Effect of CO_2 phase on CO_2 storage at pore level”

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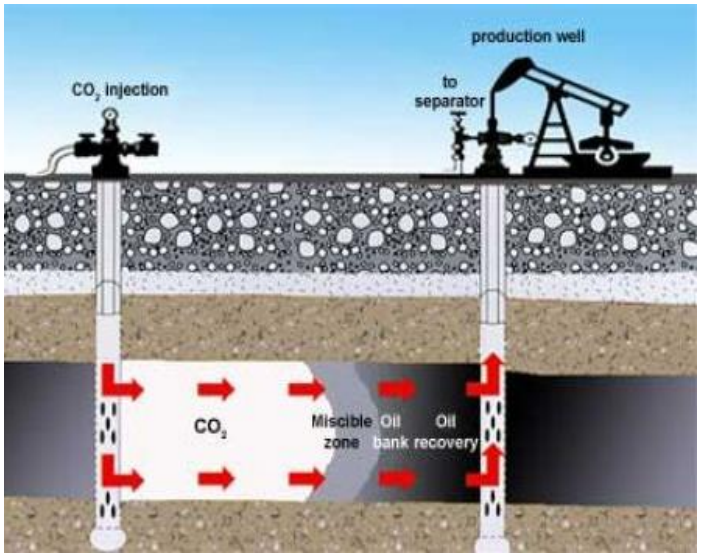
Research Activities and Interests

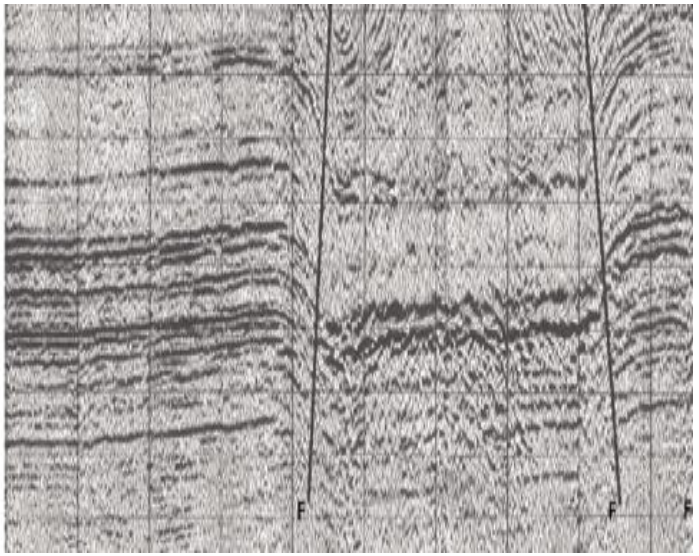
Research activities in my group

- Multiphase phase flow in porous media for CO_2 storage and enhanced oil recovery
- CO_2 capture
- Fluidization and mixing,
- Photocatalysis for waste water treatment and CO_2 reforming

Work forming today's talk is from Miss Cong Chao, Dr Xingxun Li, Dr Claudia Martin

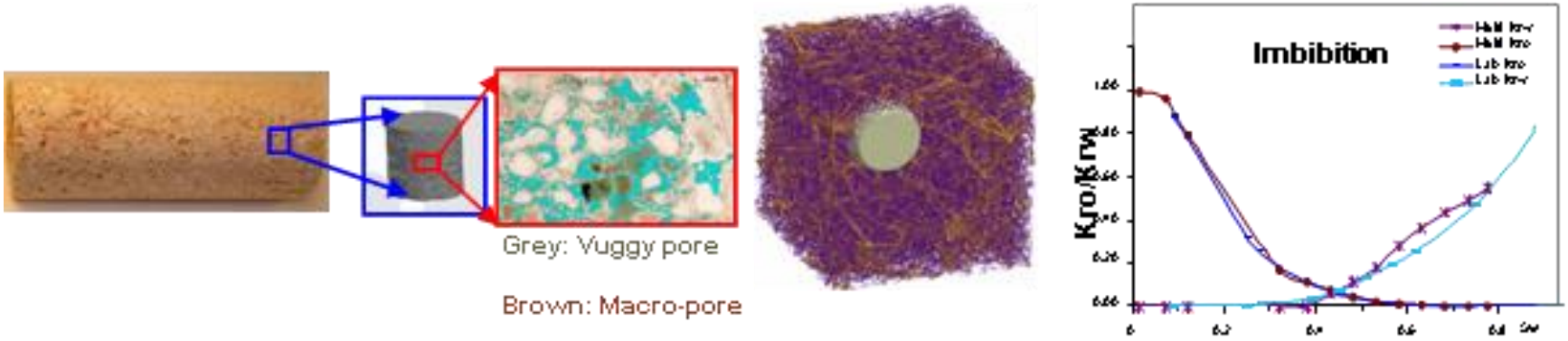
Oil/CO_2 displacement and migration at geological fault and pores,





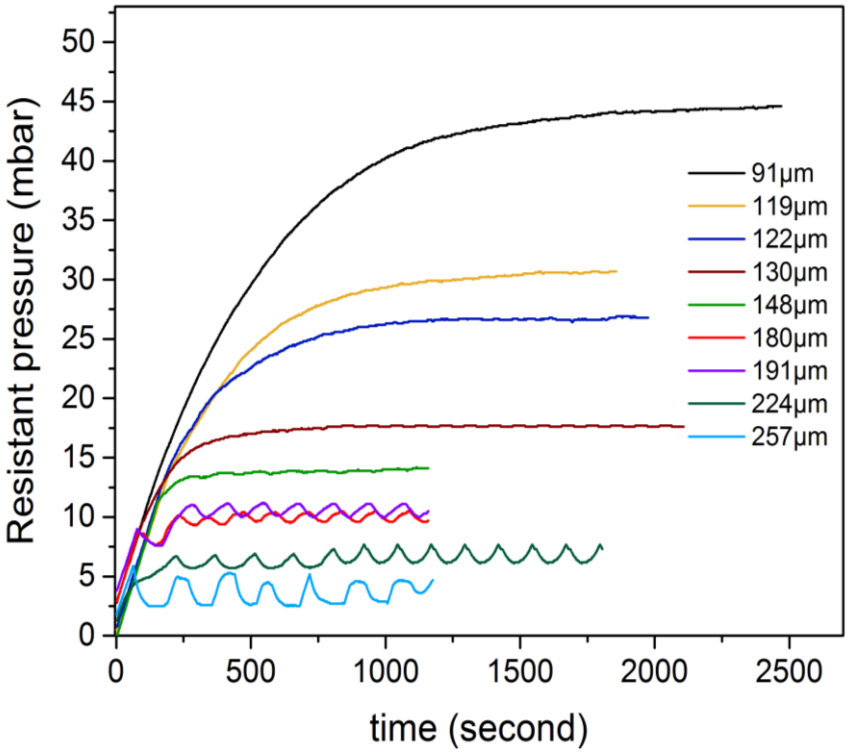
- CO_2 storage is a displacement process at pore and geological faults
- It is a geologic scale engineering, but controlled at pore level.

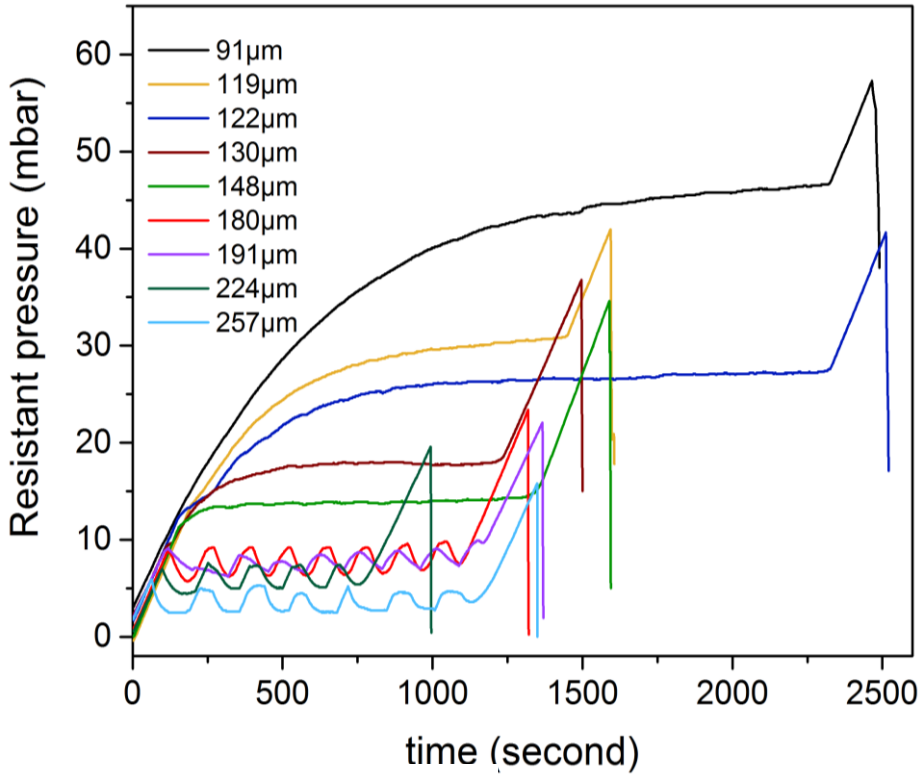
Study oil/CO_2 displacement and migration at geological fault and pores,

