Study on the Preparation and CO_2 Adsorption Performance of Carbon material

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Abstract. Carbon materials are valuable for adsorbing CO_2. In this work, carbon materials with large specific surface area and pore volume were prepared through the combination of sodium alginate and zinc chloride, were applied to adsorb CO_2 at 273 K and 298 K, showing a large adsorption capacity 2.75 mmol g^{-1} and 2.19 mmol g^{-1}, respectively. Zinc chloride acts as an activator and pore forming agent.

1. INTRODUCTION

Sodium alginate is rich in hydroxyl, which is easy to produce intramolecular hydrogen bond, thus forming gel [1-2]. In recent years, researchers have found that sodium alginate is a good precursor. By adding templates and activators to sodium alginate, carbon materials (CM) with high porosity, large specific surface area (BET) and excellent performance can be prepared. In recent years, researchers have found that sodium alginate is a good precursor. By adding templates and activators to sodium alginate, CM with high porosity, large BET and excellent performance can be prepared[3-4]. This work uses sodium alginate as raw material and zinc chloride as activator to prepare CM with large specific surface area through simple agitation and carbonization, and is used to adsorb CO_2.

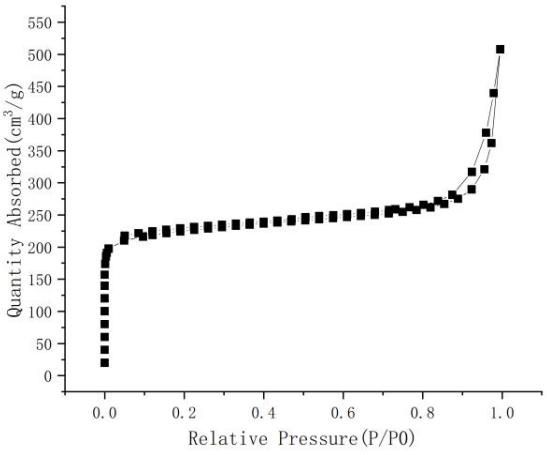
2. Methods

Add 10 grams of sodium alginate and 2 grams of zinc chloride into 100 mL of ethanol, stir for 3 hours at room temperature, and then dry in a freeze drying oven for 12 hours. After placing the product in a carbonization furnace and carbonizing at 900 ℃ for 1 hour, black powder is obtained.

3. Results and discussion

BET is important for properties of substances, and its size is relational to the pore structure. The size of the specific surface area has a significant impact on many other physical and chemical properties of a substance, especially as the particle size decreases, the specific surface area has become a very important parameter for measuring material properties, such as the widely used nanomaterials.The BET physical adsorption instrument is currently mainly used for analyzing pore structure.

As is well known, large BET and appropriate pore size are key factors determining the performance of CM. We conducted N_2 adsorption desorption experiments on samples at different carbonization temperatures, as shown in Figure 1. We calculated the BET (573 cm^2/g), pore volume (0.53 cm^3/g) of each sample using the BET method. The results show that all isotherm are IV type, and the isotherms of the samples rise significantly when p/p0 is 0.5-1, indicating that the samples contain big mesopores. The adsorption and desorption curves of the isotherm curve coincide well, indicating a narrow range of pore size distribution in mesopores[5]. These results can be verified from the aperture distribution map.



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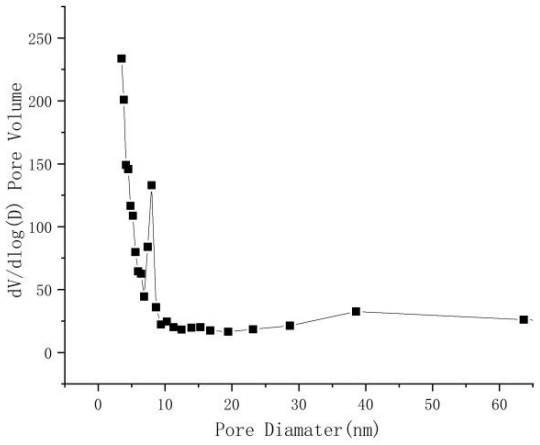

