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Fast removal of Pb^{2+} from water using new chelating fiber modified with acylamino and amino groups

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Abstract

The graft copolymerization of acrylic acid (AA) onto polyethylene glycol terephthalate (PET) fiber initiated by benzoy peroxide (BPO) was carried out in heterogeneous media. Moreover, modification of the grafted PET fiber (PET-AA) was done by changing the carboxyl group into acylamino and amino groups through the reaction with ethylenediamine. The new modified chelating fiber (NDWJN6) was characterized using elementary analysis, SEM and FT-IR spectroscopy. Adsorption kinetic curve indicated that NDWJN6 could fastly remove Pb^{2+} from water, and adsorption isotherm also indicated that NDWJN6 had high equilibrium adsorption capacity for Pb^{2+}.

Keywords: Removal; Pb^{2+}; Chelating fiber; Acylamino groups; Amino groups

The discharge of lead into the environment is a serious pollution problem affecting water quality. Long-term drink of water at high lead level will cause anemia, headache, chills, diarrhea and poisoning leading to the dysfunction of kidneys, reproductive system, liver, brain and central nervous system. Thus, lead had been a serious public health issue worldwide [1]. Adsorption is an alternative technique for removal of heavy metal ions from water. In recent years, the metal adsorption capacity of natural protein fibers has been investigated for the production of new types of adsorbents [2]. But the source of natural protein fibers is not stable, thus it is valuable to research the preparation of new adsorbents based on synthetic fibers. In present work, we synthesize new chelating fiber modified with acylamino and amino groups based on polyethylene glycol terephthalate (PET), and this new chelating fiber can fast remove Pb^{2+} from water effectively. The characterization of the new modified fiber is confirmed by using elementary analysis, FT-IR spectroscopy and SEM. Furthermore, the equilibrium adsorption isotherm and adsorption kinetic curve of Pb^{2+} on this new modified chelating fiber are studied.

1. Experimental

PET was filtered and then extracted with ethanol for 8 h in a Soxhlet apparatus and dried under vacuum at 333 K for 8 h. Acrylic acid (AA) was treated with 3% (w/w) sodium hydroxide solution, washed with distilled water until neutralization and dried over calcium chloride followed by molecular sieves. The synthetic reaction was carried out as in the following two steps and the preparation process is shown in Scheme 1.

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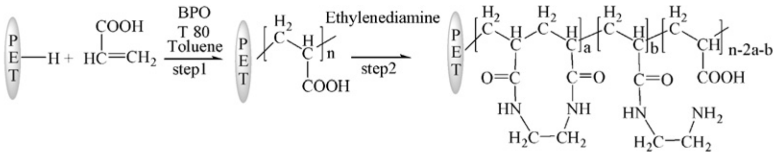

Scheme 1. Preparation process of NDWJN6.

(1) The graft copolymerization of PET fibers by polyacrylic acid (PAA) was carried out using free radical polymerization. Briefly, 1 g of PET was soaked in 50 mL distilled water in a conical flask. Then, the combined redox initiator system (BPO, toluene, Tween-80 and pyridine) was added and the mixture was vigorously shaken for 5 min. The monomer AA was added and the reaction was conducted for 4 h with stirring at 355 K. The products were filtered and washed with distilled water. The grafted copolymer was dried at 313 K until constant weight. Grafting percentage (GP) was calculated as in the following expression (Eq. (1)):

$$GP = \frac{(A - B)}{B} \times 100\% \quad (1)$$

where A and B are the weights of grafted product and PET fibers, respectively. The grafted PET fibers prepared with GP values 315% were named as PET-AA.

(2) The finally modified chelating fibers were prepared by the action of the above PET-AA fibers with 100 mL, 8% (v/v) ethylenediamine solution. The mixture was slowly stirred at 313 K for 24 h. Then, the modified chelating fibers were filtered and washed with absolute ethanol then dried at 313 K. Then the new modified chelating fiber NDWJN1 was characterized by element analysis, FT-IR and SEM.

Adsorption isotherm and adsorption kinetic curve of Pb^{2+} on NDWJN6 were conducted according to the method, which were reported in the literatures [3,4]. The concentration of Pb^{2+} (c_e) was determined using atomic adsorption spectrophotometer. Thus, q_e (mg/g), the adsorption capacity, was calculated according to Eq. (2):

$$q_e = \frac{V_1 \times (c_0 - c_e)}{W} \quad (2)$$

where V_1 is the volume of solution (L), W is the weight of dry fiber (g).

2. Results and discussion

As shown in Table 1, comparing with PET, both oxygen and nitrogen content of NDWJN6 increase after the grafting and modification, which indicate the acylamino and amino groups are grafted to NDWJN6.

The scanning electron microscopy (SEM) photos of fibers are shown in Fig. 1. Comparing with PET (Fig. 1a), NDWJN6 (Fig. 1b) shows an observed increase in diameter which is due to the insertion of the AA chains onto the PET fiber surface and the conversion of carboxyl groups into acylamino/amino groups in grafted chains. As shown in Fig. 1(c), it can be seen that particles of Pb^{2+} are adhere to the surface of NDWJN6 after sorption of Pb^{2+}.

As shown in Fig. 2, comparing with PET and PET-AA, the new modified chelating fiber NDWJN6 have various distinctive absorption peaks: abroad one in the range of δ 2900–3500 cm^{-1} which may be related to the '–N–H' bonds, as well as the peak near δ 1540 cm^{-1} belonging to '–C=O' of acylamino [5]. It indicates that acylamino and amino groups have been grafted to the PET successfully.

It was reported that chelating interactions can occur between heavy metal ions and amino groups [6]. As shown in Fig. 3, the band of '–N–H' of NDWJN6 shifts from δ 2954.9 to 2967.8 cm^{-1} after adsorbing the Pb^{2+}, which suggests that chelating interaction between '–N–H' and Pb^{2+} occurred in sorption process. Furthermore, the chelating

Table 1
Results of E.A. of the fiber adsorbent (wt%).

Adsorbent	C (%)	H (%)	O (%)	N (%)
PET	63.61	4.25	31.43	0
PET-AA	52.83	5.74	39.81	0
NDWJN6	47.32	6.25	37.64	6.41