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Application of ultrasound irradiation for absorption and desorption of CO_2 gas in MEA solvent

MEA 溶媒の CO_2 吸脱着における超音波利用の検討

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1. Introduction

Chemical absorption using an aqueous alkanolamine solution is one of the most mature technologies for CO_2 capture. Aqueous monoethanolamine (MEA) is an important absorbent in CO_2 removal process because MEA has several advantages over other alkanolamines, such as higher reactivity [(1)], lower solvent cost, lower molecular weight and higher absorption capacity on a weight basis. Absorption capacity of MEA depends on the ambient temperature and pressure and the solvent concentration. At low temperature and high pressure conditions, absorption capacity increases by 30wt%. However desorption of CO_2 from amine solvent and regeneration of alkanolamine solvent needs high temperature and consumes a lot of energy.

It is known that chemical reactions and physical actions are induced by cavities that appear during the ultrasound irradiation of aqueous solvent. Physical action generated by ultrasound irradiation has been used for degasifying in solutions.

In this study, ultrasound irradiation was utilized for low-energy desorption of CO_2 gas in MEA solvent. In addition, the effect of ultrasound irradiation on CO_2 absorption process was investigated.

2. Experiment

In this experiment, absorption and desorption of CO_2 gas in MEA solvent were investigated using two types of ultrasound frequencies (200 kHz/200 W, 28 kHz/200 W). The same experiments were conducted using stirrer (stirring speed 1000 rpm) to compare with results of the ultrasound irradiation.

2.1 CO_2 absorption experiment

MEA solvent (1M, 50 ml) was prepared using ion-exchange water. CO_2 gas was injected into the solvent at 100 ml/min flow rate under constant temperature (25°C, 60°C or 80°C) while ultrasound irradiation or stirring were applied for 20 min. The amount of absorbed CO_2 was estimated by the increase the amount of carbon in the solvent using a total organic carbon measurement system.

2.2 CO_2 desorption experiment

CO_2 desorption experiment was conducted also by applying stirring or ultrasound irradiation to MEA solvent that had absorbed CO_2. This MEA solvent was prepared by CO_2 gas injection (100 ml/min) into MEA solvent (1M, 500 ml) and stirring (1000 rpm) for 20min at 25°C. The experiments were performed under argon (Ar) or nitrogen (N_2) atmosphere (100 ml/min) at the constant temperatures (25, 60 or 80°C) for 20min. Finally, the amount of CO_2 desorption was evaluated by the weight loss of the solvent after various treatment.

3. Results and Discussions

3.1 CO_2 absorption experiment

Figure 1 shows changes in amount of absorbed CO_2 gas and pH value in MEA solvent during ultrasound irradiation for 60min. The decrease in pH value indicates that CO_2 was absorbed into MEA solvent (strongly basic alcohol). This figure shows that the amount of CO_2 absorption in MEA solvent treated by 200 kHz irradiation is higher than that treated by 28 kHz. In addition, the pH value in MEA solvent treated by 200 kHz decreased more than that treated by 28 kHz. Thus 200 kHz sonication is more effective than 28 kHz sonication for CO_2 absorption into MEA.

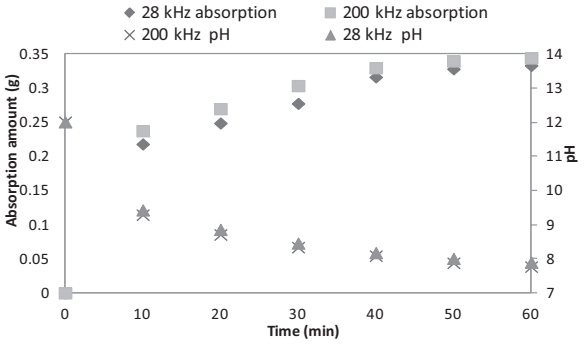

Fig.1 Absorption amount of CO_2 gas and pH value of solvent during CO_2 injection with ultrasound irradiation

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Figure 2 shows effects of stirring speed (250, 500, 750 and 1000 rpm) and solvent temperature (25, 60 or 80°C) on the amount of CO_2 absorbed in MEA solvent (1M). First we measured the amount of CO_2 absorption at various stirring speed at 25°C. After elapsed time of 20 minutes, the absorption amount reached approximately constant. The amount of absorption increases as stirring speed became faster, but reached its maximum at 750 rpm as absorption amount with stirring speed of 1000 rpm was not different from that with 750 rpm. Therefore, increasing of stirrer speed could increase absorption amount up to 750 rpm.

On the other hand, effect of temperature at 1000 rpm constant, lower temperature could increase absorption amount. This result was corresponding with previous research results.

