

Preparation and Adsorption Properties of Polyethylenimine Containing Fibrous Adsorbent for Carbon Dioxide Capture

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ABSTRACT: We successfully prepared a novel fibrous adsorbent for carbon dioxide (CO₂) capture by coating polyethylenimine (PEI) on a glass fiber matrix, using epoxy resin (EP) as crosslinking agent. The physicochemical properties of the fibrous adsorbents were characterized in terms of Fourier transform infrared spectrometry and thermogravimetric analysis. Factors that affected the adsorption capacity of the fibrous adsorbent were studied, including the crosslinking agent dosage, coating weight, moisture, adsorption temperature, and CO₂ concentration of the simulated flue gas. The experimental results indicate that the properly crosslinked fibrous adsorbent had a high thermal stability at about 280°C. With a PEI/EP ratio of

10:1, a maximum adsorption capacity of 276.96 mg of CO₂/g of PEI was obtained at 30°C. Moisture had a promoting influence on the adsorption of CO₂ from flue gas. The CO₂ adsorption capacity of the fibrous adsorbent in the presence of moisture could be 19 times higher than that in dry conditions. The fibrous adsorbent could be completely regenerated at 120°C. The CO₂ adsorption capacity of the regenerated fibrous adsorbent was almost the same as that of the fresh adsorbent. © 2008 Wiley Periodicals, Inc. *J Appl Polym Sci* 108: 3851–3858, 2008

Key words: adsorption; fibers; polyamines; separation techniques

INTRODUCTION

People in the rapidly developing economic world are dependent on fossil fuels for 85% of their energy;¹ fossil fuels will remain the main source of global energy for a long time into the future.² The problem caused by massive emission of carbon dioxide (CO₂), which results from the burning of fossil fuels (coal, gas, and oil), has been a worldwide issue. Today, about 290 billion tons of CO₂ are released into the air annually by human activities,³ including 230 billion tons from fossil fuel burning and industry. With the aggravating burden to the environment, the worldwide problem of the global warming has come up. As a result, the reduction of the emission of CO₂ has received a great deal of current interest.^{4–14}

Carbon sequestration, of which the first step is the capture and separation of CO₂ from the waste gas, has been proven an effective way of mitigating global climate warming, with no decrease in the use of fossil fuels.^{15,16} The liquid amine-based process, which uses monoethanolamine, diethanolamine, or methyldiethanolamine, is the most common method for CO₂ capture in commerce that can effectively remove CO₂.¹⁷ However, the problem of high regeneration energy, large equipment size, solvent degradation, and equipment corrosion makes the process impractical for further application.¹⁸

To overcome the disadvantage of the liquid amine-based process, several technologies, such as adsorption, cryogenic, and membrane technologies, have been studied for capturing and separating CO₂; adsorption has received much attention for its low energy consumption, low equipment cost, and ease of application. Consequently, it is a key issue for the development of a novel regenerable adsorbent of high CO₂ adsorption capacity.

A fibrous adsorbent with polyethylenimine (PEI) coating on polypropylene fibers was first reported by Andreopoulos and Economy.¹⁹ High adsorption capacities of this fibrous adsorbent for acidic gases were achieved. In this study, we prepared a fibrous adsorbent for CO₂ capture by coating PEI on glass

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fibers with bisphenol A epoxy resin (EP) as the crosslinking agent. The high surface area of the glass fiber was beneficial for enhancing the CO₂ capacity. The effects of the temperature, PEI/EP ratio, coating weight, and moisture on CO₂ adsorption were examined; meanwhile, the physicochemical properties of the material were characterized.

EXPERIMENTAL

Preparation of the fibrous adsorbent

The fibrous adsorbent of PEI coating on glass fibers, PEI fiber for short, was prepared by a wet impregnation method. In a typical preparation, water-free PEI (number-average molecular weight = 10,000, weight-average molecular weight = 25,000, Aldrich Co., St. Louis, MO, USA) was dissolved in methanol at a weight ratio 1 : 2, and EP (weight-average molecular weight = 370, Shell Chemical Co., London, England) was dissolved in dimethylformamide to prepare a 50 wt % solution. The PEI and EP solutions were mixed at different ratios of PEI to EP under stirring and were then diluted with methanol to 20 wt % total component (PEI + EP) solutions. The glass fiber (diameter = 10 μm, Changzhou Changhai GERP Products Co., Ltd., Changzhou, China), used as a substrate, was immersed in the diluted solution for 6 h and was then dried at 80°C for 6 h. For the comparison, the weight ratios of PEI to EP were 1 : 1 to 30 : 1, and the coating layer weight was 15–287%; the PEI fibers thus obtained were labeled FA-R_{x:y}-W_z, where *x:y* is the mass ratio of PEI to EP and *z* is the weight percentage of the PEI and EP coating layer (equal to the mass of the PEI and EP coating divided by the mass of the glass fiber).

