Development of a new carbon dioxide-capturing polyacrylic sorbent

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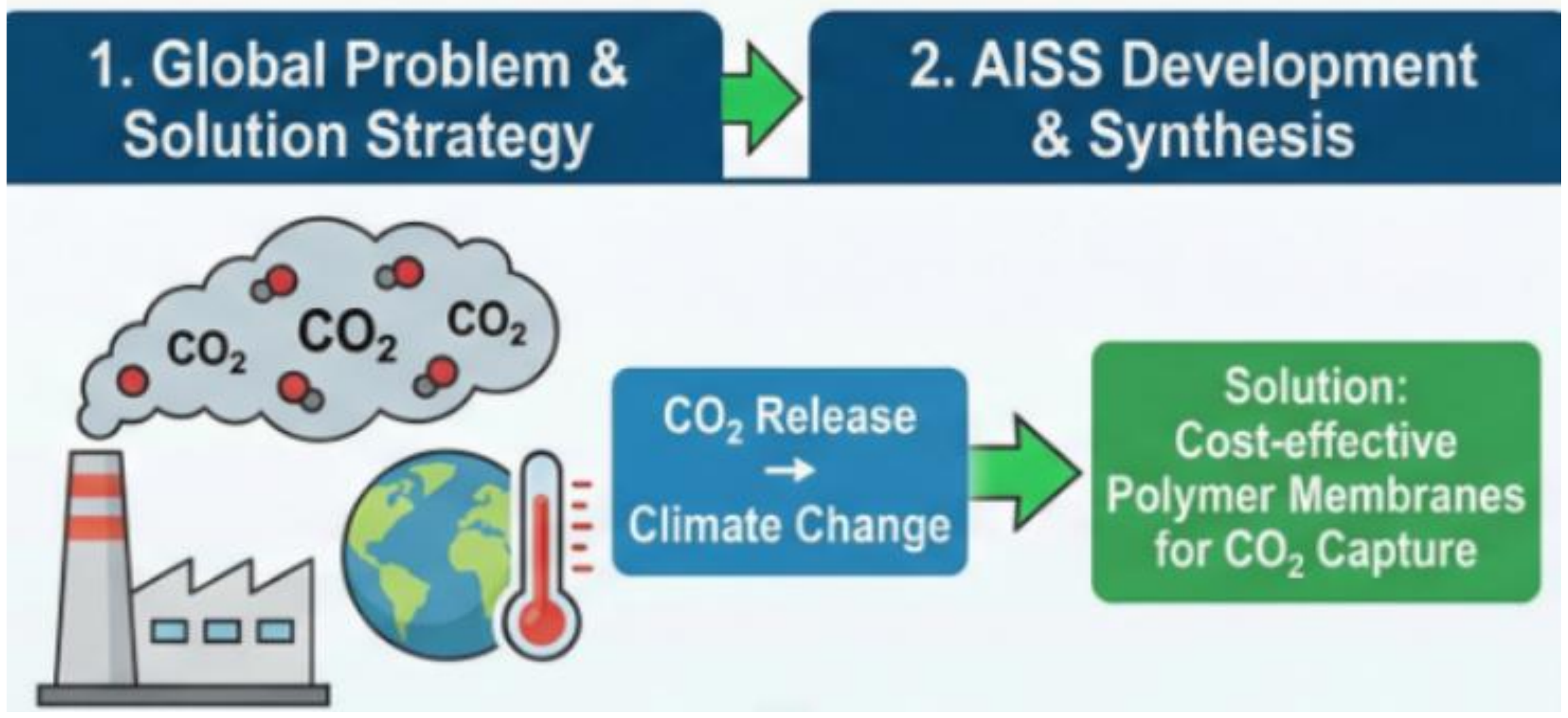
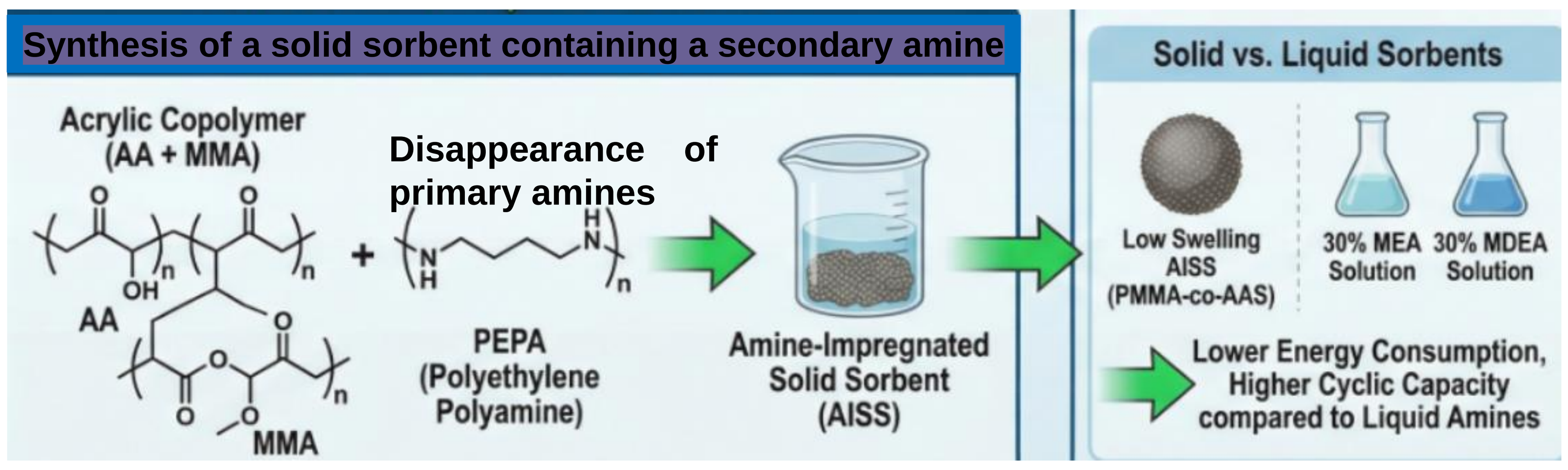
INTRODUCTION & AIM