Fig 1. N_2 adsorption-desorption curve

Thermal gravimetric analysis is used to measure the relationship between the mass of a substance and temperature in Figure 2. In order to study the pyrolysis process of organic aerogel at high temperature, thermogravimetric analysis was carried out on the synthetic organic aerogel in this project. By analyzing the thermogravimetric curve, we found that the weight loss of the sample before 100 ℃; The weight loss is obvious at 350 ℃ - 370 ℃ and 550 ℃ - 700 ℃ in Figure 2, where the thermal weight loss rate of organic aerogel reaches the maximum, and the weight loss rate is about 34%. In this range, the cured organic aerogel undergoes decomposition reaction, and the molecular chain gradually splits, producing water vapor, carbon monoxide, carbon dioxide and other substances. After 700 ℃, the curve shows little change, and the degree of carbonization deepens, gradually forming a heat-resistant and solid glassy carbon material. During this process, deep carbonization mainly produces small molecule gases such as hydrogen gas[6].

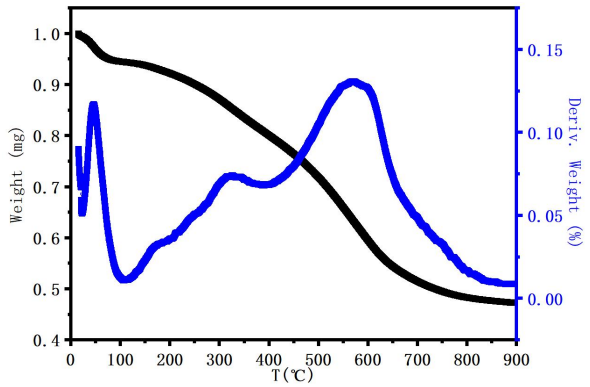

Fig 2. TG images

The project conducted SEM testing on the prepared samples in Figure 3. Figure 3 exhibits a typical three-dimensional nanonetwork structure, with nanoparticles cross-linked and stacked together to form a three-dimensional interconnected network, which is a unique structure of CM. EDS energy spectrum is an instrument for analyzing material elements, elemental distribution of CM were studied in this work. N and O elements were discovered in CM.

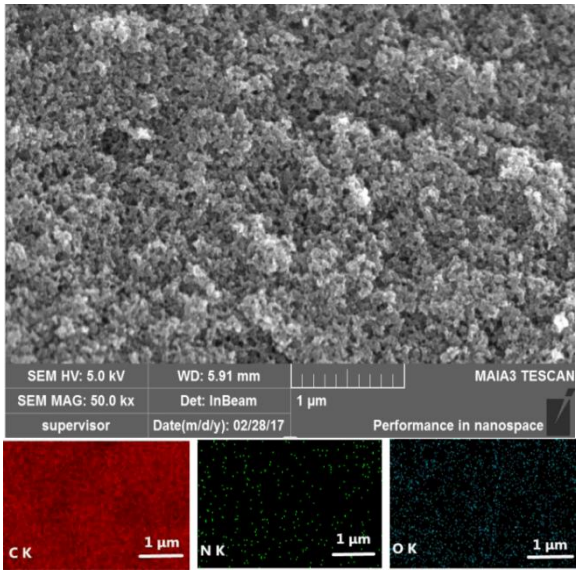

Fig 3. SEM images and mapping

FT-IR spectra of sodium alginate and obtained carbon material are displayed in Fig. 4. The peaks of obtained carbon material at 1639, 1579, 1411 and 1060 cm^{-1} were attributed to C=N, C=C, C-N and C-O bonds[7], respectively. The broad bands at 3130–3430 cm^{-1} could be ascribed to O-H and N-H bonds[8]. These findings reveal that N and O elements have been successfully doped into carbon material.

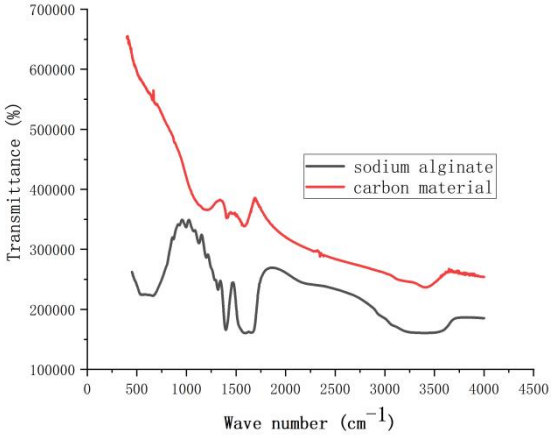

Fig 4. FT-IR spectra

XPS is widely used in the element composition and valence analysis of material surface. XPS combined with imaging function and ion sputtering etching, can be used for surface distribution and depth analysis of element composition and valence state on solid surface[9-10]. Fig. 5 (a), (b), (c) showed magnified C1s, N1s and O1s spectra, respectivityly.

