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Short communication

Preparation and characterization of sucrose-based microporous carbons for increasing hydrogen storage

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ABSTRACT

Sucrose-based microporous carbons were prepared for hydrogen storage. Carbon precursors were generated by ultrasonic and heat treatment of a solution of sucrose in sulfuric acid. Chemical activation was performed with KOH at various temperatures, leading to enhanced specific surface area and micropore volume. The structural properties and the morphology were evaluated XRD and SEM, respectively. The textural properties were determined from N_2/77 K adsorption–desorption isotherms using the BET method and HK equation. The hydrogen storage capacity was influenced by the activation temperature, and the optimal hydrogen storage capacity of 2.5 wt.% at 77 K and 1 bar.

Introduction

Hydrogen is a promising energy resource that is anticipated to find commercial application in fuel cell systems due to its numerous benefits. The advantages of hydrogen as a fuel include its high energy efficiency, high abundance, and the lack of noxious chemicals emitted upon combustion [1–4]. Thus, hydrogen is an ideal energy resource as a substitute for fossil fuels. However, due to the lack of effective methods for hydrogen storage, technological improvements are required for practical exploitation of hydrogen energy. Many storage methods have been investigated to resolve the hydrogen storage issue. These approaches involve the use of metal hybrids, liquefied hydrogen, compressed hydrogen, and physical adsorption by porous materials [5–11]. Adsorption by porous materials offers certain merits over the alternate approaches, such as stability, reversibility, and economic viability. Carbon is widely utilized as an adsorption material [12–14], where carbon adsorbents have good heat and chemical stability, reproducibility, hydrophobicity, and industrial accessibility [15–17]. The hydrogen storage capacity of carbon materials is influenced by the specific surface area and microporosity [18,19]. Thus, high porosity is an important feature of carbon adsorbents. Porous carbons can be prepared by a number of techniques, such as direct carbonization of various precursors and templating other porous materials such as metal-organic frameworks (MOFs) and zeolites [20–23].

Sucrose is a disaccharide comprising α-glucose and β-fructose. Sucrose can be obtained from sugar cane or sugar beet and can be used as a precursor for preparation of porous carbon. Cai et al. reported the sucrose-based template carbon materials and their hydrogen storage capacity (1.43 wt.%, 700 °C) [24]. However, generally most porous carbons prepared by direct carbonization have relatively low specific surface area and microporosity but Shcherban et al. reported the porous carbon materials from direct carbonization of sucrose and their hydrogen storage capacity (1.48 wt.%, 900 °C) [25]. Activation is generally performed with a chemical reagent to enhance the specific surface area and micropore volume of carbon materials. Chemical activation can increase the microporosity of carbons by erosion of the carbon surface [26–28].

In this study, sucrose-based microporous activated carbons are prepared by chemical activation using potassium hydroxide. The effect of the activation temperature on the specific surface area and microporosity of the carbon materials and hydrogen storage capacity at 77 K and 1 bar is discussed.

Experimental

Materials and preparation

A solution containing 5 g sucrose (Aldrich 99.5%), 20 mL distilled water, and 0.3 g sulfuric acid (DUKSAN 97%) was

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treated with ultrasonic for 2 h at room temperature. After ultrasonic treatment, the solution was placed in an oven and dried at 100 °C for 4 h and then at 160 °C for 3 h. The obtained precursor was ground in an agate mortar and placed into a tubular furnace and heated to 800 °C for 1 h under flowing nitrogen gas (flow rate 200 mL/min). The precursors and carbonized precursors are termed SUC-N and SUC-N-800, respectively; the details are explained in an earlier report [29].

Chemical activation was performed with mixtures of KOH and SUC-N. A solution containing 50 mL distilled water, 50 mL ethanol, 10 g KOH (DUKSAN 85%), and 5 g SUC-N was stirred with heat treatment at 80 °C for 12 h. After heat treatment, the solution was placed in a vacuum oven and heated at 80 °C for evaporation. The mixtures of KOH/SUC-N were then heated to respective temperatures of 700, 800, 900, and 1000 °C in a tubular furnace under nitrogen atmosphere (flow rate 200 mL/min) and maintained for 1 h. After cooling to room temperature, the materials were removed and washed with distilled water and 0.01 M HCl to reduce the potassium residue until the pH value was adjusted to neutral. The KOH activated SUC-N samples are denoted as A-SUC-*T*, where *T* is the activation temperature.

