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Fabrication of core–shell particles for a fluidized bed electrode in seawater desalination

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ABSTRACT

Active carbon particles have been coated with cation-exchanged polymer for the fabrication of core–shell particles, to be used as a fluidized bed electrode in seawater desalination. To adequately utilize the features of the core–shell particles, the polymer should be uniformly coated on the surface of independent active carbon particles. To do that, the active carbon particles prior to the polymer coating were modified with an acid for individual separation without agglomeration between particles, producing a more effective coating of polymer on the carbon particles. The modified carbon particles were well dispersed in an aqueous solution with cation-exchanged polymer by the hydrophilic groups generated on the carbon chain, resulting in the homogeneous coating of polymer on the surface of individual carbon particles. This means that the core–shell particles prepared with heterogeneous materials could be applicable to a fluidized bed electrode in seawater desalination.

1. Introduction

Recently, capacitive deionization (CDI) has been applied to seawater desalination equipment because of the relatively low energy consumption compared with the reverse osmosis method [1–4]. However, the CDI method decreases the desalination efficiency because the absorbed ions remain in the pores of the inner carbon and/or the desorbed ions accumulate on the surface of the electrode in the repeated adsorption and desorption processes. Therefore, a membrane-CDI method using an ion-exchanged membrane has been developed [5–8]. However, in the case of a membrane-CDI consisting of a fixed carbon electrode and membrane, ion absorbability gradually decreases because ion absorption mainly takes place at the interface area in contact with solution, reducing the absorption–adsorption efficiency of the electrode. Therefore, a fluidized bed electrode is applied to seawater desalination to overcome the limited absorbability of the fixed bed electrode and eliminate the recycle process.

In the present work, the fluidized bed electrode was made in a core–shell shape coated with polymer on the surface of the carbon particle [9,10]. In addition, two key points were considered in the fabrication of desirable core–shell particles to improve the coating efficiency between hetero-particles; the coating process was conducted in an aqueous solution, producing a homogeneous polymer coating, and the active carbon particles were modified with an acid to independently disperse carbon particles in an aqueous solution, caused by carboxylic acid groups produced by the acid [11,12]. Consequently, the core–shell particles could be effectively prepared. The polymer coating on the carbon particles was demonstrated using various analytical techniques.

2. Experimental procedure

Nafion (Sigma-Aldrich Korea, Yongin, Korea) and the active carbon (Korea Institute of Energy Research, Daejeon, Korea) were used as a cation-exchanged polymer and a carbon electrode, respectively [13]. The active carbon particles were suspended in a mixture of sulfuric and nitric acids (3:1 by vol.%). This mixture was sonicated for 3 h and stirred for 24 h [14]. After stirring, the acid-treated carbon particles were filtered and washed with distilled water until pH 7, and then the carbon particles were dried at 80 °C for 48 h. Nafion was diluted in distilled water using an ultrasonicator (Sonifier 450, Branson Ultrasonics, Danbury, CT, USA) for 1 h at room temperature. The modified carbon particles were added to the 0.05 M Nafion solution, and then the mixture (Nafion solution:carbon particles = 10:1 by vol.%) was sonicated for 24 h at room temperature. The Nafion–carbon particle mixture was filtered and dried at 80 °C for a period of 24 h. Consequently, the core–shell structure of the active carbon coated with the cation-exchanged polymer was prepared. The scheme for preparing the core–shell particles is shown in Fig. 1.

The structures of the active carbon and core–shell particles were analyzed using a Fourier transform infrared spectrometer (FT-IR; Nicolet, Thermo Fisher Scientific, Waltham, MA, USA) and an X-ray diffractometer (XRD; X-pret MPD, Model PW3040; Philips, Eindhoven, Netherlands). The morphology and microstructure of the active carbon and core–shell

