

Synthesis of Functionalized Mesoporous Carbon for Uranium Sorption in Acidic Conditions

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1. Introduction

Since the Kori nuclear power plant in Korea was shut down permanently, researchers have focused on the development of decommissioning and decontamination technology of nuclear power plant. Various radionuclides generated from nuclear power plants are mainly removed by conventional filters or resins. However, a large amount of secondary radioactive wastes is generated. Recently, in order to reduce secondary radioactive wastes, radionuclide separation technology conjugating solid phase extraction has been intensively developed.

In this work, the ordered mesoporous carbon of CMK-3 was used as an adsorbent for uranium extraction from liquid phase since it has very good thermal, chemical and mechanical strength [1]. CMK-3 has been successfully functionalized with phenyl phosphate. Studies on the U(VI) sorption behavior on CMK-3 and CMK-3-AP-PO₄ will be performed as the next step.

2. Methods

2.1 Adsorbent preparation

The ordered mesoporous carbon of CMK-3 was synthesized using the ordered mesoporous silica of SBA-15 as the hard template and sucrose as the carbon source [2,3]. CMK-3 was functionalized with amino phenol through diazotization method. The resulting material of CMK-3-AP was phosphorylated using phosphoric acid for obtaining CMK-3-AP-PO₄.

2.2 Characterization of CMK-3

Small angle X-ray diffraction patterns were recorded using Cu-K_α radiation. The N₂ adsorption-desorption isotherms at 77 K were operated to identify the surface area and pore structure of the materials. The specific surface area was measured by the Brunauer-Emmett-Teller (BET) method, and the total pore volume was obtained using Brunauer-Joyner-Halenda (BJH) method. The surface topography was analyzed by transmission electron microscopy (TEM). Fourier transform-infrared spectra (FTIR) were obtained to identify phenyl phosphate on the surface of CMK-3.

2.3 Sorption experiments

Batch U(VI) sorption experiments were carried out as function of pH. 10 mg of sorbent was suspended in 50 mL solution containing 10⁻⁴ M U(VI) with different pHs. The ionic strength and pH was adjusted by using 0.1 M NaClO₄ and 0.1 M HClO₄/NaOH, respectively. Separating the sorbent from solution was conducted with 220 nm PES membrane filters. The concentration of U(VI) in the filtrate was determined by inductively coupled plasma optical emission spectrometer (ICP-OES). The sorption capacity (q_e , mg/g) and the distribution coefficient (K_d) were calculated as follows.

$$q_e = \frac{(c_0 - c_e)}{m} \times V \quad (1)$$

$$K_d = \frac{(c_0 - c_e)}{c_e} \times \frac{V}{m} \quad (2)$$

where C_0 and C_e (mg/L) is the initial and equilibrium U(VI) concentration, respectively. V is the volume of the solution (L) and m is the mass of sorbent (mg).

3. Results

Fig. 1 shows the SAXRD patterns of CMK-3 and CMK-3-AP-PO₄. The three peaks are assigned to (100), (110) and (200) planes associated with $p6mm$ hexagonal symmetry [2]. The result indicates that the ordered structure of CMK-3 was preserved.

From the N₂ adsorption-desorption isotherms at 77 K, it was found that CMK-3 exhibits large surface area (1495 m²/g) and pore volume (1.26 cm³/g). After functionalization with phenyl phosphate, the surface area and the pore volume decreased to 1011 m²/g and 0.73 cm³/g. It is attributed to loading of functional groups onto the surface of CMK-3.

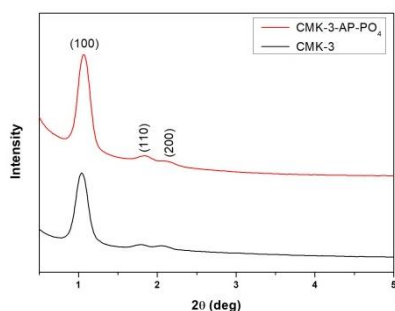


Fig. 1. SAXRD patterns of CMK-3 and CMK-3-AP-PO₄.

TEM images shown in Fig. 2 demonstrated that the pore structure remains retained even after functionalization. The FTIR analysis was conducted to identify the functional group, as presented in Fig. 3. The peaks at 1178 and 1507 cm⁻¹ appeared in CMK-3 and CMK-3-AP-PO₄, which are assigned to the C-O and C=C stretching vibrations of aromatic ring, respectively. The peak at 1076 cm⁻¹ in CMK-3-AP-PO₄ is attributed to phosphate group.

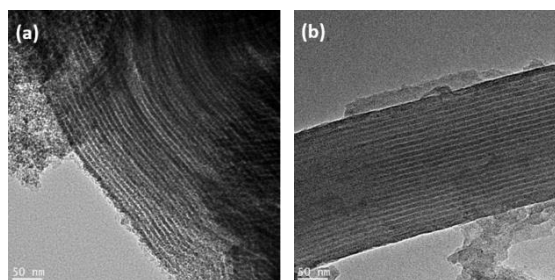


Fig. 2. TEM images of (a) CMK-3 (b) CMK-3-AP-PO₄.

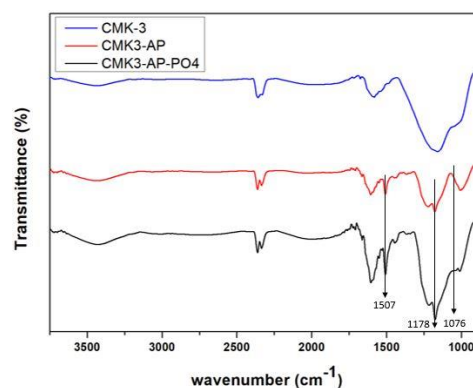


Fig. 3. FTIR spectra of CMK-3, CMK-3-AP and CMK-3-AP-PO₄.

ACKNOWLEDGEMENT

This work was supported by a grant from the Nuclear R&D Program of the National Research Foundation of Korea funded by the Korean Ministry of Science and ICT (Grant codes: 2017M2A8A5014801).

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