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Facile preparation of glucose functionalized multi-wall carbon nanotubes and its application for the removal of cationic pollutants

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ABSTRACT

Glucose functionalized multi-wall carbon nanotubes (MWCNT/Gl) composites adsorbent was prepared. Adsorption characteristic of MWCNT/Gl was applied to deal with wastewater solution containing rhodamine B (RhB), methylene blue (MB), methyl orange (MO), malachite green (MG) and congo red (CR). The effects of adsorbent dosage, dye species, pH and contact time were conducted, and the adsorption kinetic and isotherm of adsorption process were investigated. The results indicate that MWCNT/Gl has desirable adsorption efficiency for cationic dyes. Especially for RhB, the adsorption efficiency achieves 99.8%. Kinetic data was well fitted by pseudo second-order model, and the equilibrium data were fitted by Langmuir isotherm model.

1. Introduction

Carbon nanotubes (CNTs) have been used in various fields, such as drug delivery, catalyst support and removal of dioxins. CNTs can be classified into single-wall CNTs (SCNT) and multi-wall CNTs (MWCNT). Due to its unique physical and chemical properties such as high mechanical properties, unique electronic performance and gigantic specific surface area [1], MWCNT have been proven to possess great potential [2]. Moreover, many researchers [3] have reported that CNTs modified with nitric acid, hydrogen peroxide, ethylenediamine and so on, have a higher cation adsorption capacity than the pristine CNTs. In this work, MWCNT was functionalized with glucose to form MWCNT/Gl composites, containing a great deal of oxygenic functional groups, which can adsorb cationic dyes due to the electronic conjugation of MWCNT and its negative charge of surface oxygenic functional groups. The adsorption behavior, adsorption isotherm and kinetic model were investigated.

2. Experimental section

2.1. Preparation

N, N′-carbonyldiimidazole (CDI, 500 mg) dissolved in deionized water (50 mL) was added into three-necked flask. Then, MWCNT-COOH (250 mg) was added, and the mixture was stirred for 2 h. Following, glucose (500 mg) was added into the mixture and further stirred for 2 h. The reaction mixture was centrifuged, washed, collected and dried under vacuum to give the product of MWCNT/Gl. The synthetic route of MWCNT/Gl is shown in Fig. 1(A).

2.2. Characterizations

FTIR was recorded with an FTIR spectrometer. Thermogravimetric analysis (TGA) was performed on a Netzsch STA 449 C instrument. The zeta potential of sample suspensions was measured using a Zeta Meter 3.0 equipped with a microprocessor unit. The size and morphology were obtained on a PHI-Tecnai 12 transmission electron microscope (TEM).

2.3. Adsorption performance

The adsorption efficiency ($D\%$) of dye was calculated according to the dye solution concentration difference under adsorption performance by the following Eq. (1):

