CO_2-adsorption

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Motivation and Goals

The goal of this project was to synthesize different sorbent material for CO_2 adsorption and test their adsorption and desorption capacity. The materials tested were 5.7wt% of MgO and BaO on γ-Al_2O_3 for the purpose of trying other materials other than CaO that has been used in previous research. This could be useful in various applications such as water-gas shift reactions and ethanol reforming for enhancing production of hydrogen by removing carbon dioxide from the equilibrium and also where lowering CO_2 emissions is of high importance.

Background

In previous work, bulk CaO was used as a CO_2 sorbent and showed an effective ability to adsorb CO_2. However the material formed a shell of calcium carbonate, $CaCO_3$ that limited any additional adsorption and required high temperature to desorb CO_2 from material. CaO dispersed on a high surface area such as γ-Al_2O_3 showed great improvements in terms of higher uptake of CO_2 and some desorption capability when no CO_2 was present in the atmosphere.

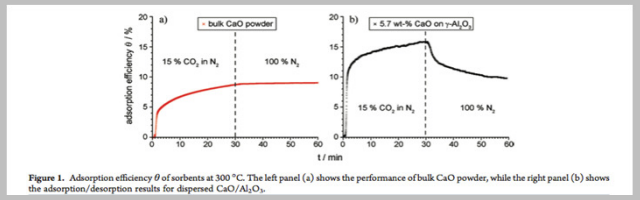


Figure 1. Adsorption efficiency θ of sorbents at 300 °C. The left panel (a) shows the performance of bulk CaO powder, while the right panel (b) shows the adsorption/desorption results for dispersed CaO/Al_2O_3.

This project will perform experiments during similar conditions as previous research with CaO on γ-Al_2O_3 to give a good comparison of the different material's adsorption and desorption capacity.

Experimental procedures

The sorbent material is synthesized using the incipient wetness impregnation technique, an easy and safe method for synthesizing catalysts and sorbents. The precursor's solubility is a keyfactor in preparing the solution.

- 5.7wt% of metal solution is prepared with metal nitrate precursors.
- γ-Al_2O_3 with high surface area is used as a metal carrier.
- An amount of solution equal to the carriers' pore volume is added to the carrier.
- The sorbent powder is dried to remove water and the calcined at 700° C to remove the nitrate and other impurities.
- Each material is characterized using BET and XRD.

Thermal gravimetric analysis (TGA)

- The sample is kept in a crucible which is placed on a sensitive scale.
- A constant flow N_2 comes from underneath the crucible and goes through the system.

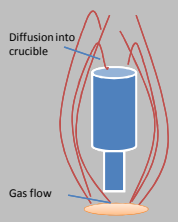


Figure 2. Schematic of instrument setup in TGA

- A portion of the flowing gas is diffusing into the crucible.
- When the furnace has cooled to 300° C, 15% CO_2 in N_2 is introduced to the system for 30 minutes after which it is switched back to 100% N_2.
- Adsorption occurs when CO_2 is introduced to the gas flow and desorption when switch back to N_2.
- The instrument measures changes in mass relative to input mass.

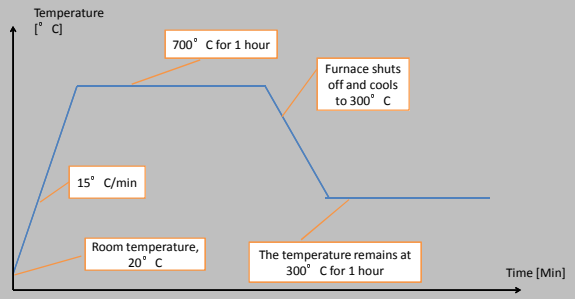


Figure 3. Schematic of temperature program for TGA analysis

Results

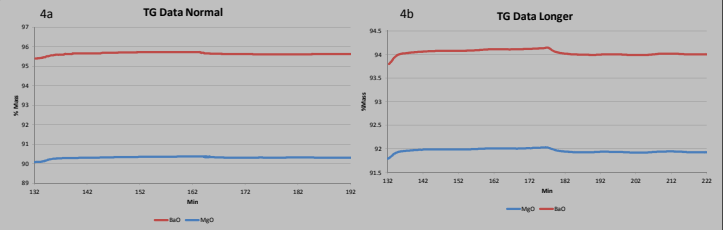


Figure 4a. Percentage mass plotted against time according to regular temperature program.
Figure 4b. Same as Figure 4a. except adsorption/desorption time is increased from 1 hour to 1.5 hours

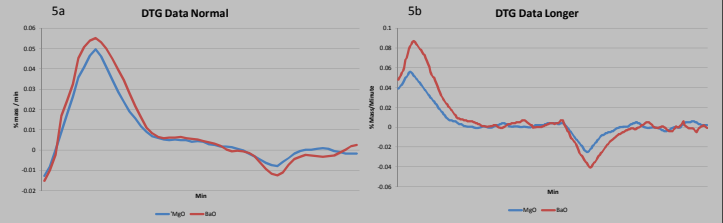


Figure 5a and 5b. First derivative of Figure 4a and 4b gives a better overview of adsorption and desorption

Further Experimental Work

- Niobium oxide, NbO will also be tested as a CO_2-sorbent. Even though niobium is expensive and rare it will be interesting to see as this will be the first attempt in using niobium in CO_2 adsorption.
- Characterization with BET to determine pore size and surface area to respective material.
- More tests will be performed to determine stability of materials and possibly verifying results through reproducibility.

Discussion

- Barium oxide is more stable at higher temperatures and loses less mass than magnesium oxide which would benefit applications at intermediate temperatures.
- Barium's stability reduces sintering of active sites and could possibly explain why barium shows more efficient adsorption and desorption capacity of CO_2.
- Both materials could act as an sorbent for CO_2 capture with regenerable ability. There needs however more extensive research to take it to an industrial scale.

References

P. Gruene, A.G. Belova, T.M. Yegulalp, R.J. Furrauto and M.J. Castaldi, Dispersed Calcium Oxide as a Reversible and Effeient CO_2-sorbent at Intermediate Temperature, Industrial & Engingeering Chemistry Research, (2011), 50, 4042-4049

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