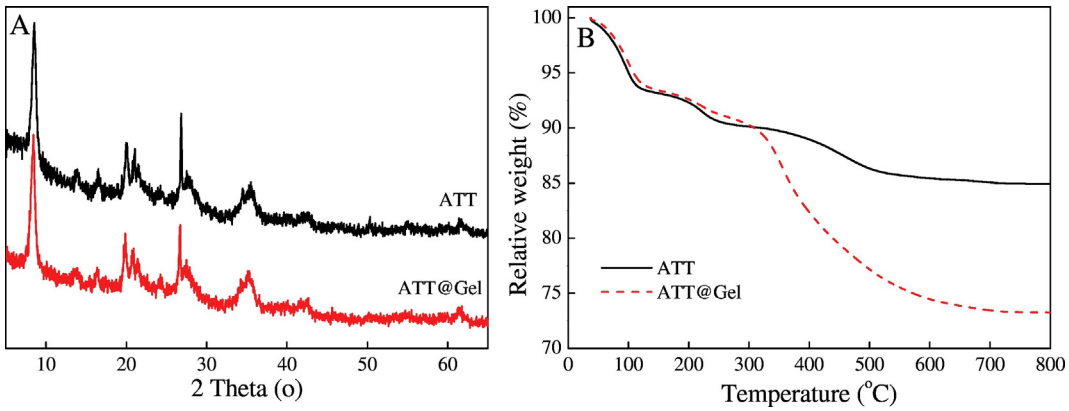

Fig. 1. The XRD patterns (A) and TGA curves (B) of ATT and ATT@Gel.

treated ATT was added into 100 mL 10.0 g/L gelatin solution and reacted at 50 °C for 3 h under magnetic stirring, and then washed with Milli-Q water and dried at 50 °C. The resulted materials were denoted as ATT@Gel.

2.2. Adsorption experiment

The adsorption experiment was performed by batch adsorption technique. After the adsorbent (ATT and ATT@Gel) was pre-equilibrated with NaCl for 12 h in polyethylene tubes, U(VI) stock solution and Milli-Q water were added to obtain the desired composition, and the pH values were adjusted by diluted nitric acid or sodium hydroxide. After shaken for requested time, the suspensions were centrifuged at 18,000 rpm for 10 min (Beckman Coulter 64R) at the temperature in adsorption experiments. The residual U(VI) concentration in supernatant was measured by arsenazo III spectrophotometric method. All adsorption were repeated for three times, and the uncertainties of adsorption data were <5%.

2.3. Characterization

The ATT and ATT@Gel samples were characterized by SEM, XRD, TGA, and XPS. The SEM images were obtained on a FEI Sirion 200 FEG scanning electron microscope. The XRD patterns were measured on a D/MAX-2500 V equipped with Cu K_α radiation. The TGA measurements were performed on a Shimadzu TGA-50 thermogravimetric analyzer. The heating rate and air flow rate were 10 °C /min and 40 mL/min, respectively. XPS measurements were performed on an ESCALab220i-XL surface microanalysis system equipped with an Al K_α source.

3. Results and discussion

Fig. 1A shows the XRD patterns of ATT and ATT@Gel samples. The XRD peaks at $2\theta = 8.4°$, 13.8°, 19.7°, 21°, 27.5°, 35.0° and 42.6° indicate the crystal structure of ATT [18]. Quartz and montmorillonite are also found in the attapulgite samples. The XRD peak positions of ATT and

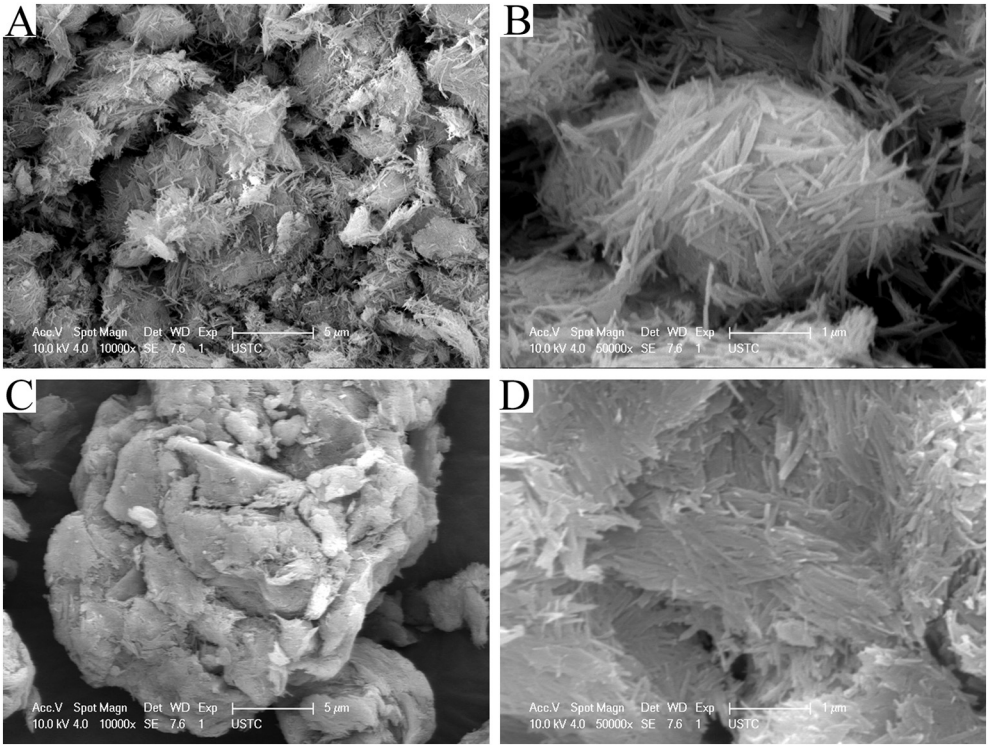

Fig. 2. SEM images of ATT (A, B) and ATT@Gel (C, D).