Characterization of the fibrous adsorbent

The morphology of the glass fiber was obtained with a ZOOM 645S series stereo microscope (SSM, Shanghai, China). The infrared spectra were obtained in the 4000–800 cm⁻¹ with a Nicolet 670 Fourier transform infrared instrument (Nicolet Instrument Co., Madison, WI, USA) with the materials placed on the microsample holder. A NetzschTG-209 thermogravimetric analyzer (Bavaria, Germany) was used for the thermogravimetric analysis. We carried out the experiments by heating the PEI fiber from 50 to 700°C at a constant rate (20°C/min) with the flux of the protective gas (nitrogen) and sweeping nitrogen being 20 and 40 mL/min, respectively. The nitrogen adsorption isotherm of the fiber was measured with an ASAP 2020 apparatus.

Water adsorption measurement

The adsorption capacity for water was calculated according to the differences in the weight before and

after the adsorption for water. The PEI fiber was outgassed at 80°C *in vacuo* for 24 h before adsorption; then, it was placed in a tube, into which a water vapor flow was switched to pass until the weight of the PEI fiber maintained a constant.

CO₂ adsorption measurement

The CO₂ adsorption performance of the PEI fiber was measured by an Agilent 6820 gas chromatograph (Agilent Technologies, Inc. Shanghai, China). In an adsorption/desorption process, about 1 g of PEI fiber was outgassed at 80°C *in vacuo* and was placed in a columned sample tube, in which a dry nitrogen flow was introduced to pass through at a flow rate of 20 mL/min for 10 min to remove the air and moisture in the tube. The length and radius of the columned sample tube were 10 and 1 cm, respectively. The adsorbent filled the sample tube in a random state. Then, the dry or moist CO₂/N₂ mixture gas was introduced through the tube at a flow rate of 25 mL/min. The flow rate of the gas was controlled by electronic flow control instruments. We produced the moisture by bubbling the gas through water, and the relative humidity was measured by a hygrometer. In the CO₂ adsorption experiments, the relative humidity was controlled to about 80%. The concentration of CO₂ in the effluent gas was analyzed at regular intervals with an Agilent 6820 gas chromatogram. After adsorption, the PEI fiber was heated to 120°C for 30 min to be regenerated.

RESULTS AND DISCUSSION

Characterization of the fibrous adsorbents

Figure 1 shows the morphology of the glass fiber without any coating material, and the IR spectra of the PEI fiber are presented in Figure 2. For the sample with PEI only [Fig. 2(1)], the broad adsorption band at 3700–2980 cm⁻¹ corresponded to the stretching vibration of O–H and N–H, and the peaks near 2940 and 2828 cm⁻¹ were due to the stretching vibration of methylene. The double peaks at 1360 and 1380 cm⁻¹ came from the symmetry bend vibration of dimethyl in the spectra of the sample with EP only [Fig. 2(2)], and the peak at 915 cm⁻¹ was the characteristic adsorption peak of an end epoxy group. In the spectra of both PEI only and FA-R_{5:1}, the peaks at 3700–2980 cm⁻¹ were strong, which demonstrated that the amine compounds were coated on the glass fiber. In the spectrum of FA-R_{5:1} [Fig. 2(3)], the peak at 915 cm⁻¹ was not observed, which was the same in the spectra of other PEI fibers. One possible reason is that this peak was overlapped by the broad peak of PEI at 1234–828 cm⁻¹. Also, the end epoxy groups may have been consumed to form a crosslinking structure.