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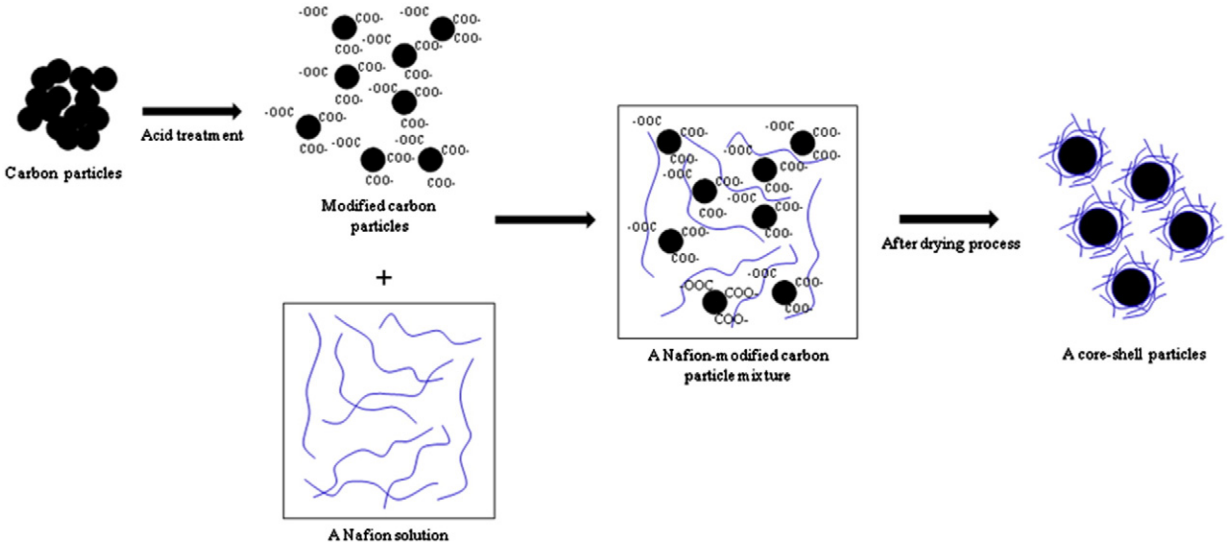

Fig. 1. The fabrication of core–shell particles using active carbon and cation-exchanged polymer.

particles were observed using a scanning electron microscope (SEM; JEOL Model JSM-5610, Tokyo, Japan) and a field emission transmission electron microscope (FE-TEM; JEM 2100F, Tokyo, Japan). Element analysis of the carbon particles was carried out using an energy dispersive X-ray spectrometer (EDS; energy resolution 133 eV; Oxford Inst., Oxford, UK).

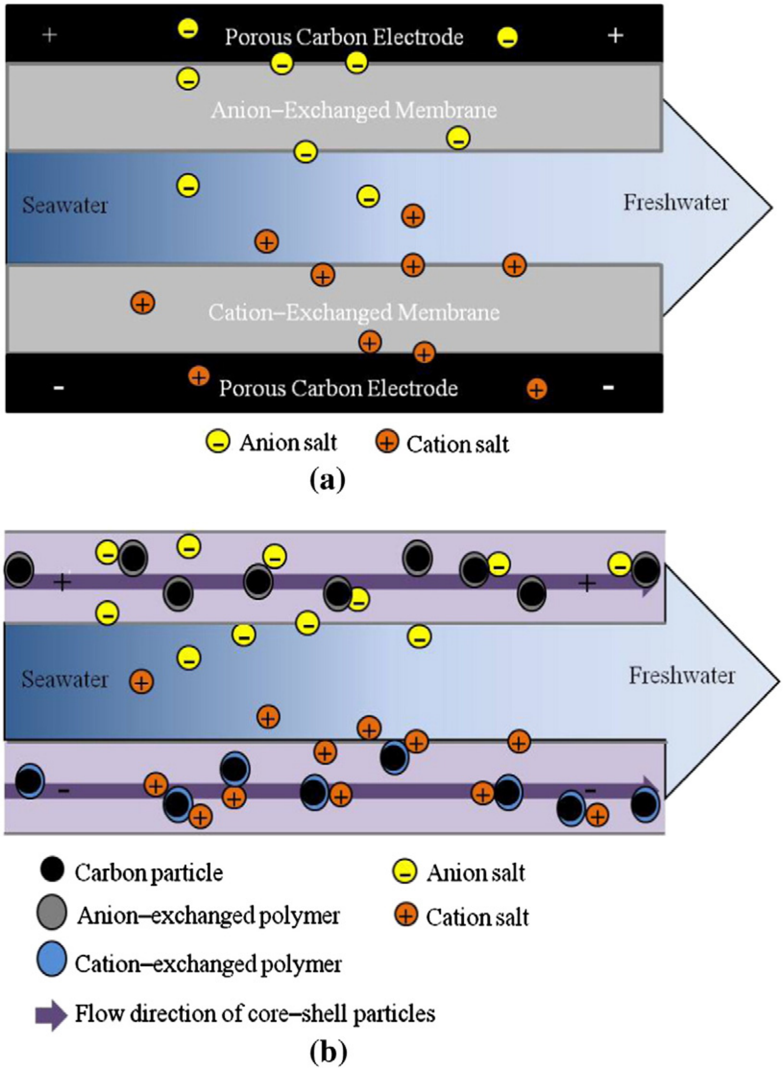

Fig. 2. Two processes for seawater desalination using (a) fixed bed electrode and (b) fluidized bed electrode.