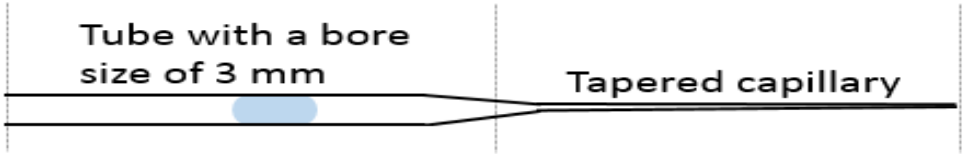


- Displacement is controlled by pore structure, pore wettability, pore surface chemistry, interaction between pore surface, water, oil, CO_2
- Core scale study gives statistic data of the displacement and migration.
- Permeability is a summery of the effect of many factors

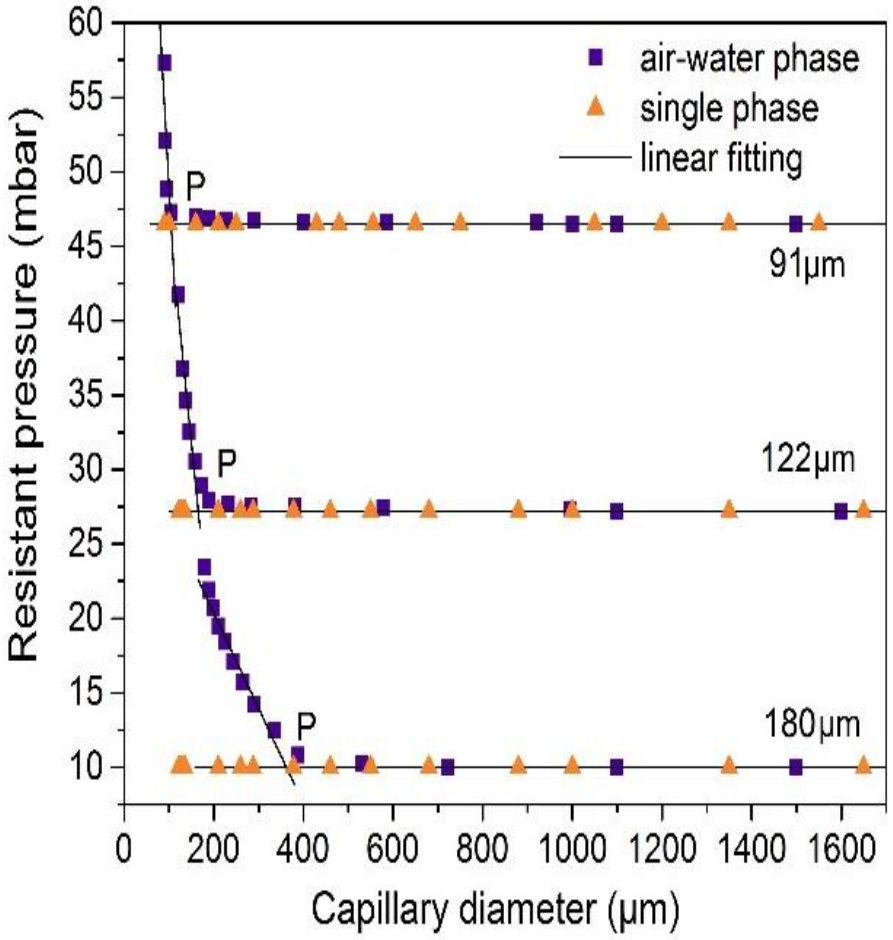
Pressure resistance to single and two phase flows in a capillary (Miss Cong Chao)

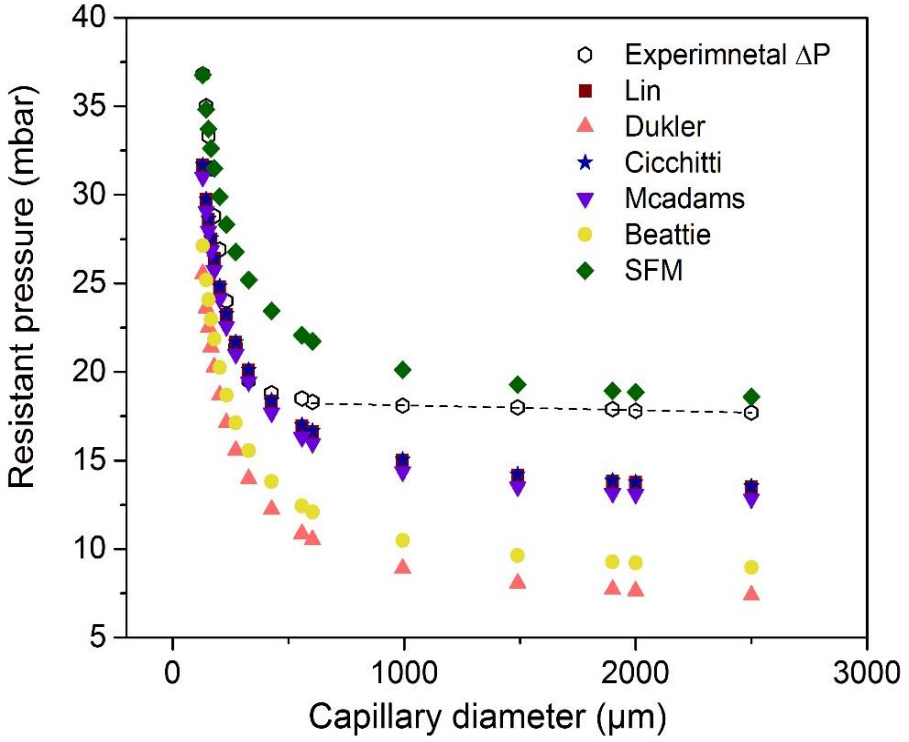




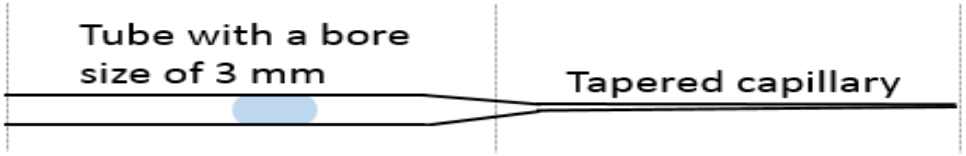


Pressure resistance to single and two phase flows in a capillary





Prediction of the pressure resistance from the tapered capillary



$$\Delta P = \Delta P_{f1} + \Delta P_{f2} + \Delta P_c + \Delta P_{contration} - \frac{\rho}{2}(u_1^2 - u_2^2)$$

where ΔP_{f1} is the frictional pressure drop in the tube with an inner diameter of 3 mm,

ΔP_{f2} is the frictional pressure drop for fluid flowing through the tapered capillary,

$\Delta P_{contration}$ is the pressure loss due to the sudden contraction

ΔP_c is the capillary pressure.

u_1 and u_2 are the mean fluid superficial velocity in the tube with an inner diameter of 3 mm and at the tip point of a tapered capillary, respectively.

Prediction of the pressure resistance from the tapered capillary

Frictional pressure was predicted based on homogeneous flow model and separated flow model

$$\Delta P_{TP} = \frac{f_{TP}\rho_m Q^2}{\pi^2 k r^4} = 32\frac{\mu_m Q}{\pi k r^3}$$

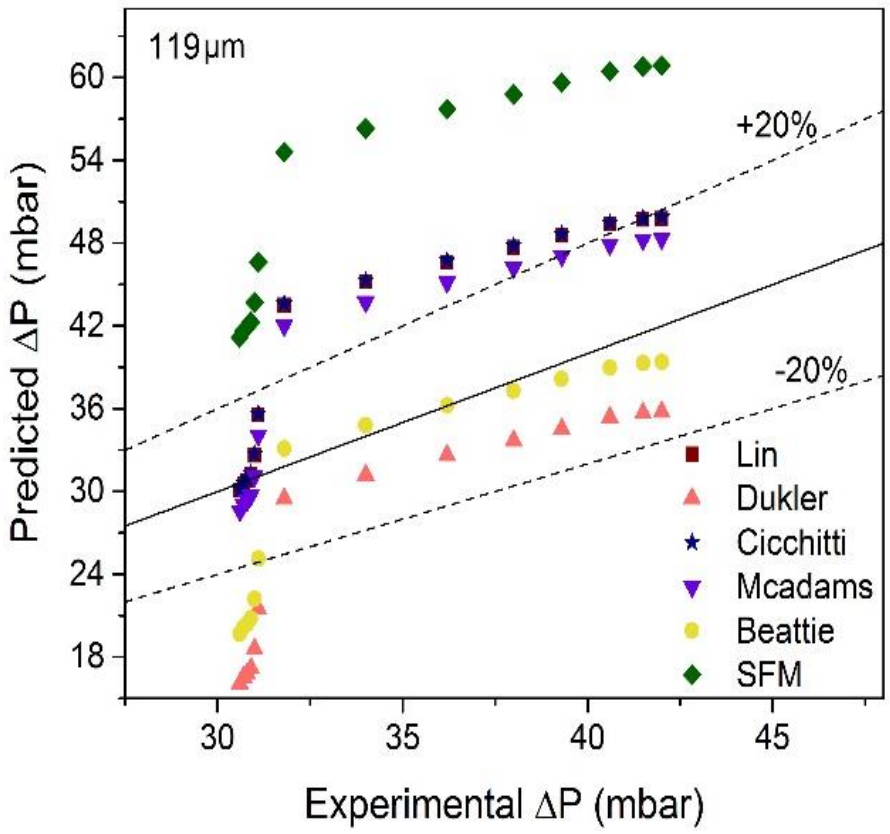
$$\Delta P_{TP} = \phi^2 \Delta P_{SP} = \phi^2 \frac{f\rho_l Q^2}{\pi^2 k r^4}$$