Measurements

The structural properties of the sucrose-based carbons were investigated using a X-ray diffraction (XRD) model Bruker-AXS D2 Phaser Desktop X-ray Diffractometer with a Lynx-Eye detector using Cu*K*α radiation at 40 kV and 10 mA (λ = 1.5406 Å). The diffraction patterns were measured with a scan step time of 2 s and step size of 0.03°. The scanning electron microscope (SEM) images were obtained using a Hitachi Co., Ltd., Model S-4300SE instrument. Fourier-transform infrared spectroscopy (FT-IR) was measured using a Bruker Co., Ltd., Model VERTEX 80 V, scanning range of 400–4000 cm^{-1}. The textural properties were studied by means of nitrogen adsorption–desorption isotherms acquired at 77 K using a gas adsorption analyzer (BEL Co., Ltd., Model BEL-SORP). The samples were degassed at 473 K for 6 h prior to measurement. The hydrogen storage capacity was evaluated by using a BEL Co., Ltd., Model BEL-SORP instrument at 77 K and 1 bar. Ultrahigh purity hydrogen (99.9999%) was used in order to remove the influence of other impurities and the volumetric measurement method was used to determine the hydrogen storage capacity.

Results and discussion

Fig. 1(a) shows the XRD patterns of the SUC-N-800 and of the A-SUC-*T* samples. The patterns show peaks typical of carbon

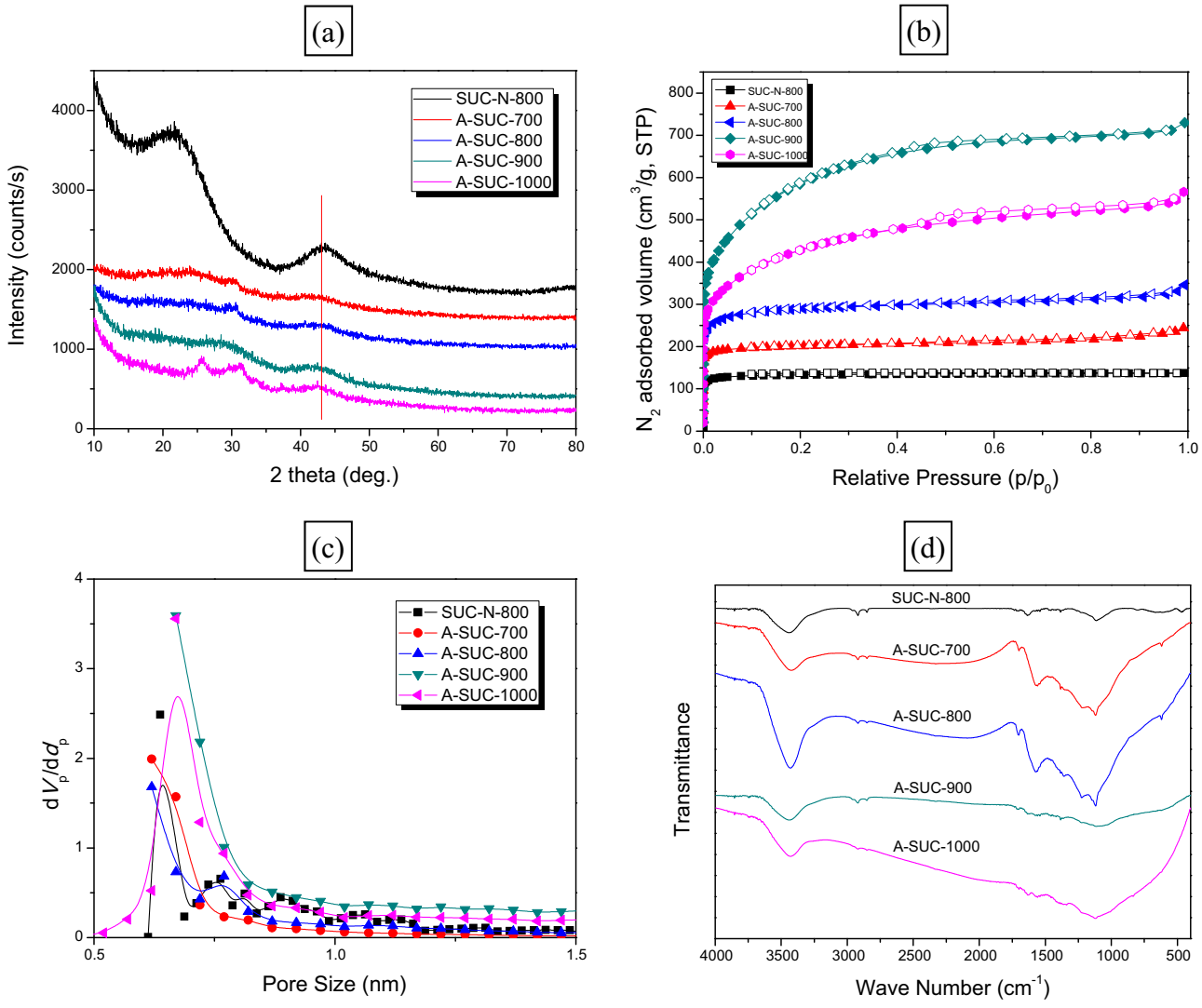

Fig. 1. Characterization of SUC-N-800 and A-SUC-*T* samples (a) XRD patterns, (b) N_2/77 K adsorption–desorption isotherms, (c) pore size distribution and (d) FT-IR spectra.