Figure 1 Morphology of the glass fiber. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Thermogravimetric analysis thermograms of the PEI fibers are presented in Figure 3. FA-R_{10:1} [Fig. 3(3)] showed a 0.32% weight lost at 100°C because of the desorption of CO₂, moisture, and some other gases adsorbed. When heated to 200°C, FA-R_{10:1} exhibited a 3.17% weight loss, and the temperature at 5% weight loss was 240.22°C; in other words, FA-R_{10:1} retained its thermal stability at 240.22°C. FA-R_{1:1} [Fig. 3(1)] showed a 0.25% weight loss at 100°C, which was also attributed to the desorption of CO₂, moisture, and some other adsorbed gases. FA-R_{1:1}, which had the best thermal stability, retained its thermal stability at 278.76°C, whereas FA-R_{5:1} [Fig. 3(2)] only retained its thermal stability at 269.96°C. As the PEI/EP ratio increased, that is, as the crosslinking density decreased, the thermal stability tem-

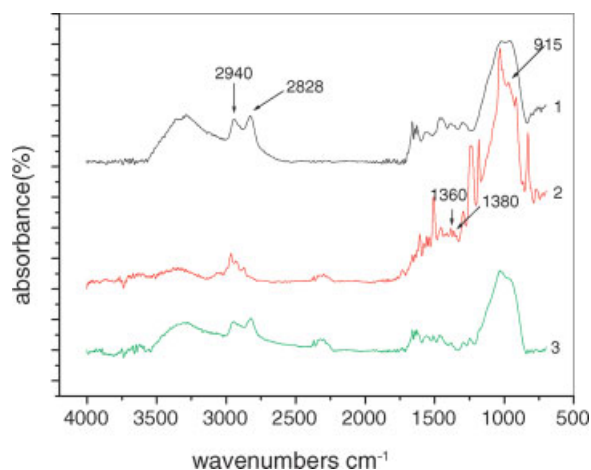


Figure 2 IR spectra of (3) the PEI fiber FA-R_{5:1} and its related (1) component PEI and (2) EP. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

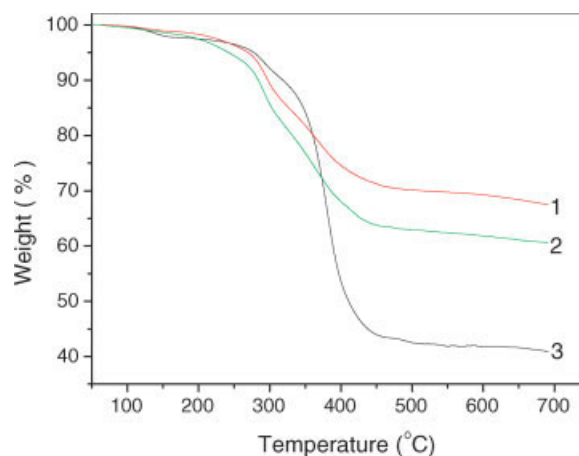


Figure 3 Thermal stability of the PEI fibers with different PEI/EP ratios: (1) FA-R_{1:1}, (2) FA-R_{5:1}, and (3) FA-R_{10:1}. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

perature of the PEI fiber decreased. The results show that the proper crosslinking agent dosage was propitious for the formation of the network structure of the crosslinking agent with amine and for the improvement of the thermal stability of the PEI fibers. The results also show that the properly crosslinked PEI fiber retained its thermal stability well at about 280°C.

Water adsorption amount

The water adsorption capacity of the PEI fiber, as shown in Figure 4, increased with increasing coating weight. For FA-R_{1:1}-W₁₅, the water adsorption capacity was only 32 mg of H₂O/g of adsorbent. Then, with a higher coating weight, the PEI fiber showed a larger water adsorption capacity. For example, for FA-R_{1:1}-W₂₉₀, the adsorption capacity was 1029 mg of H₂O/g of adsorbent, which was 31 times higher than that of FA-R_{1:1}-W₁₅.

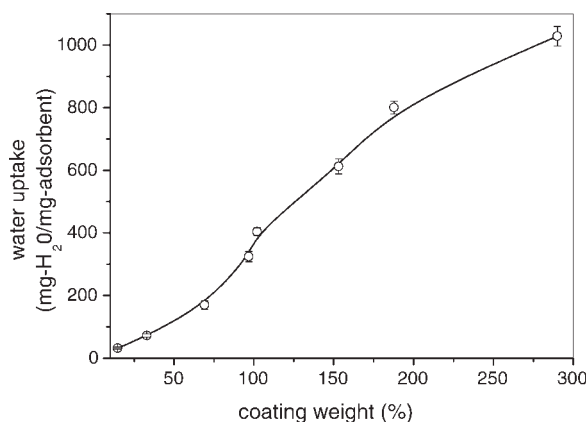


Figure 4 Plots of water adsorption capacity versus coating weight of FA-R_{1:1}.