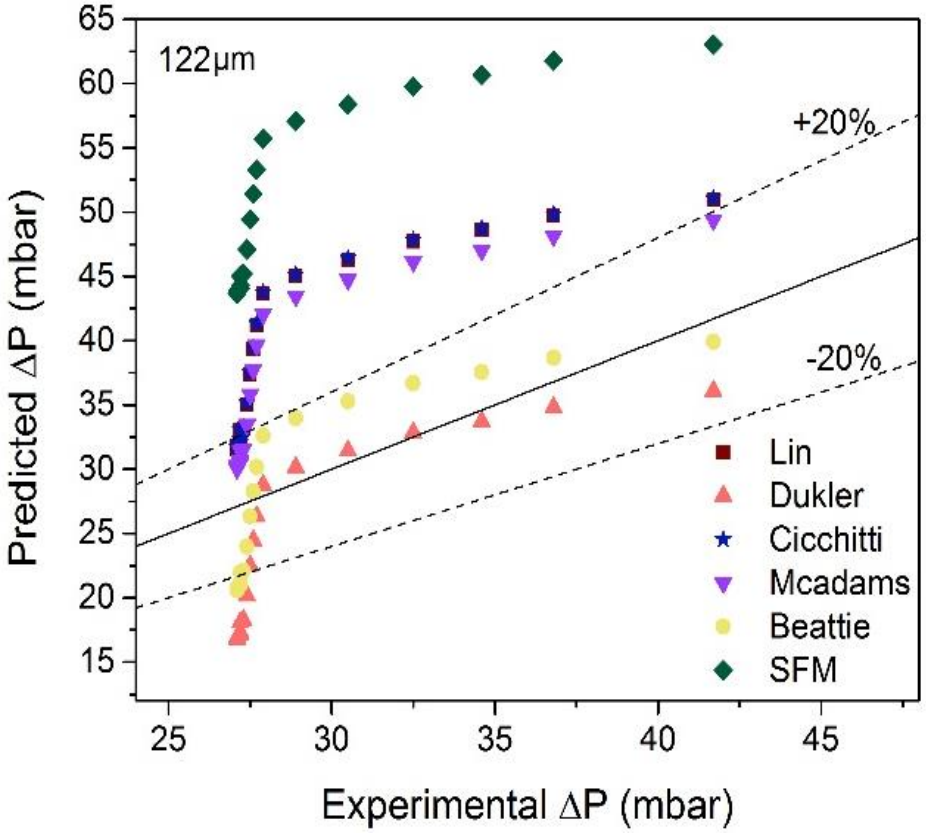
Pressure drop due to the sudden contraction

$$\Delta P_{contraction} = \frac{G^2}{2\rho_l}\left[\left(\frac{1}{C_C} - 1\right)^2 + 1 - K^2\right]\left[1 + x\left(\frac{\rho_l}{\rho_g} - 1\right)\right]$$

Capillary pressure

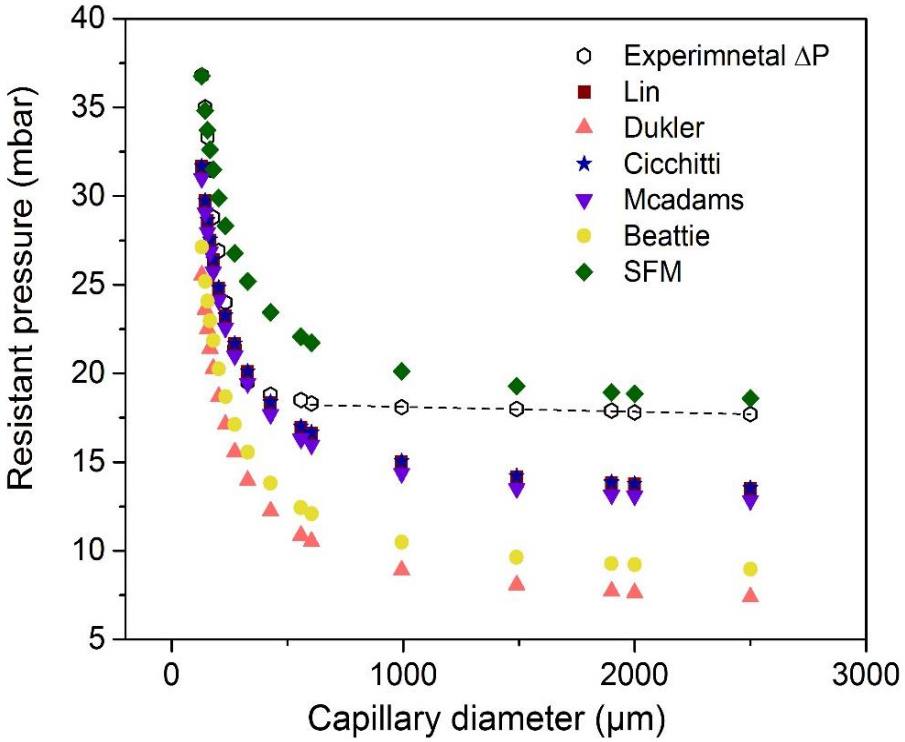
$$P_c = \frac{2\gamma cos\theta}{r}$$

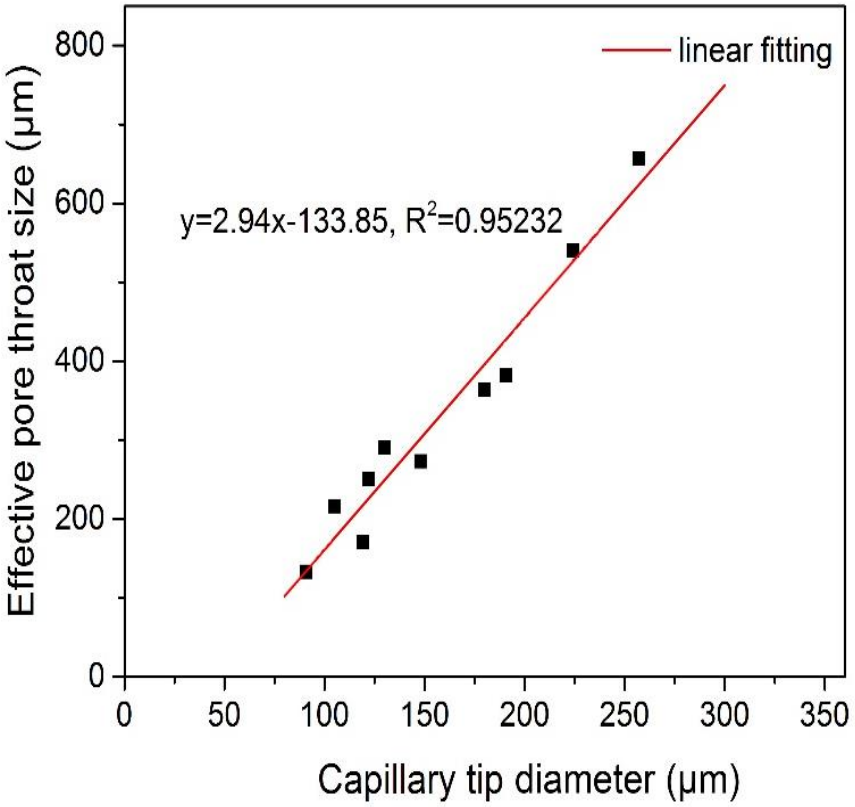


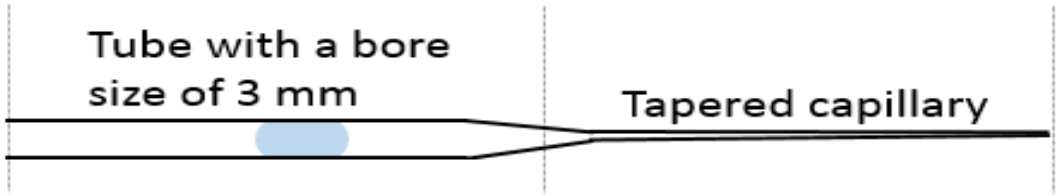


Experimentally measured pressure drop versus the predicted pressure for two-phase flows in tapered capillaries with tip size ranging from 91 to 257 µm

