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論 文 要 旨
THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This research focuses on developing an effective carbon capture, utilization, and storage (CCUS) technique that reduces CO_2 emissions while minimizing energy requirement and ensuring environmental safety. The concept of utilizing alkanolamine-based absorbent through integrated absorption-mineralization (multicycle IAM) is proposed to maximize the effectiveness of CO_2 capture and utilization, operating under near-room temperature and atmospheric pressure.

The multicycle IAM process involves absorption, precipitation/ regeneration, and preparation. The main objectives are to improve CO_2 conversion and decrease absorbent degradation while reducing overall operation times. The absorption process involves using an alkanolamine absorbent to gather atmospheric CO_2 in the form of carbonate and bicarbonate ions. In the precipitation/ regeneration process, the ionic CO_2 is spontaneously transformed into solid carbonates through an aqueous carbonation approach using industrial waste brine. The brine waste from various industries such as oil refineries, power plants, and desalination industries require wastewater treatment at high cost. The use of multicycle IAM can provide a supplement of mineral ions and replace brine waste. The alkanolamine absorbent is continuously regenerated and nonreactive gas as nitrogen gas is injected to remove the existing acid gas before the CO_2 reabsorption in the subsequent cycle. The regenerated alkanolamine absorbent is repeatedly used to enhance precipitated carbonates and reduce toxicity to the environment. The production of high-purity solid carbonates through multicycle IAM presents a compelling economic advantage over conventional synthesis methods and is poised to gradually overtake the traditional production of solid carbonates in the near future.

Monoethanolamine (MEA), diethanolamine (DEA), triethanolamine (TEA), and aminomethyl propanol (AMP) were used as aqueous alkanolamine absorbents, as well as blended absorbents that have two amine components. The parameters of CO_2 absorption capacity and rate, CO_2 conversion, absorbent degradation, and energy consumption were evaluated during multicycle IAM. The optimization of the multicycle IAM process was achieved by prioritizing the conversion efficiency and absorbent degradation.

The first phase of the research focused on investigating the potential for CO_2 utilization through the production of carbonate precipitation using multiple cycles of absorbent reuse. The results showed that the aqueous MEA absorbent was capable of capturing additional CO_2 gases and producing a higher amount of precipitated carbonate with a recovery rate of 50% compared to traditional IAM without recycled MEA. The evaluation of multicycle IAM with a 5 wt.% MEA absorbent concentration revealed that optimal performance was not achieved. The eight-cycle process resulted in a CO_2 conversion rate of only 49%, which failed to meet the criteria for optimal operation, which requires a conversion rate of greater than 70%. Additionally, the absorbent exhibited a high degradation efficiency of 94%, which also failed to

meet the criteria, which requires a degradation efficiency of less than 60%. These results suggest that further improvements are necessary to optimize the multicycle IAM process using MEA absorbent.

Correspondingly, the multicycle IAM with double precipitation/ regeneration increased carbonate generation by 34% and reduced operation time, with minimal impact on CO_2 absorption capacity.

The second phase of the research aimed to address the limitations of using MEA in the multicycle IAM by evaluating alternative absorbents, namely DEA, TEA, and AMP. The results indicated that both TEA and AMP have the potential absorbents, with TEA showing consistent results and low degradation, and AMP showing an impressive high CO_2 conversion. The four-cycle of 5 wt.% AMP absorbent was close to meeting the criteria for optimal multicycle IAM operation, providing a high CO_2 conversion of 90% and moderate degradation of 64%, owing to its chemical structure which enhanced the selectivity of CO_2 and absorbent. Additionally, the 5 wt.% AMP absorbent consumed a low regeneration energy, 47 kilojoules per gram of CO_2, 33% less than 5 wt.% MEA. It should be noted that the energy consumption in multicycle IAM is relatively low compared to conventional CO_2 scrubber.

The final phase of the research focused on the ongoing development of amine-based absorbents for multicycle IAM. The evaluation of various blended alkanolamine absorbents and their components and proportions revealed that blended absorbents demonstrated improved CO_2 conversion and reduced absorbent degradation, thereby optimizing the multicycle IAM operation. The optimal absorbent was determined to be a combination of 15 wt.% TEA and 5 wt.% MEA, exhibiting CO_2 conversion up to 80% and degradation efficiency less than 60%. This blend showed exceptional productivity in terms of amount of CO_2 absorbed and converted per overall operation time, as well as lower energy consumption, requiring 41 kilojoules per gram of CO_2, a reduction of 42% and 29% compared to the single absorbents of 5 wt.% MEA and 15 wt.% TEA, respectively.

In conclusion, the multicycle IAM utilizing alkanolamine-based absorbents holds great potential for mitigating CO_2 emissions, with a focus on balancing economic stability and environmental sustainability. Further research is imperative to enhance the efficiency of the multicycle IAM and expand its application.