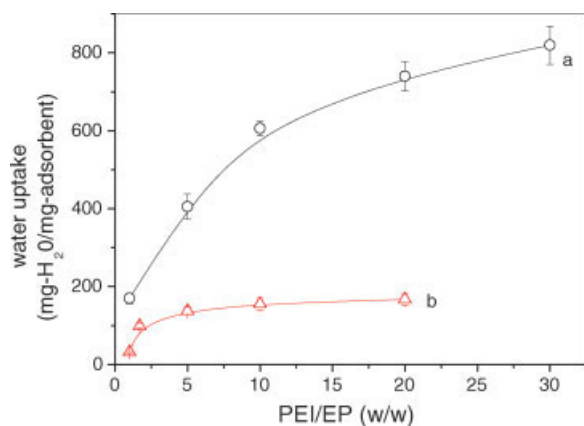


Figure 5 Effect of PEI/EP ratio on the water adsorption capacity of the PEI fibers (a) FA- W_{70} and (b) FA- W_{20} . [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

As shown in Figure 5, when the PEI/EP ratio increased, in other words, when the crosslinking agent content decreased, the water adsorption capacity increased. For FA- W_{70} [Fig. 4(a)], when the PEI/EP ratio increased from 1 : 1 to 30 : 1, the water adsorption capacities increased from 106 to 820 mg of H_2O/g of adsorbent for FA- W_{70} [Fig. 4(a)], whereas that of FA- W_{20} [Fig. 5(b)] increased from 32 to 167 mg of H_2O/g of adsorbent with an increasing PEI/EP ratio from 1 : 1 to 20 : 1. This reveals that the densely crosslinked PEI fiber showed a lower water adsorption capacity than the more loosely crosslinked PEI fiber. With increasing crosslinked agent dosage, the amount of uncrosslinked amine groups decreased. Because the adsorption of water relied on the amount of amine groups that could chemically bond with water, the decrease in uncrosslinked amine groups resulted in the decrease in the water adsorption capacity.

CO₂ adsorption

Effect of the PEI/EP ratio on the CO₂ adsorption capacity

The breakthrough curves of CO₂ adsorption for PEI fibers with different PEI/EP ratios with a 70% coating weight are shown in Figure 6, where C_0 and C are the concentrations of the influent and effluent gases, respectively. At the very beginning, CO₂ was completely adsorbed by the PEI fiber. Then, increasing inlet gas, C gradually increased. In about 30–40 min, the adsorption of CO₂ reached equilibrium. The equilibrium adsorption capacities of the fibers at the dynamic adsorption condition, calculated on the basis of total adsorbent mass and PEI coating mass, are presented in Figure 6(a). Among the four PEI fibers, FA- $R_{10:1}$ had the highest CO₂ adsorption capacity of

89.11 mg of CO₂/g of adsorbent, which was equal to 276.96 mg of CO₂/g of PEI, with a utilization of 30%. The surface area of FA- $R_{10:1}$ - W_{70} was 2.45 m²/g, which was obtained by the calculation of the mass and radius of the glass fiber. However, the Brunauer–Emmett–Teller surface area of FA- $R_{10:1}$ - W_{70} on the basis of the nitrogen adsorption isotherm was 3.65 m²/g, which was close to the calculated value of the glass fiber. It appeared that PEI coated on the surface of the glass fiber just formed a membrane with few microspores formed, which contributed little to the surface area. Also, a PEI membrane may have formed between the filaments of glass fiber. Thus, PEI had more efficient contact with CO₂, which led to a higher adsorption speed and a larger adsorption capacity, although FA- $R_{1:1}$ showed the lowest adsorption capacity of 117.86 mg of CO₂/g of PEI, which was near 40% of that the capacity of FA- $R_{10:1}$. So it was obvious that the CO₂ adsorption capacity increased with PEI/EP ratio.