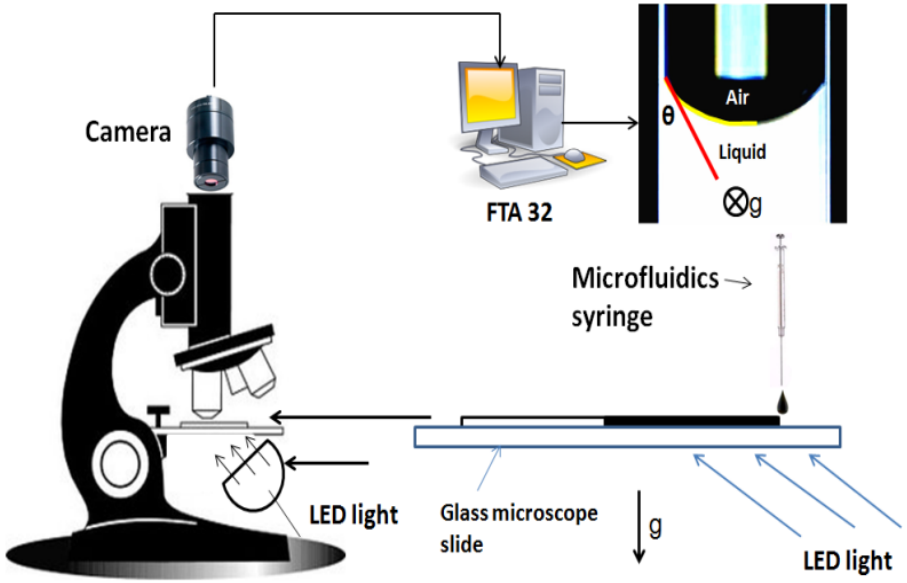
Effective Pore throat

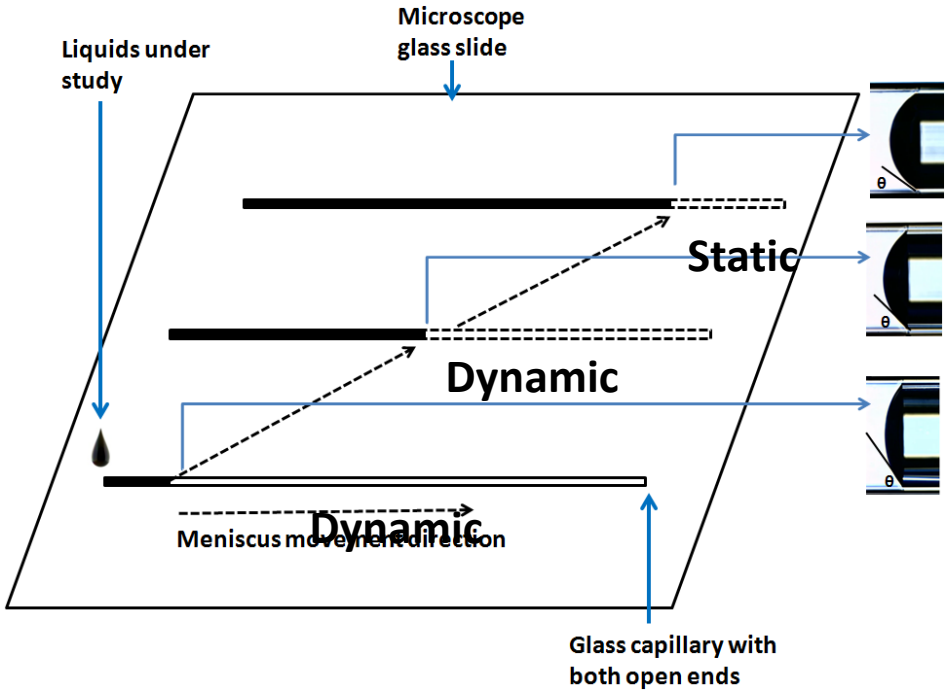






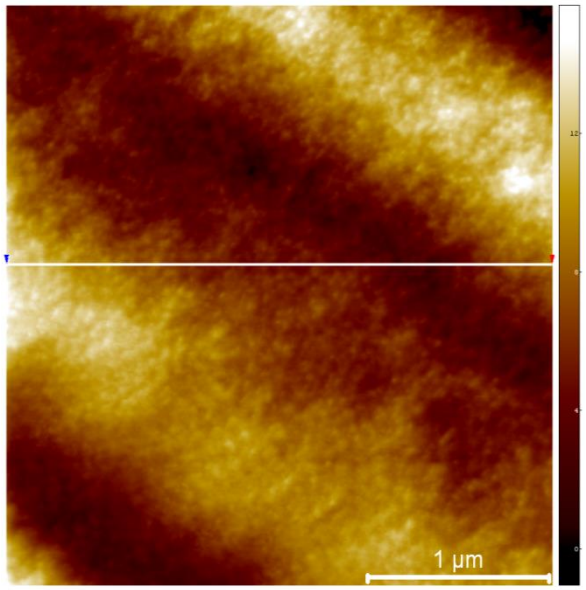
Measurement of pore wetting
Dr xingxun Li

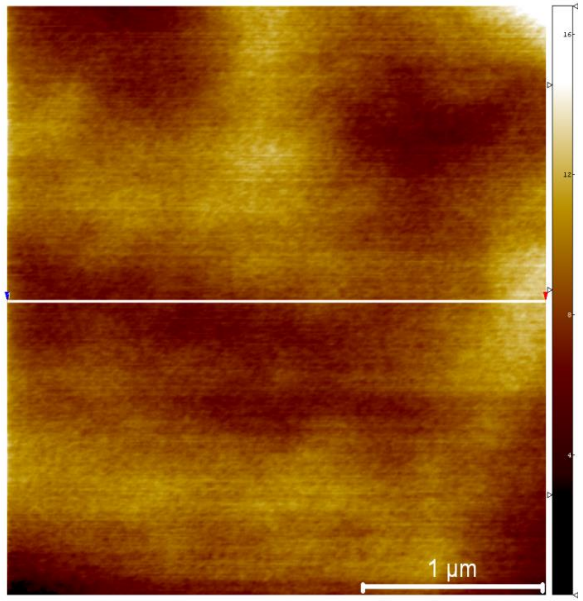


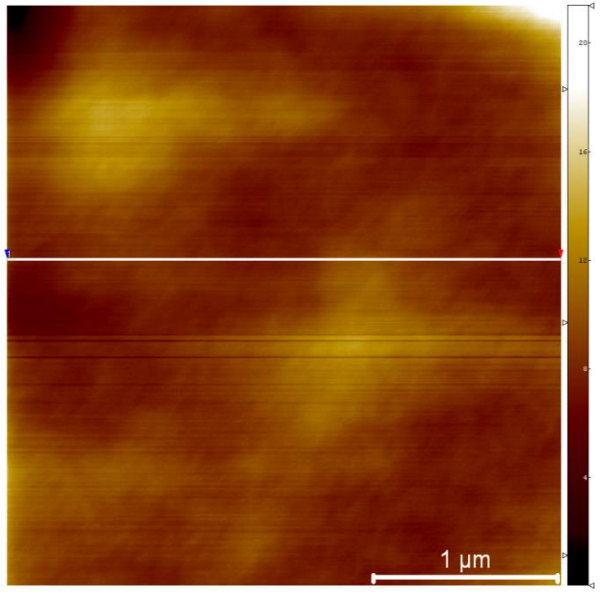


This microscopic image technique developed in our lab works very well for contact angle measurements of liquids in a small pore. This technique has been used for static pore wetting, dynamic pore wetting, chemical structure effect on pore wetting, pore wettability alteration studies and also applied to reservoir liquid-CO2 pore wetting under high pressure.