The release of CO_2 gas into the atmosphere is one of the important causes of global climate change. To solve this problem, cost-effective technologies are being sought. Polymer membranes are innovative materials that can be widely used in the process of capturing and separating CO_2 gas.



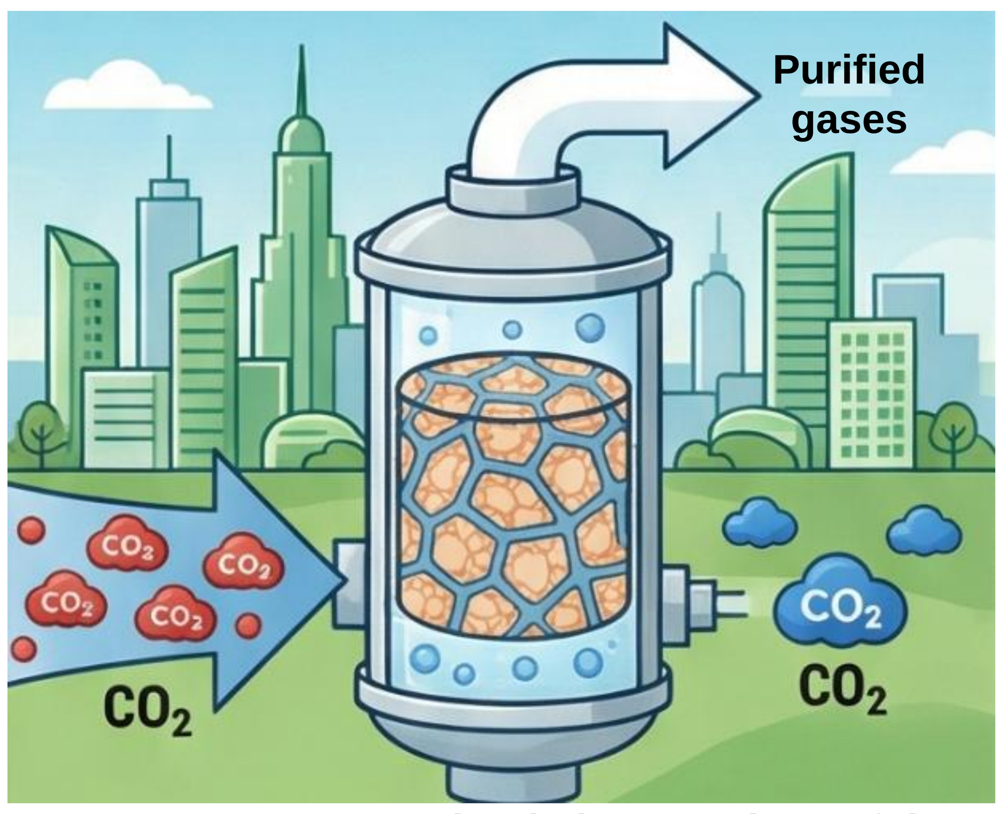
METHOD

In this work, an optimal amine-impregnated solid sorbent (AISS) containing copolymer (PMMA-co-AA), which consists of acrylic acid (AA) and methyl methacrylate (MMA), and PEPA (polyethylene polyamine), was developed. For the first time, sorbents based on homopolymers and copolymers of acrylic acid and methyl methacrylate were compared for their ability to capture CO_2 gas.