With plentiful amine groups, PEI can combine with CO₂ and H₂O to form carbamate or bicarbonate in a humid conditions. As shown in eqs. (1)–(6), 1 mol of amine group can react with 1 mol of CO₂:

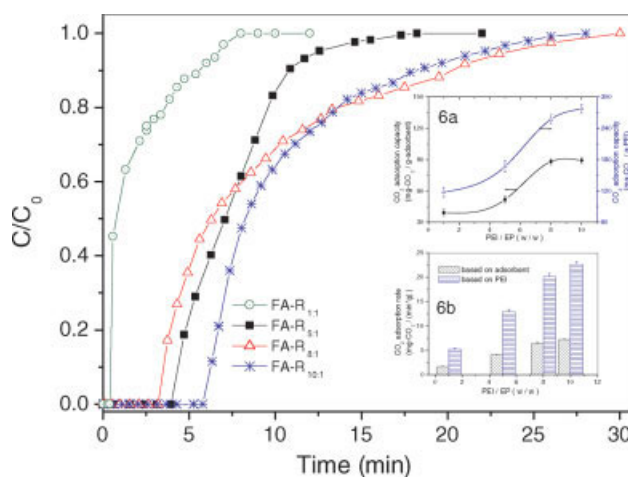
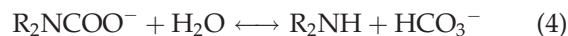
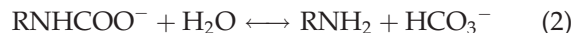


Figure 6 Comparison of the dynamic adsorption of CO₂ on PEI fibers with different PEI/EP ratios: (a) dynamic CO₂ adsorption capacities and (b) average CO₂ adsorption rate of the PEI fibers (temperature = 30°C, feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

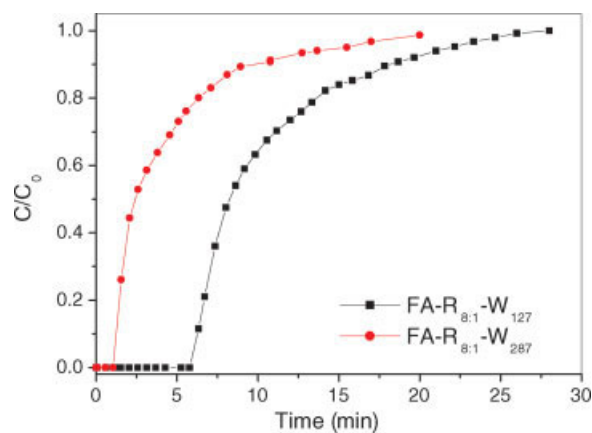


Figure 7 Comparison of the CO₂ breakthrough curves of different coating weights (temperature = 30°C, feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]



Equation (1) shows the process of formation of carbamate ion from a primary amine, which is hydrolyzed by water and regenerates an amine molecule [eq. (2)] and the secondary amines [eq. (3)]. These reactions make the adsorption of CO₂ faster, whereas the primary amines have better kinetics properties than the secondary amines. The kinetics for CO₂ capture by tertiary amines are the slowest because of the slower formation rate of bicarbonate ion (R5) than that of carbamate.¹⁷

In the preparation of the PEI fibers, EP was added to form a network structure, which should have improved the thermal stability and other properties of the adsorbents. However, H atoms of the amines were consumed to make amine crosslink with EP; as a result, the primary amines crosslinked turned into secondary amines, and the secondary amines crosslinked became tertiary amines. Consequently, with the increase in crosslinking agent dosage, the amount of primary and secondary amine groups decreased, which caused the slowing down of the adsorption rate for CO₂ capture.

The average adsorption rates of the adsorbents in the first 10 min are presented in Figure 6(b). For FA-R_{1:1} and FA-R_{5:1}, the adsorption rates were 5.25 and 12.93 mg of CO₂/(g of PEI min), respectively, and the adsorption rate enhanced to 20.14 mg of CO₂/(min g of PEI) for FA-R_{8:1}, whereas that of FA-R_{10:1} was 22.69 mg of CO₂/(min g of PEI), which was 3.32 times higher than that of FA-R_{1:1}. Generally, the CO₂ adsorption rate increased with decreasing crosslinking agent dosage; this agrees well with the previous analysis.

Effect of the coating weight

As shown in Figure 7, the adsorption rate was rapid in the beginning phase, which led to a near-zero concentration of CO₂ in the effluent gas for several minutes. FA-R_{8:1}-W₁₂₇ lasted a longer time for complete adsorption than FA-R_{8:1}-W₂₈₇. However, the CO₂ adsorption capacity increased with the decreasing coating weight, as shown in Figure 8. For FA-R_{8:1}-W₂₈₇, the CO₂ adsorption capacity was 29.13 mg of CO₂/g of adsorbent, which was equal to 46.64 mg of CO₂/g of PEI, whereas FA-R_{8:1}-W₇₀ had the highest capacity of 257.32 mg of CO₂/g of PEI, 4.5 times higher than that of FA-R_{8:1}-W₂₈₇. The same trend was also shown in another series of samples with a PEI/EP ratio of 10:1. The thickness of the adsorbents increased as result of the increasing coating weight, which caused the transfer route of CO₂ to be longer. In other words, the inner PEI could not be used effectively. Therefore, the CO₂ adsorption capacity per mass unit decreased with the increase in coating weight.