Roughness of Inner Pore Surface by AFM



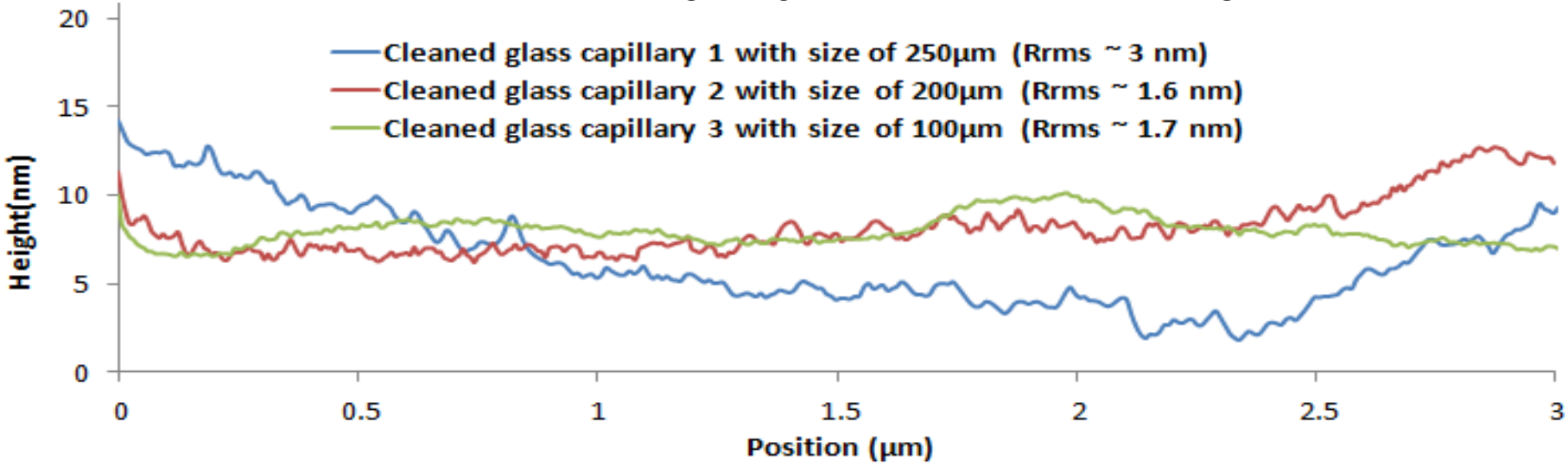




R_{RMS} ~ 3 nm

RMS ~ 1.6 nm

RMS ~ 1.7 nm



Pore Wetting -- Static Pore Contact Angle

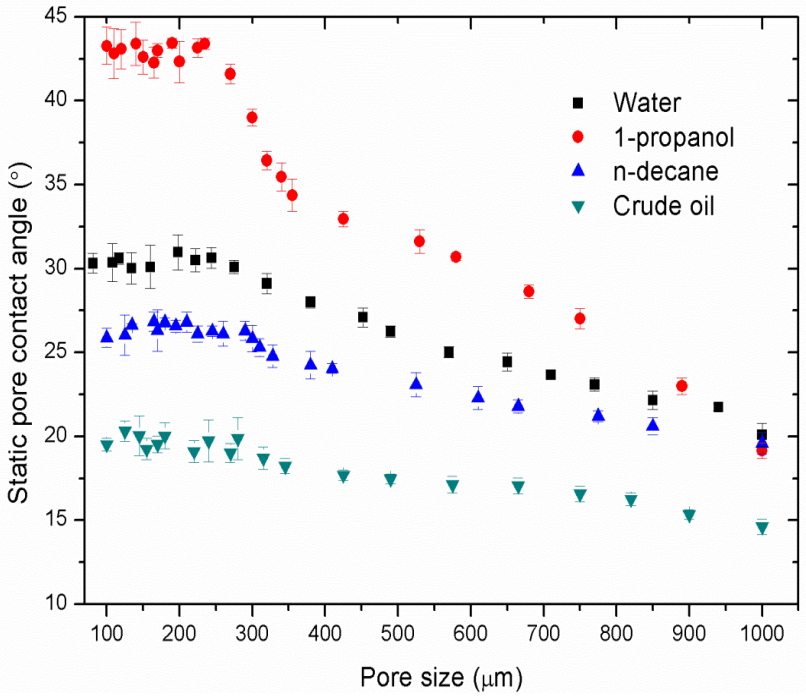
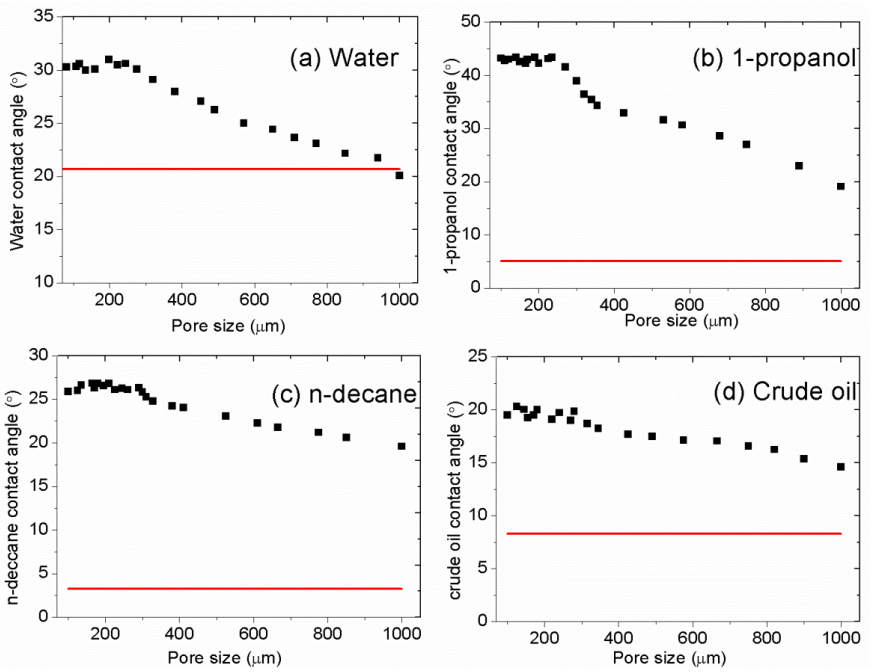


Fig.1 Effect of pore size on static pore wetting

- **Pore contact angle varies with pore size.**
- **Contact angles in pores are largely different from the contact angles measured from flat surfaces.**
- **Chemical structure of liquid might affect its contact angle in a glass pore**



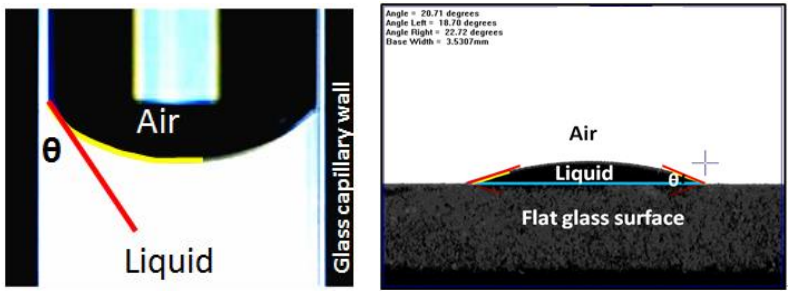
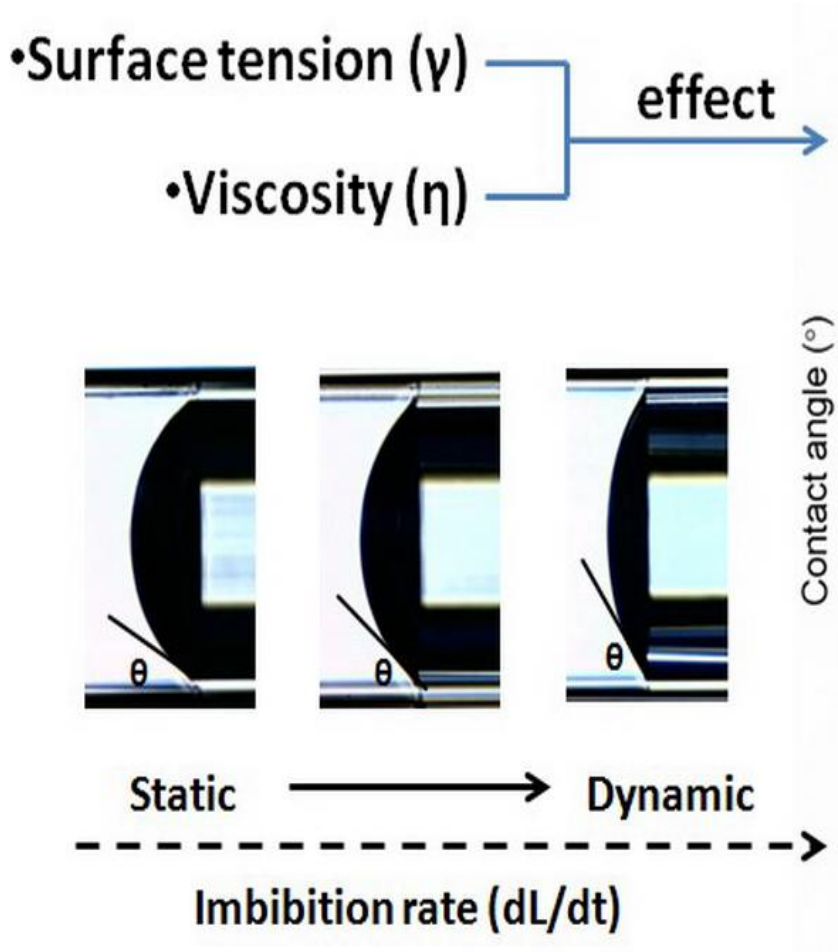
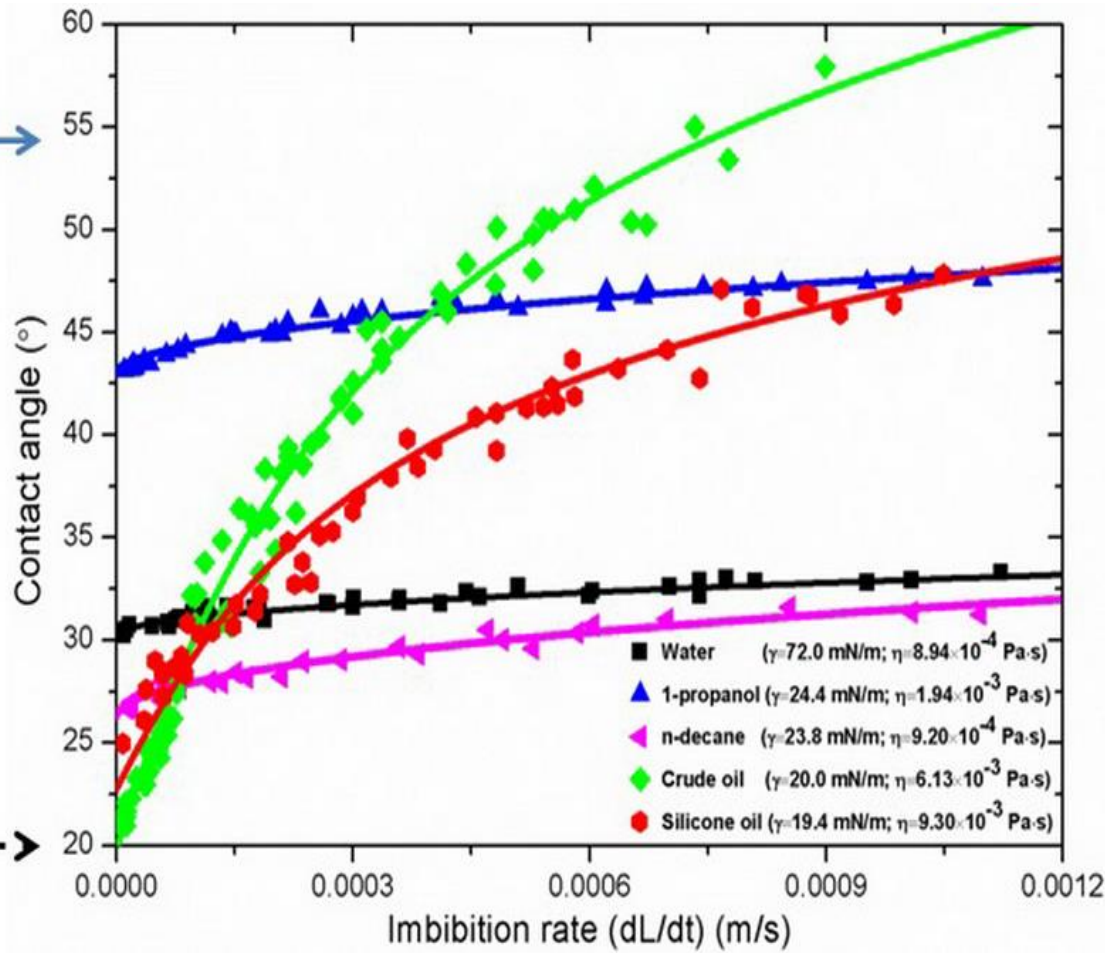