Heat capacities and sensible heat values of sorbents

Sorbent name	Temp. grad., °C	Heat capacity J/(g·°C)	Sensible heat J/g
MEA 30%	40-120	3,457	276.56
MDEA 30%	40-120	3,607	288.56
PMMA-co-AAS	40-70	2,1716	65.149



Comparison of heat capacities of solid bases and water

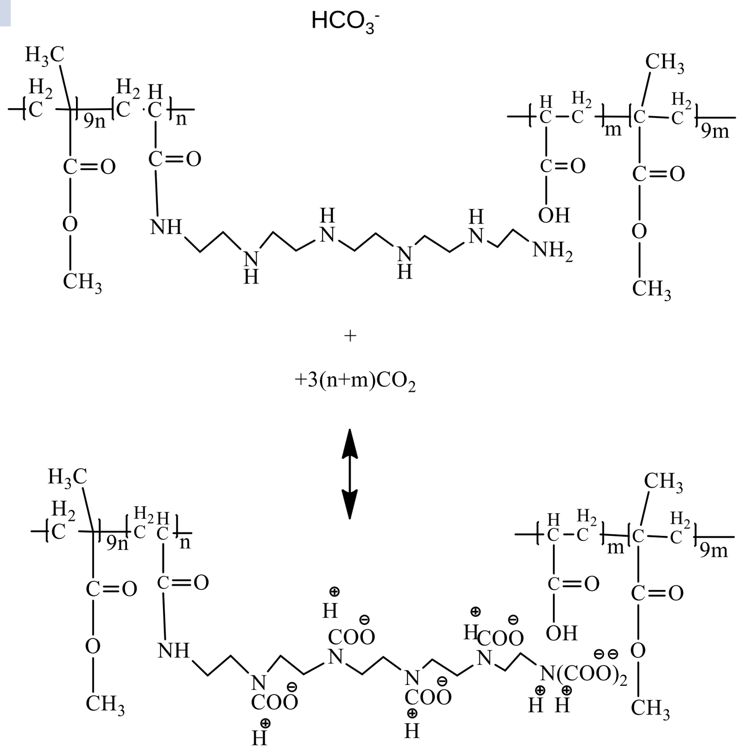
Name	Water	PMMA	PAA	PMMA-co-AA (90:10)
Heat capacity, J/g*K	4.184	1.931	2.146	1.952

CO_2 adsorbsion reactions of the developed and conventional sorbents

$OHC_2H_4\text{-}NH_2 + CO_2 \leftrightarrow RNHCOO^- + H^+$

$OHC_2H_4\text{-}NH_2 + CO_2 + H_2O \leftrightarrow OHC_2H_4\text{-}NH_3^+ + HCO_3^-$

$(C_2H_4OH)_2\text{-}N\text{-}CH_3 + CO_2 + H_2O \leftrightarrow (C_2H_4OH)_2\text{-}NH^+\text{-}CH_3 + HCO_3^-$



The sensible heat, adsorption heat, vaporization heat and total regeneration heat in formulae below:

$$Q_r = \Delta H_a + mC_{p,s} \cdot \Delta T \text{ [Gray et al.]}$$

Here, Q_r (kJ/mol) is the heat of regeneration, ΔH_a (kJ/mol) is the heat of adsorption, m (kg) is the mass of the adsorbent, $C_{p,q}$ (kJ/kg K) is the heat capacity of the solid, and ΔT (K) is the temperature change.

$$Q_{reg} = Q_{des} + Q_s + Q_v$$

were calculated for the PMMA-co-AAS CO_2 capture system and compared with the aqueous 30% MEA / MDEA systems. The sensible heat of the sorbents Q_s is the heat or energy that must be supplied to raise the temperature to the desired temperature. While 276.56 J/g of energy is required to raise a 30% MEA solution from 40 °C to 120 °C, for the PMMA-co-AAS sorbent this value requires 65.149 J/g for the temperature range 40-70 °C.