As presented in Fig. 5(a), C1s of CM could be deconvoluted into 4 individual component peaks. Besides, the peaks of N1s could be deconvoluted into 4 peaks[11]. The binding energies for O1s could be divided 4 peaks.

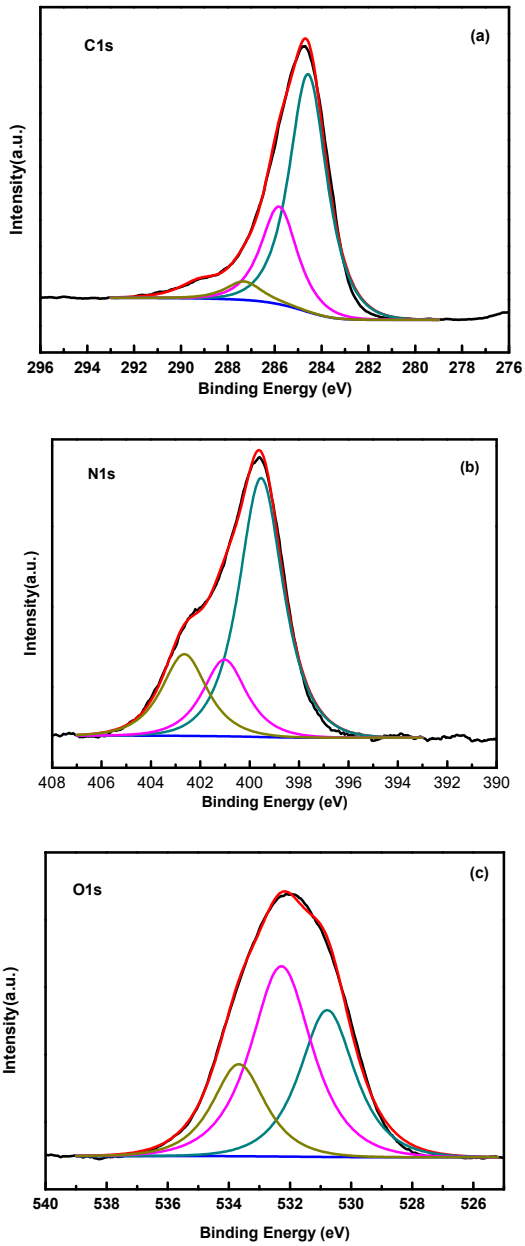

Fig 5 XPS spectrum

The methods used to measure include XRD and Raman spectroscopy. The XRD spectrum (Figure 6) shows two diffraction peaks of about 24.1 and 43.5°, respectively accounting for (002) and (101) diffraction peaks of graphite carbon[12]. Carbon material is composed of symmetrical C-C covalent bonds. Even if the structure of this carbon material changes slightly, they can be detected[13]. Raman spectra (Figure 7) clearly showed peaks at 1347/cm and 1534/cm. I_D/I_G is shown in Figure 7, I_D/I_G=0.76 was lower than that of Commercial activated carbon.