Fig.2 The difference between contact angles measured in a pore and on a flat surface

Dynamic pore contact angles





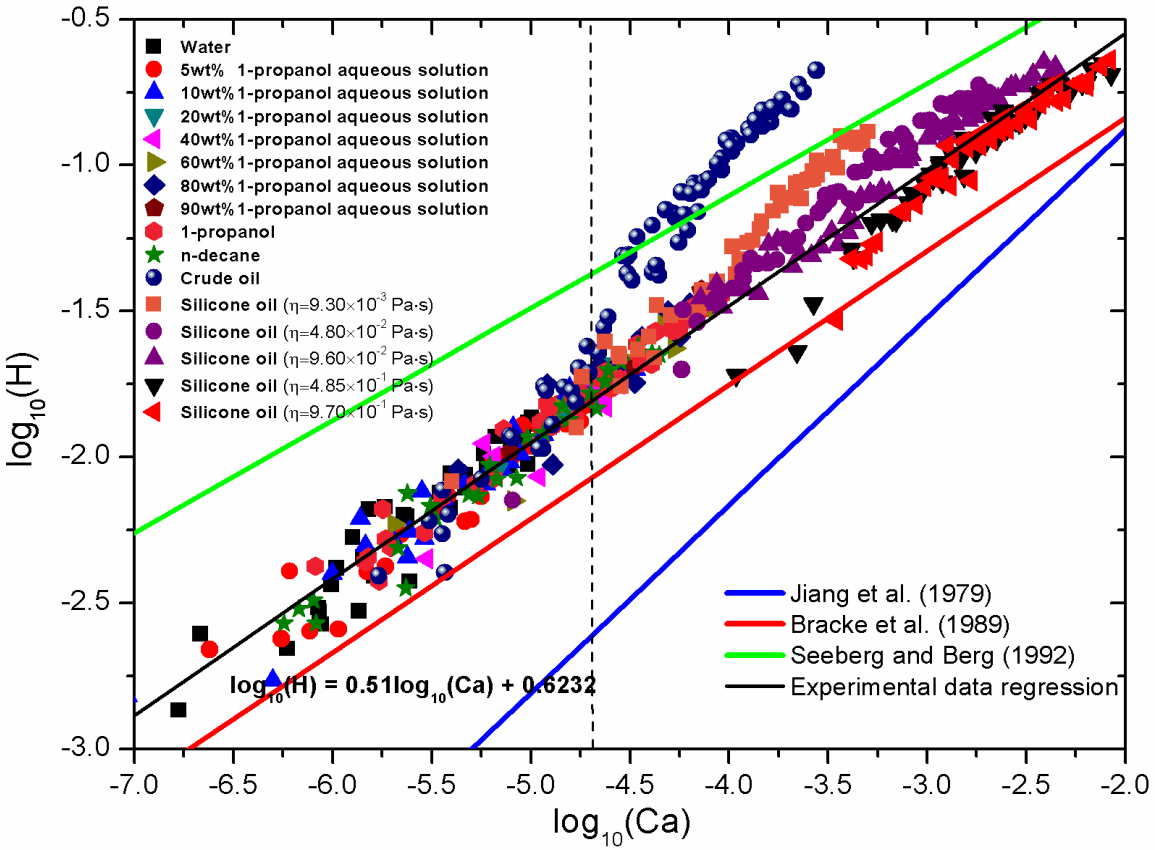
Effects of imbibition rate, surface tension and viscosity on dynamic pore contact angle

Dynamic pore contact angles

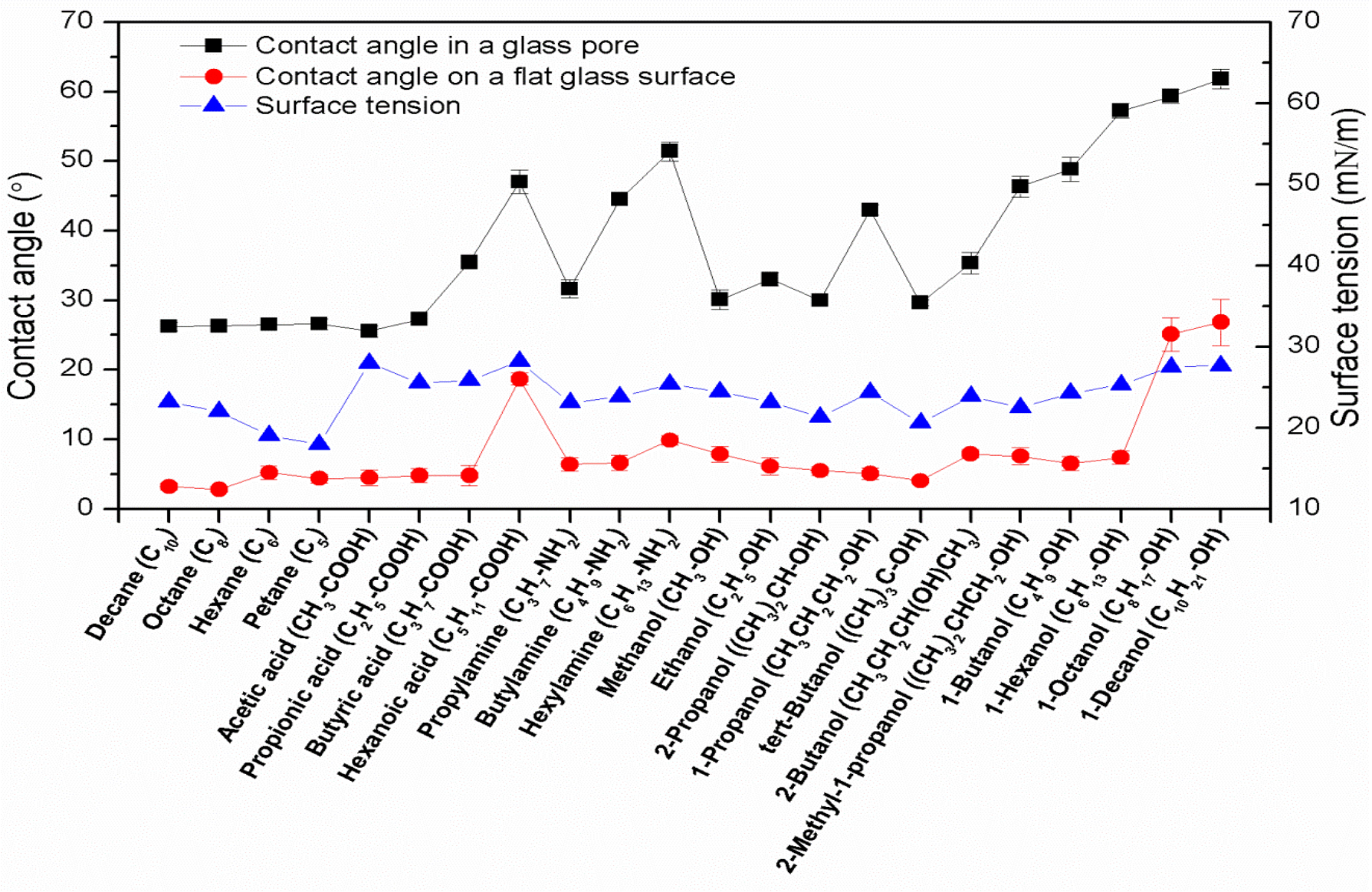
- Dynamic contact angle of liquids in a pore depends on and contact-line velocity, surface tension and viscosity of liquids.
- A new empirical correlation proposed based on our experimental data can predict the dynamic contact angles for liquids in a small pore at a low capillary regime ($1.0\times10^{-7} < Ca < 1.8\times10^{-5}$).