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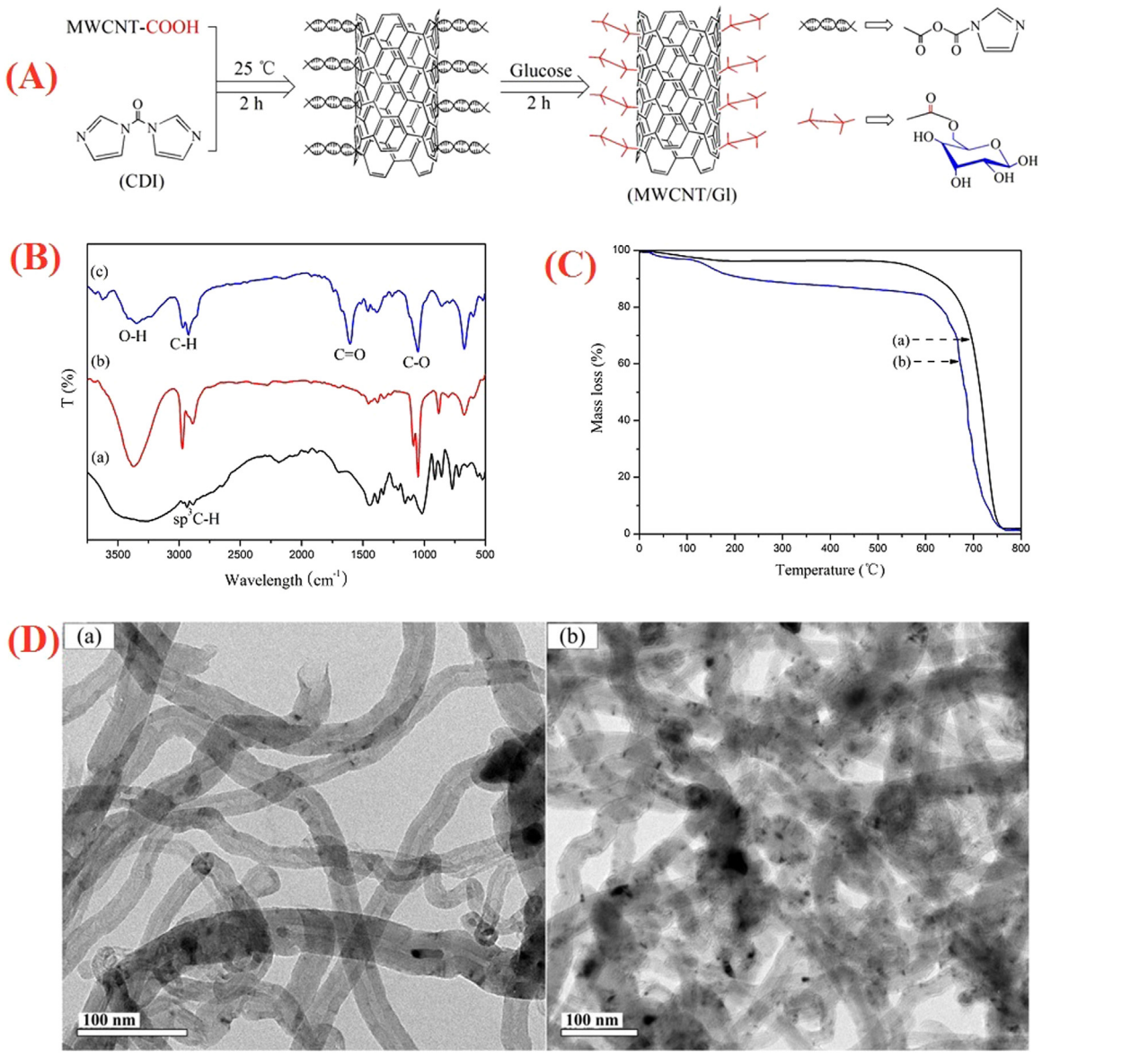

Fig. 1. (A) Chemical attachment of glucose to MWCNT; (B) FT-IR spectra of MWCNT-COOH (a), glucose (b) and MWCNT/Gl (c); (C) TG curves of MWCNT-COOH (a) and MWCNT/Gl (b); (D) TEM images of MWCNT-COOH (a) and MWCNT/Gl (b).

$$D(\%) = \frac{C_o - C_t}{C_o} \times 100\% \quad (1)$$

where C_o (mg/L) is the initial concentration and C_t (mg/L) is the concentration at time t (min) of the different dye solution, respectively.

The adsorption amount (q_t, mg/g) was calculated according to the following Eq. (2):

$$q_t = \frac{V(C_o - C_t)}{m} \quad (2)$$

where C_o and C_t are the initial and temporary concentrations of dye, respectively (mg/L); V is the volume of the dye solution (L); and m is the mass of MWCNT/Gl (g). The adsorption amount of dye at equilibrium (q_e, mg/g) was calculated from the following Eq. (3):

$$q_e = \frac{V(C_o - C_e)}{m} \quad (3)$$

where C_e is the dye concentration at equilibrium.

3. Results and discussion

From Fig. 1 (B), the characteristic absorption peak (curve a) at around 3300 cm^{-1} is attributed to the stretching vibration of O–H bands of carboxylic acid moieties from the surface of MWCNT-COOH; the weak peak at around 2932 cm^{-1} is related to aliphatic sp^3 C–H [4]. The absorption peaks located at 1457 and 1386 cm^{-1} are ascribed to the C=C and the O–H groups, respectively [5]. The absorption peaks (curve b) at 1056 and 1097 cm^{-1} are assigned to the C–O stretching modes [6]. The peaks (curve c) at 3449, 2929 and 1608 cm^{-1} are corresponding to –OH, –CH [7] and C=O groups, respectively.

The first mass loss (Fig. 1 (C)) is light from the room temperature to 100 °C, which is originating from the removal of adsorbed H_2O. MWCNT-COOH (curve a) is stable up to 600 °C. From curve b, it is become unstable with the temperature upon 100 °C, which may be due to the decomposition of the functionalized organic moieties attached to the surface of MWCNTs. From Fig. 1 (D), MWCNT-COOH shows the typical nano-tubular shape and 20–30 nm outer diameters; and MWCNT/Gl still remains the nano-

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