The swellability of the sorbents was calculated using the following equation after the 48 hours of submerging:

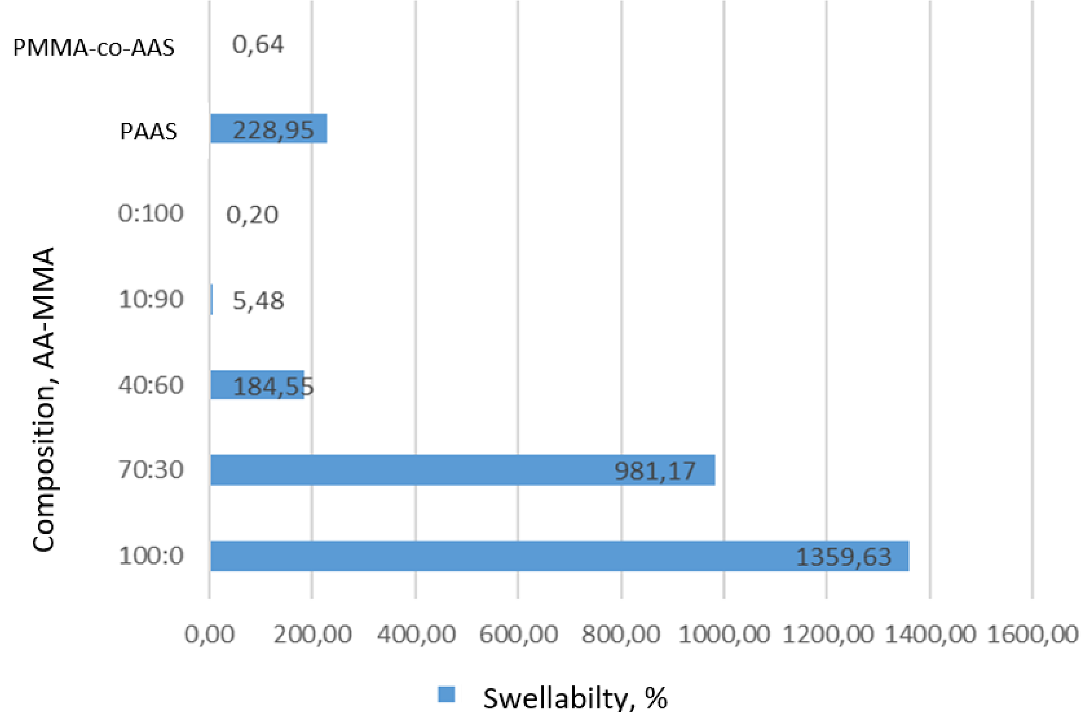
$$B = (W_s - W_d)100 / W_d,$$

Here W_s and W_d are the weights of the bulk and dry polymer, respectively.

RESULTS & DISCUSSION

Water swellability of copolymers and sorbent membranes composed of acrylic monomers.

Besides the synthesis of low swelling AISS, a calculation of its energy consumption and a comparison of its cyclic capacity with 30 % water solutions of monoethanolamine and methyldiethanolamine (MEA and MDEA) were performed. The solid sorbent PMMA-co-AAS showed a higher cyclic capacity than others, corresponding to the order PMMA-co-AAS (23 mg/g) > PAAS (16 mg/g) > MDEA (10 mg/g) > MEA (6 mg/g).