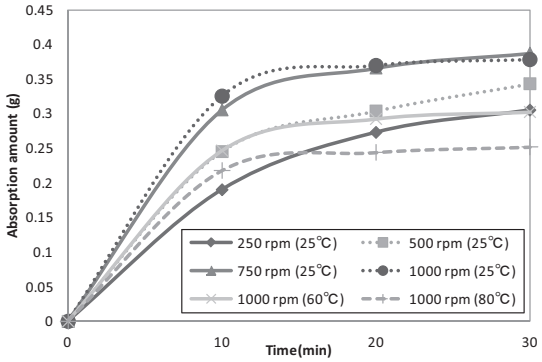

Fig.2 Effects of stirring speed and solvent temperature on CO_2 absorption amount of MEA (1M)

3.2 CO_2 desorption experiment

It is known that Ar and N_2 readily generate cavitations when ultrasound irradiation is applied. Therefore these gases may advance CO_2 desorption efficiency. In addition, gases of higher specific heat ratio introduce chemical action. Thus Ar (specific heat ratio = 1.67) was used and injected into the solvent at the flow rate of 100 ml/min during sonication or stirring. For comparison with Ar gas, N_2 gas (specific heat ratio = 1.40) was also used and the effects of chemical reaction generated by ultrasound irradiation for CO_2 desorption from MEA was evaluated. The desorption rate (%) was calculated by the following formula; desorption amount / absorption amount $\times 100$.

Figure 3 shows the effect of temperature on desorption rate of CO_2 in MEA solvent stirred at 1000 rpm under atmospheres rich in different inactive gases. These results show that CO_2 desorption rate heavily depended on the solvent temperature.

Figure 4 shows effects of ultrasound frequency and temperature on CO_2 desorption rate under inactive gases (Ar, N_2). There was no difference in desorption rate between Ar and N_2 atmospheres, suggesting that chemical reaction such as radicals did not contribute to desorption of CO_2 from MEA. CO_2 desorption rate using 28 kHz ultrasound was higher than that using 200 kHz at low temperature condition. Due to the amount of dissolved gas became less with increasing solvent temperature, this results opposite from the absorption experiment (Fig.1). Thus, we reasoned that physical actions generated by ultrasound irradiation into the solvent help desorption of CO_2 from MEA.

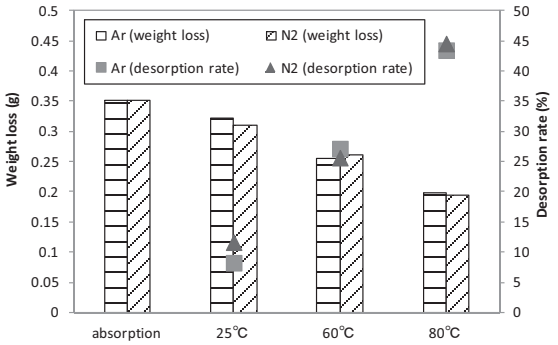

Fig.3 Weight loss of solvents and CO_2 desorption rate using stirrer at Ar and N_2 atmospheres

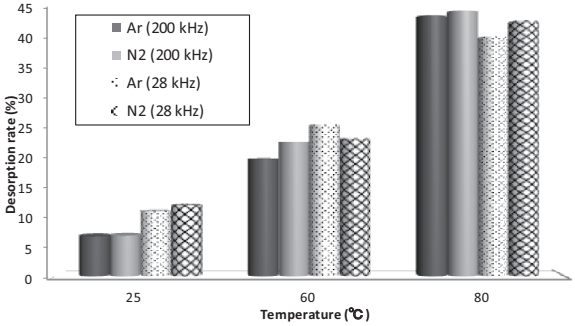

Fig.4 Effect of the solvent temperature on CO_2 desorption rate using ultrasound irradiation for 20 min

4. Conclusion

In this study, the amount of CO_2 absorption increased with lower temperature and faster stirrer speed. Comparison between two ultrasound frequencies revealed that 200 kHz is more effective in absorbing CO_2 than 28 kHz.

When ultrasound irradiation was applied instead of stirrer, 28 kHz ultrasound resulted in higher desorption rate than 200 kHz. In addition, there were no difference in the amount of CO_2 desorption between Ar and N_2 atmospheres during 200 kHz irradiation, suggesting that chemical reaction did not contribute. Therefore, we conclude that physical action, such as stirring effect, are important for desorption of CO_2 from MEA.

References

1. Young Eun Kim, Jin Ah Lim, Soon Kwan Jeong, Yeo Yoon, Shin Tae Bae, and Sung Chan Nam: Bull. Korean Chem. Soc. **3** (2013) 783