Effect of moisture

Figure 9 shows the CO₂ breakthrough curve of FA-R_{10:1}, with simulated dry and moist flue gas. In moist conditions, CO₂ was adsorbed completely for the first 6 min. With the slow increase in *C*, the adsorption reached equilibrium at last. However, in dry conditions, the initial value of *C/C*₀ was higher than 80%. Totally, the CO₂ adsorption capacity was 276.96 mg of CO₂/g of PEI in moist conditions, whereas it was only 13.84 mg of CO₂/g of PEI in dry conditions.

The chemical reactions between amine and CO₂ are different in dry conditions and humid conditions. As mentioned previously, 1 mol of amine

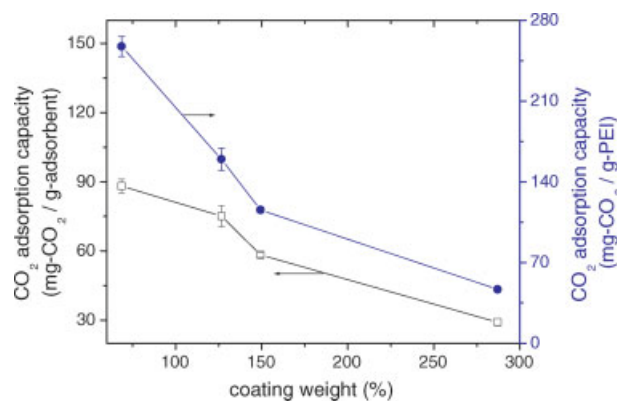


Figure 8 Plots of CO₂ adsorption capacity versus coating weight of the PEI fibers (temperature = 30°C, feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

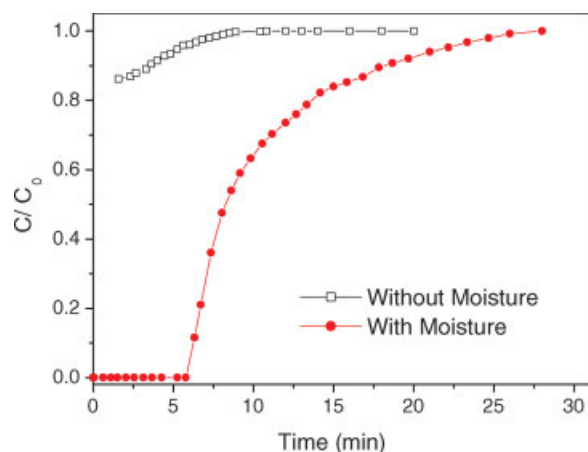


Figure 9 Comparison of the adsorbed volumes of CO₂ from simulated dry and moist flue gases (temperature = 30°C, feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

group can adsorb 1 mol of CO₂ in humid conditions. In dry conditions, the main reaction is the formation of carbonate, as shown in eqs. (1), (2), and (7); 2 mol of amine is consumed to adsorb 1 mol of CO₂, which will, therefore, limit the CO₂ adsorption capacity. Also, the dissolution of CO₂ in water might increase the adsorption capacity:



To make clear which factor mainly determined the adsorption capacity, the adsorption of CO₂ by the glass fiber matrix without any coating materials was carried out in dry and humid conditions. The CO₂ adsorption capacities turned out to be 28.90 and 27.53 mg of CO₂/g of adsorbent, respectively, which revealed that the humid conditions had little influence on the CO₂ adsorption for glass fiber. Accordingly, the remarkable difference between the adsorption capacities in dry and moist conditions was attributed to the different chemical reactions of the PEI coating with CO₂ with the presence and absence of moisture. Also, the PEI fibers were swollen after the adsorption of water, which favored the diffusion of CO₂ and could have improved the CO₂ adsorption.