$$H = 4.2\,Ca^{0.51}$$

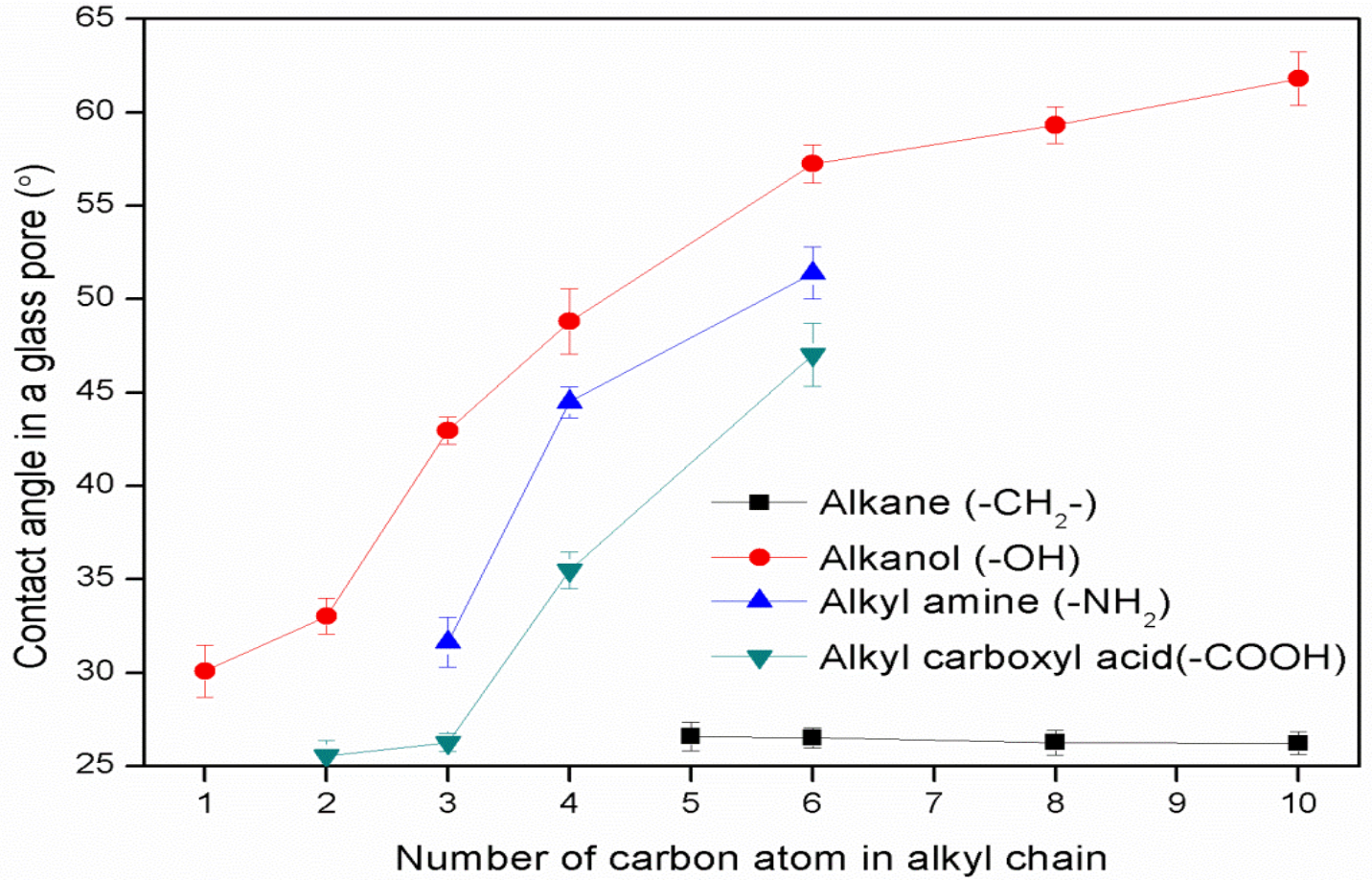
$$H = \frac{\cos\theta_s - \cos\theta_d}{\cos\theta_s + 1} = ACa^B$$



Effect of Chemical Structure on Pore Wetting

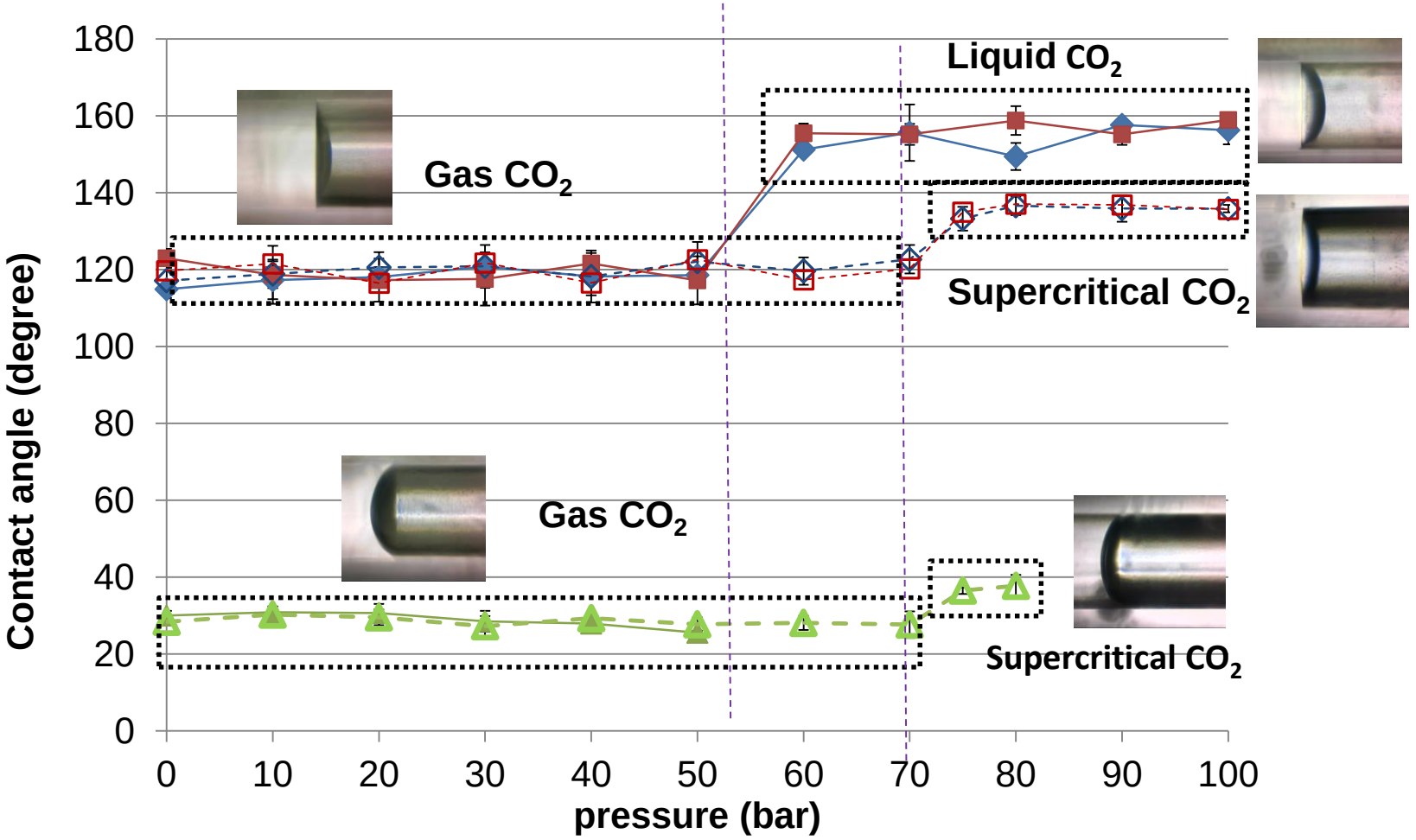


Effect of Alkyl Chain Length on Pore Wetting



The pore contact angle of non-polar organics does not depend on the alkyl chain length. The pore contact angle of amphiphiles increases dramatically with the straight alkyl chain length.

Pore Wetting of CO_2 –water-brine-n-decane

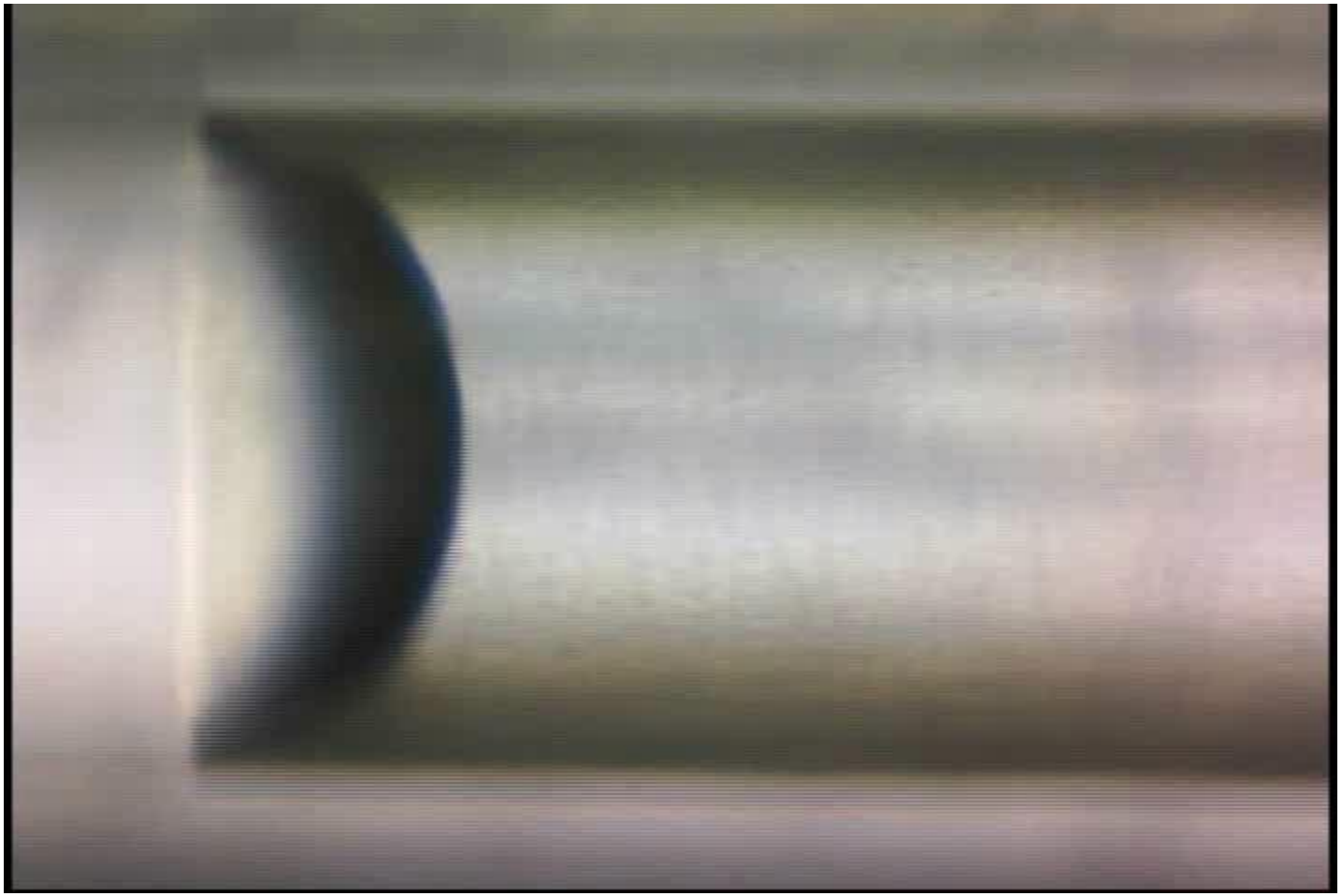


- FEP is a hydrophobic material, which could represent the oil-wet mineral surface in an oil reservoir. The CO_2 turns from gas phase to liquid phase at approximately 60 bars.
- The wetting property of liquid CO_2 is different from gas CO_2 in the FEP pores.
- Salinity effect is not significant on pore wetting in this FEP pore.

