Strategies for CO_2 Mitigation – A Holistic Approach

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Introduction

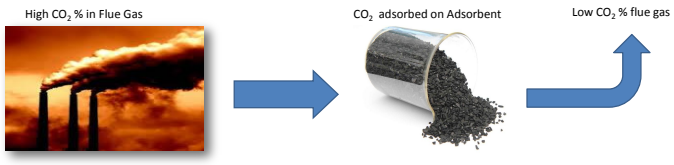
Carbon Dioxide is one the main anthropogenic pollutants associated with global warming; as a consequence, carbon capture strategies have been developed to reduce its atmospheric concentration.

Sorbents such as Metal-Organic Frameworks (MOFs) and Resorcinol-Formaldehyde (RF) xerogels are materials that offer excellent gas adsorption characteristics, such as high surface areas, pore size and pore volume, which have significant potential to be tailored [1] for carbon capture applications.

Solid adsorbents are an alternative to amine liquid absorbents used in industry for carbon dioxide capture [2], as they can enhance uptake through physical interactions, as well as reducing cost and hazardous waste products.

Aims

- Controlling the chemical and physical properties (microscopic / macroscopic).
- Developing a consistent synthesis method.
- Volumetric and Gravimetric characterization.
- Study material selectivity for CO_2.
- Material regeneration and life cycle study.



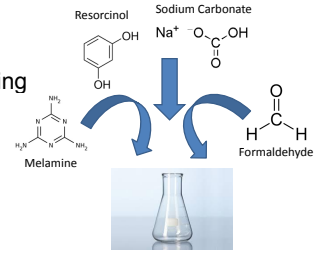
Materials and methods

Sol-Gel Transition

A sol becomes a gel simply when the solid nanoparticles agglomerate, forming a solid network throughout the liquid. In the particular case of RF gels in a basic medium it occurs through the formation of cluster that crosslinks through the volume of the solution [3].

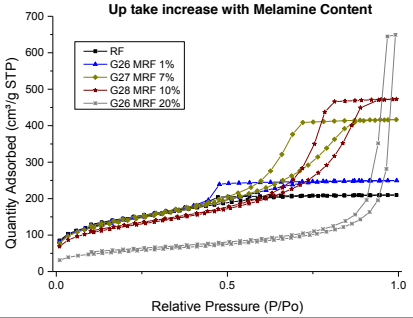
Synthesis Procedure

- Solution preparation and pre-heating
- Gelation and Curing
- Solvent Exchange
- Drying.



Results

- According to the IUPAC isotherm classification, Melamine-Resorcinol-Formaldehyde Gels exhibit nitrogen adsorption type IV.
- Hysteresis loop (capillary condensation) type H2 (RF, MRF 1%, MRF 7% and MRF 10%), and H1 (MRF 20%).
- H2 refers usually to: Differences in mechanism for Adsorption/Desorption, pore "ink bottle" and network distribution.
- H1 refers usually to: compact and uniform spheres distributed in a regular array, therefore narrow pore size distribution.
- Mesopores material.

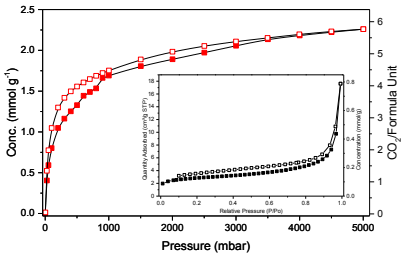


Materials and methods

The considered MOF adsorbents are synthesised via a one-pot room temperature reaction generating powdered samples, or using a solvothermal reaction which produces single crystalline materials. Components usually consist of inorganic copper metal salts and organic linkers with solvent.

Adsorption Analysis

- Surface area analysis carried out on Micromeritics ASAP 2420.



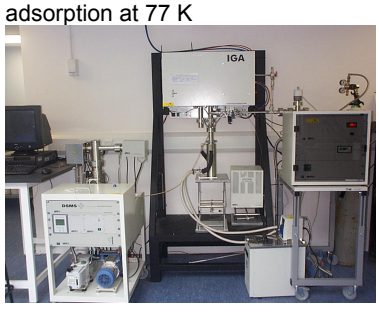
- CO_2 adsorption isotherms obtained using Intelligent Gravimetric Analyser (IGA) from Hiden Isochema Ltd.

Results

- (Above: Insert) N_2 adsorption at 77 K suggests surface area of 10.4 ± 0.2 m^2 g^{-1}, type II isotherm, non-porous.
- Comparison of max adsorbed vol. of N_2 and CO_2:
  - 0.025 cm^3 g^{-1} for N_2 (ρ = 0.808 g cm^{-3}),
  - 0.102 cm^3 g^{-1} for CO_2 at 298 K (ρ = 1.023 g cm^{-3})
- Does not agree with Gurvitsch's rule, pore filling is incomplete ⟶ activated diffusion

Adsorption of CO_2 at 298 K shows very different behaviour for the synthesised materials w.r.t. N_2 adsorption at 77 K

Highlights the importance of studying the adsorption mechanism by modelling individual pressure steps for adsorption kinetics.



Literature cited

1. Tamon, H.I., H.; Mikami, M.; Okazaki, M., *Porous structure of organic and carbon aerogels synthesized by sol-gel polycondensation of resorcinol with formaldehyde.* Carbon, 1997. 35(6): p. 791-796.
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3. Mulik, S. and C. Sotiriou-Leventis, *Resorcinol-Formaldehyde.* Aerogels handbook, 2011: p. 215-34.
4. L. Gurvitsch, J. Phys. Chem. Soc. Russ., 1915, 45.
5. S. J. Gregg, K. S. W. Sing, Adsorption, Surface Area and Porosity; Academic Press Inc., London, 1967, pp. 212.

Future Work

- CO_2 Adsorption (IGA), CHN analysis, FTIR (Fourier Transform Infrared).
- Kinetic analysis of isothermal data.
- X-ray diffraction analysis of crystalline materials.
- Study interaction of Nitrogen functionalities with CO_2.
- Lifetime cycling studies.