Effect of the CO₂ concentration of the simulated flue gas

From 0.6% in a spaceship²⁰ to 15% for most of the coal combustion systems,²¹ the concentration of CO₂ varies in different conditions. It was necessary to investigate the effect of CO₂ concentration of the influx on adsorption capacity of the adsorbents. The

CO₂ breakthrough curves of FA-R_{10:1} for different CO₂ concentration are presented in Figure 10. It appeared that the PEI fibers effectively captured CO₂ in a range from 8 to 16%. They completely adsorbed and removed CO₂ from the simulated flue gas at the beginning even when the initial concentration of CO₂ was as high as 16%. From the experimental results, the dynamic adsorption capacity of the PEI fiber was closely related to the initial concentration of CO₂. With an initial concentration of 16%, the CO₂ adsorption capacity was 276.96 mg of CO₂/g of PEI. However, when the concentration decreased to 12%, the CO₂ adsorption capacity decreased to 251.65 mg of CO₂/g of PEI. With a concentration of 8%, the adsorption capacity decreased to 223.24 mg of CO₂/g of PEI, which was about 19.4% lower than that at the 16% concentration. The CO₂ concentration of the influent gas had a remarkable influence on the CO₂ adsorption capacity of the PEI fibers. In theory, the time spent before breakthrough in the lower CO₂ concentration condition should have been longer than that in a higher CO₂ concentration condition. However, it was interesting that the time spent before breakthrough of the three curves were all about 6 min, and 25 min was needed for the adsorption to reach equilibrium, which indicated that the PEI fiber had a high adsorption rate for CO₂.

Effect of the adsorption temperature

The breakthrough curves of CO₂ adsorption on PEI fibers at different temperatures are shown in Figure 11. With a temperature of 30°C, there was no CO₂ penetrating at the first phase; however, when

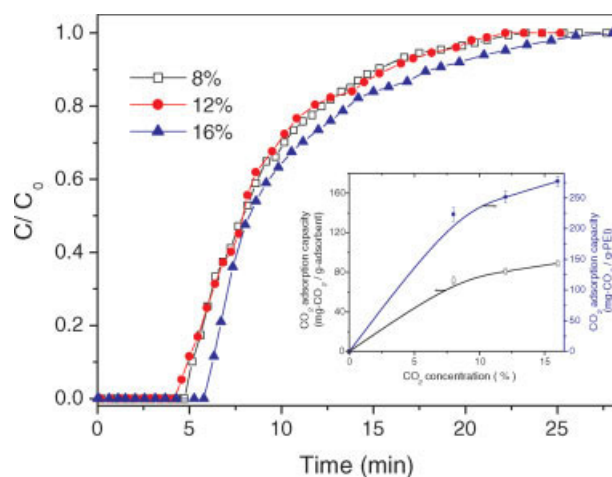


Figure 10 Comparison of the CO₂ breakthrough curves for different CO₂ concentrations of the simulated flue gas. The insert illustrates the CO₂ adsorption capacity (temperature = 30°C, feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

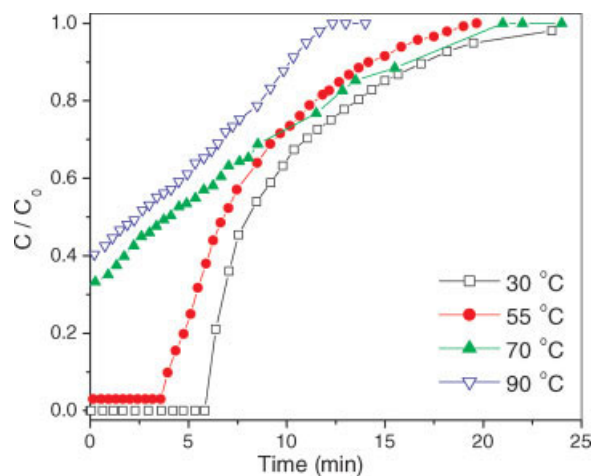


Figure 11 Comparison of the CO₂ breakthrough curves for different temperatures (feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

the temperature increased, CO₂ could not be adsorbed completely, and about 2.96% of the CO₂ permeated at 55°C. With further increasing temperature, the amount of CO₂ permeating increased.