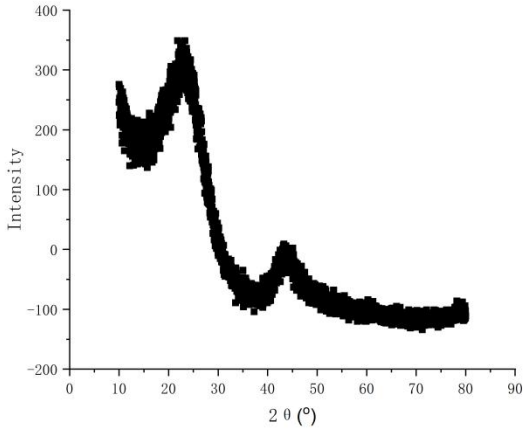

Fig.6 XRD

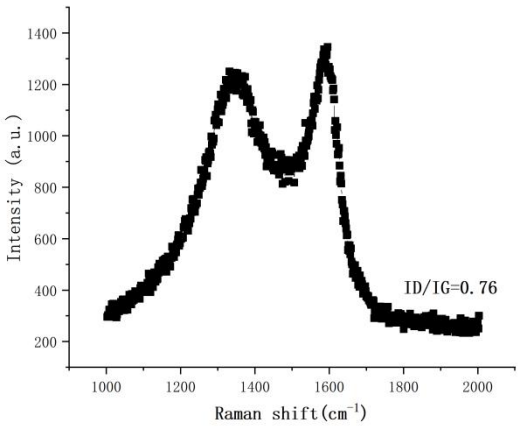

Fig. 7 Raman spectra

This article mainly introduces in detail the method for measuring the CO_2 equivalent adsorption heat of activated carbon materials. In the experiment, the activated carbon sample was tested for the isotherm of CO_2 adsorption by the 3Flex gas adsorption instrument of Mack Instruments. The constant temperature of the sample during the test was controlled by the iso controller low-temperature thermoelectric refrigeration dewar. After the test is completed, calculate the equivalent adsorption heat for all surface coverage ranges (from zero to saturation) using MicroActive software from Mac Instruments. With the increasing attention to climate change and environmental protection, the capture and storage of CO_2 has received significant attention from media, scientific research, and public policies[14-15].

The CO_2 adsorption performance of samples was measured, and the isotherm is shown in Figure 8. All isotherm have no hysteresis, showing the reversibility of adsorption and desorption, indicating that these materials can easily desorb adsorbate during the desorption process. Therefore, the materials obtained can be recovered without need others. The CO_2 adsorption isotherm shows a growth trend, especially at lower pressure, because CO_2 has excellent polarizability and quadrupole moment, and has strong interaction with the prepared materials[16]. From Figures 4 and 5, adsorption capacity of material for

CO_2 at 273 K and 298 K is 2.75 and 2.19 mmol g^{-1}, respectively.

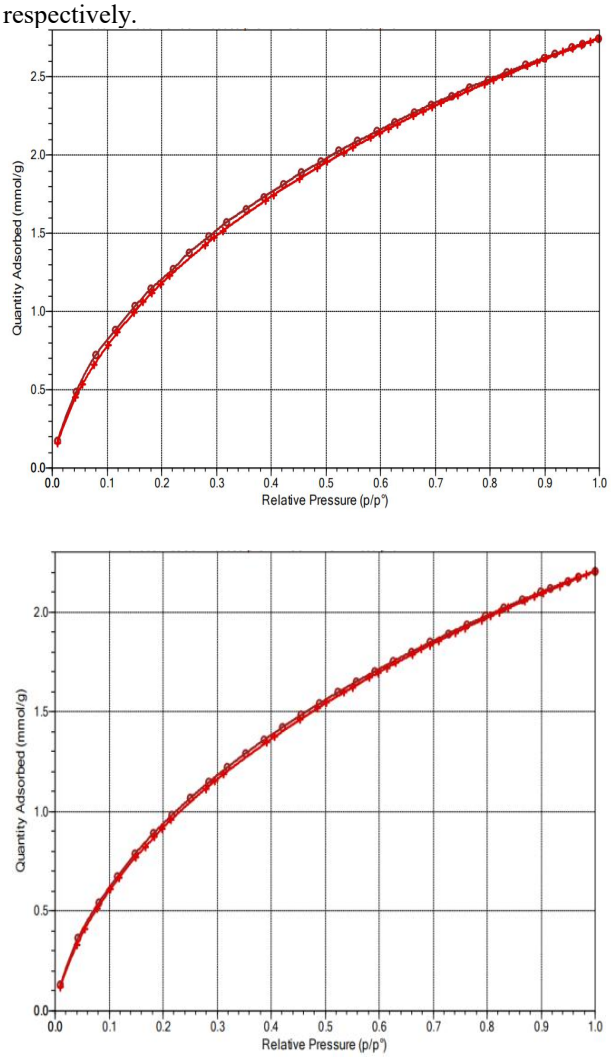

Fig 8. CO_2 adsorption performance

4. Conclusion

With sodium alginate as raw material and zinc chloride as activator, the BET of 573 cm^2/g and pore volume of 0.53 cm^3/g were prepared. Most pores are mesopores. Zinc chloride acts as an activator and pore forming agent. Nitrogen and oxygen were successfully doped into the material. Adsorption capacity of the material for CO_2 at 273 K and 298 K is 2.75 and 2.19 mmol/g, respectively. Therefore, the obtained carbon material is a CO_2 adsorption material with potential application value.

Acknowledgments

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