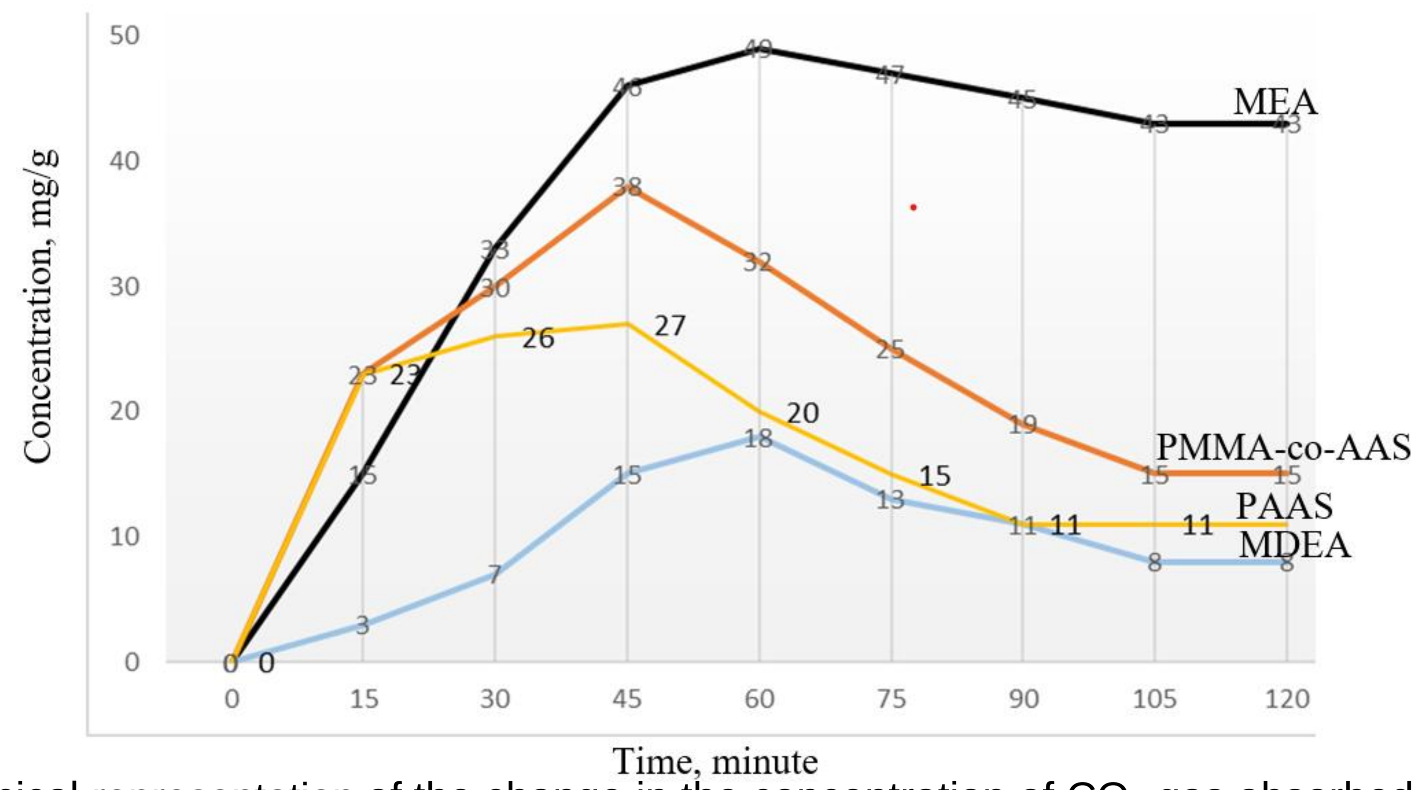


The average absorption rate for these sorbents was in the sequence of MEA > PMMA-co-AAS > PAAS > MDEA at 40 °C, and the desorption rates were PMMA-co-AAS > PAAS > MDEA > MEA for these sorbents at 70 °C, correspondingly. When the amount of acrylic acid in the copolymer was varied from 0 to 100%, its water absorption capacity ranged from 0.2 to 1359.63%. Among them, the swelling ability of the sorbent prepared from the 10% AA-containing copolymer and PEPA was 0.64%.

Carbon dioxide gas capture properties of MEA, MDEA, PMMA-co-AA.

Name	Maximum loading (R_{max}), g/kg	Minimum loading (R_{min}), g/kg	Cyclic capacity (ΔR), g/kg
MEA	49*	43***	6
MDEA	18*	8***	10
PAAS	27**	11***	16
PMMA-co-AAS	38**	15***	23

Carbon dioxide gas capturing properties of MEA, MDEA, AISSs.
** - 60 min, 40 °C, ** - 45 min, 40 °C, *** - 60 min, 70 °C*



Graphical representation of the change in the concentration of CO_2 gas absorbed by the sorbent during the first absorption/adsorption and desorption cycle.

CONCLUSION

It can be seen from the table that the difference in the heat capacities of the bases, namely water and PMMA-co-AA, is 2.143 times. This indicates the energy efficiency of the obtained solid sorbent. Currently, the industry mainly uses aqueous alkanolamines MEA and MDEA. In this case, the absorption temperature is on average 40 °C, the pressure is 35-42 kgf / cm^2, and the regeneration temperature is 120 °C, the pressure is 0.65-0.95 kgf / cm^2. The energy efficiency of the synthesized sorbent membranes is that the adsorption temperature is 40 °C, the pressure is 200 mm H_2O (≈0.02 kgf / cm^2) or above, the regeneration temperature is 70 °C, and the regeneration pressure can be carried out under the atmosphere or vacuum (if high purity CO_2 is required). This means that the energy consumption is 4.25 times less than for the MEA solution and 4.43 times less than for the MDEA solution.

REFERENCES

Gray, M.L.; Hoffman, J.S.; Hreha, D.C.; Miller, M.S.; Saucier, D.E.; Johnson, J.K. Parametric study of solid amine sorbents for the capture of carbon dioxide. *Energy Fuels* **2009**, *23*, 4840–4844.