The amount of CO₂ adsorbed was calculated with the mass unit of both PEI on the adsorbents and total adsorbent, and the results are presented in Figure 12. The PEI fiber could adsorb 276.96 mg of CO₂/g of PEI at 30°C. However, when the temperature increased, the CO₂ adsorption capacity tended to decrease, for the reaction of CO₂ and PEI was an exothermic process.²² At 55 and 70°C, the adsorption capacities were 234.78 and 209.43 mg of CO₂/g of PEI. When the temperature increased to 90°C, the adsorption capacity sharply decreased to 104.73 mg of CO₂/g of PEI. The results show the remarkable

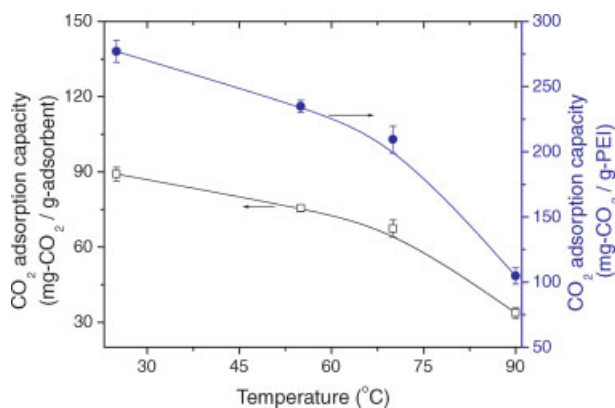


Figure 12 Plots of CO₂ adsorption capacity versus adsorption temperature (feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

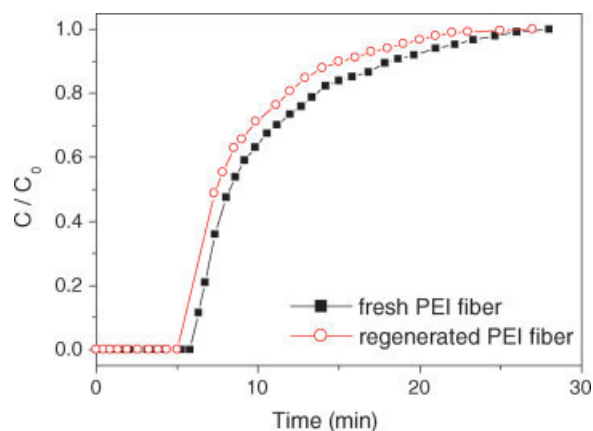


Figure 13 Comparison of the breakthrough curves for fresh and regenerated adsorbents (temperature = 30°C, feed flow rate = 25 mL/min, dry gas composition = 16% CO₂ and 84% N₂). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

effect of temperature on the CO₂ adsorption capacity. However, the CO₂ adsorption capacity could still maintain a value higher than 100 mg of CO₂/g of PEI at 90°C.

Regeneration of adsorbents

For long-term use, the PEI fiber should be able to be regenerated. The regeneration of PEI fibers was carried out at 120°C for 30 min, and the CO₂ breakthrough curve of FA-R_{10:1}-W₇₀ is presented in Figure 13. The breakthrough curve for the regenerated adsorbent [Fig. 13(b)] was similar to that for the fresh PEI fiber [Fig. 13(a)]. The CO₂ adsorption capacity for the regenerated adsorbent was 258.35 mg of CO₂/g of PEI, whereas that for the fresh PEI fiber was 276.96 mg of CO₂/g of PEI. This revealed that the PEI fiber could maintain its adsorption capacity for CO₂ very well and that desorption was complete and adsorbent was stable in the adsorption and renew processes.

CONCLUSIONS

We developed fibrous PEI adsorbents with high CO₂ adsorption capacities by coating PEI crosslinked with EP onto glass fibers. The CO₂ adsorption capacity of the adsorbent at 1 atm, 30°C, and about 80% relative humidity could reach 27.7% of the adsorbent weight with a utilization of 30%. The CO₂ adsorption was greatly facilitated by water vapor, which may have created a liquid–gas environment. With the absence of water vapor, the obvious adsorption of CO₂ was not observed in this kind of adsorbent.

Factors that affected the performance of the adsorbents included the thickness of the coating, the ratio of PEI to EP of the coating, moisture, the CO₂ concentration in the simulated flue gas, and the adsorption temperature. A concentration of 86.96% PEI in the coating composition was the proper proportion for achieving a high adsorption capacity. Moisture had a promoting influence on the adsorption of CO₂ from the flue gas; the CO₂ adsorption capacity of the PEI fiber in the presence of moisture was 19 times higher than that in dry conditions. The CO₂ adsorption capacity of this novel adsorbent still reached 104.73 mg of CO₂/mg of PEI even at 90°C. The adsorbent was completely regenerated by heating to 120°C.

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