Water, Gas and Liquid CO_2 in a Capillary Tube

Increase pressure from 55 bar

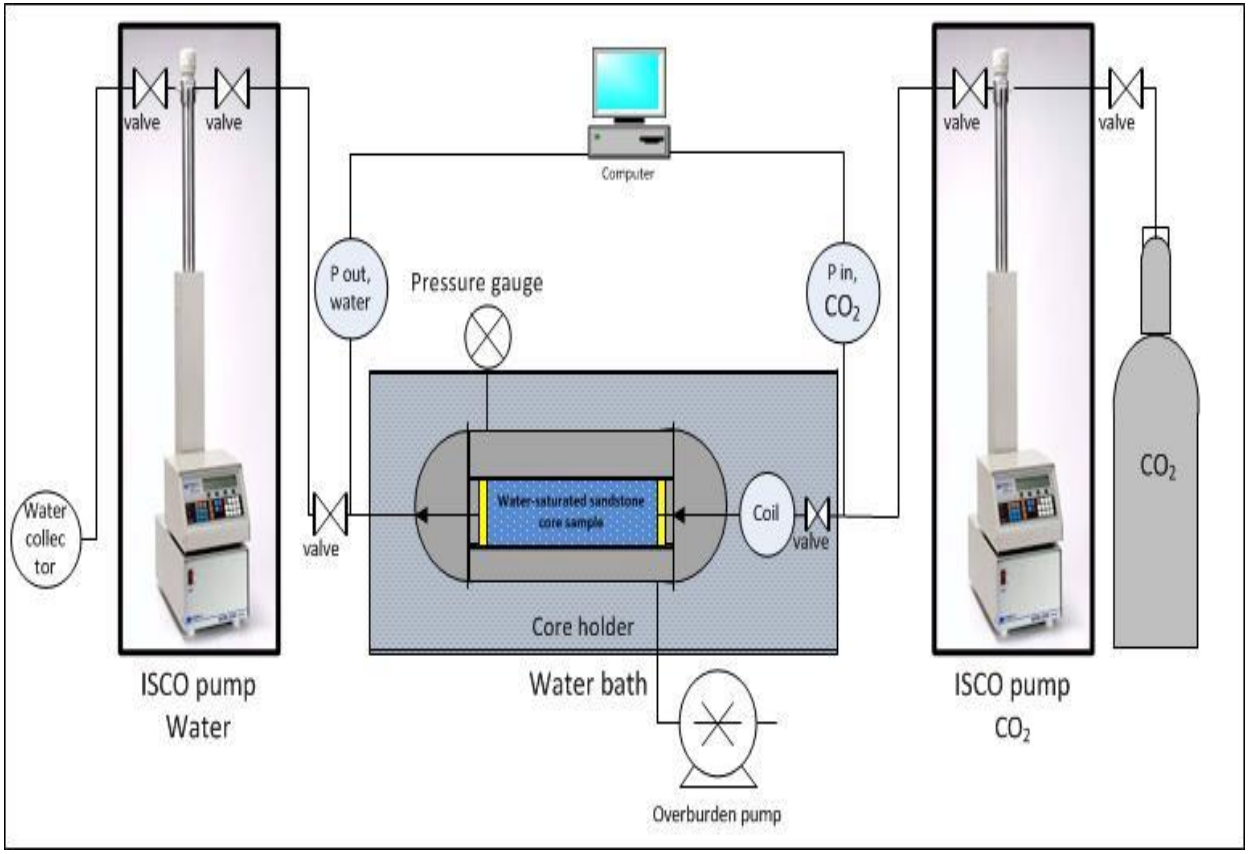
Water, Gas and Liquid CO_2 in a Capillary Tube

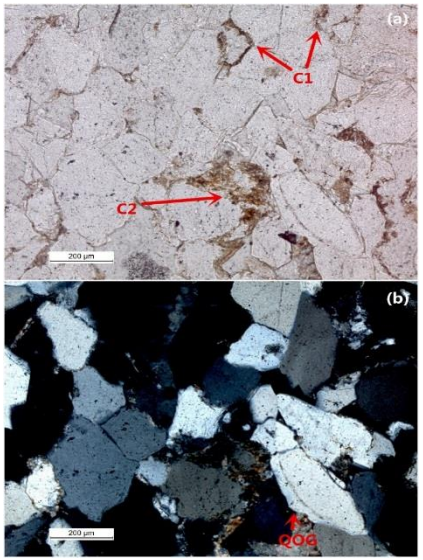


Decrease pressure from 60 bar

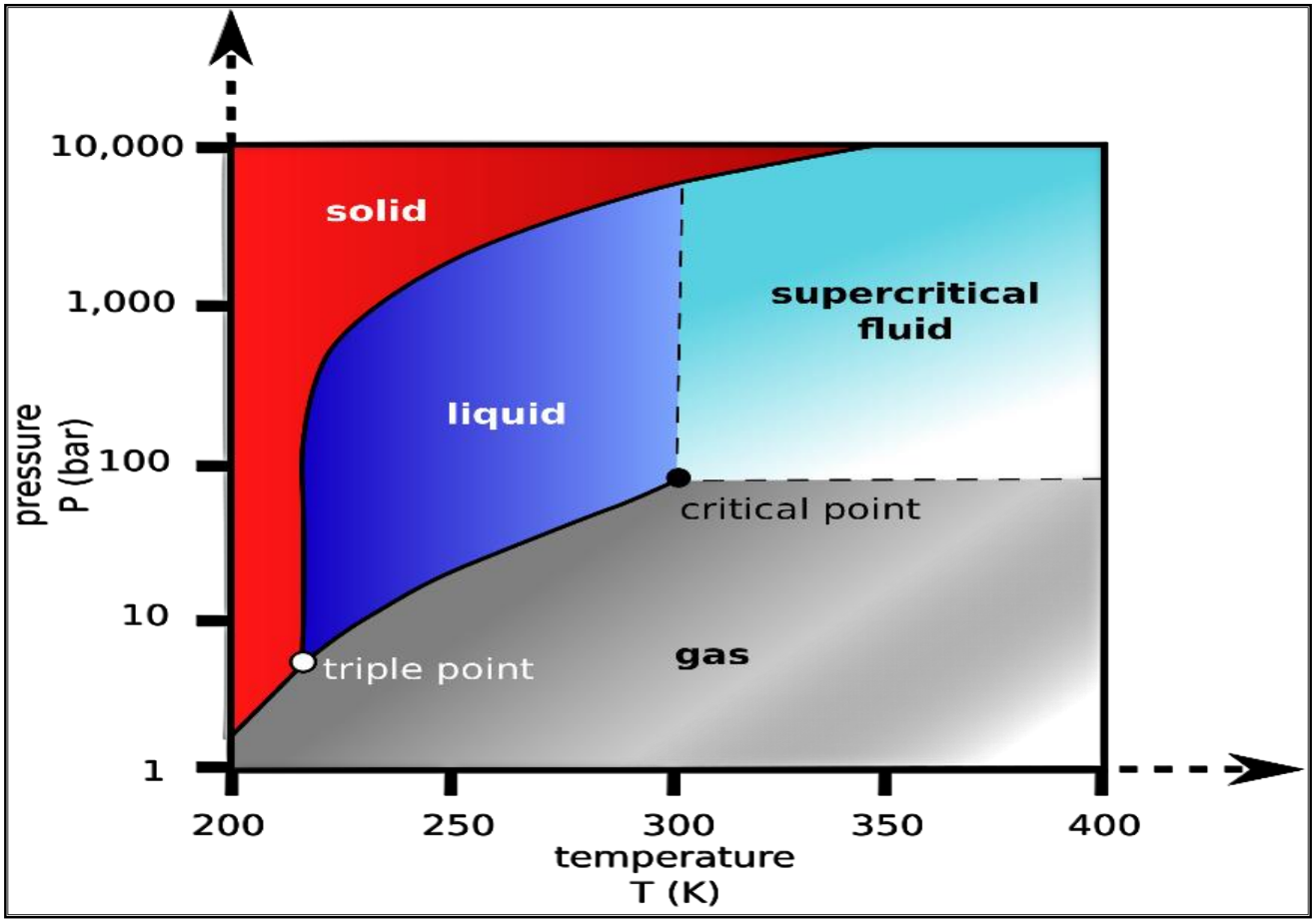
Effect of CO_2 phase on CO_2-water displacement

Dr Xingxun Li, Mr Al-Zaidi

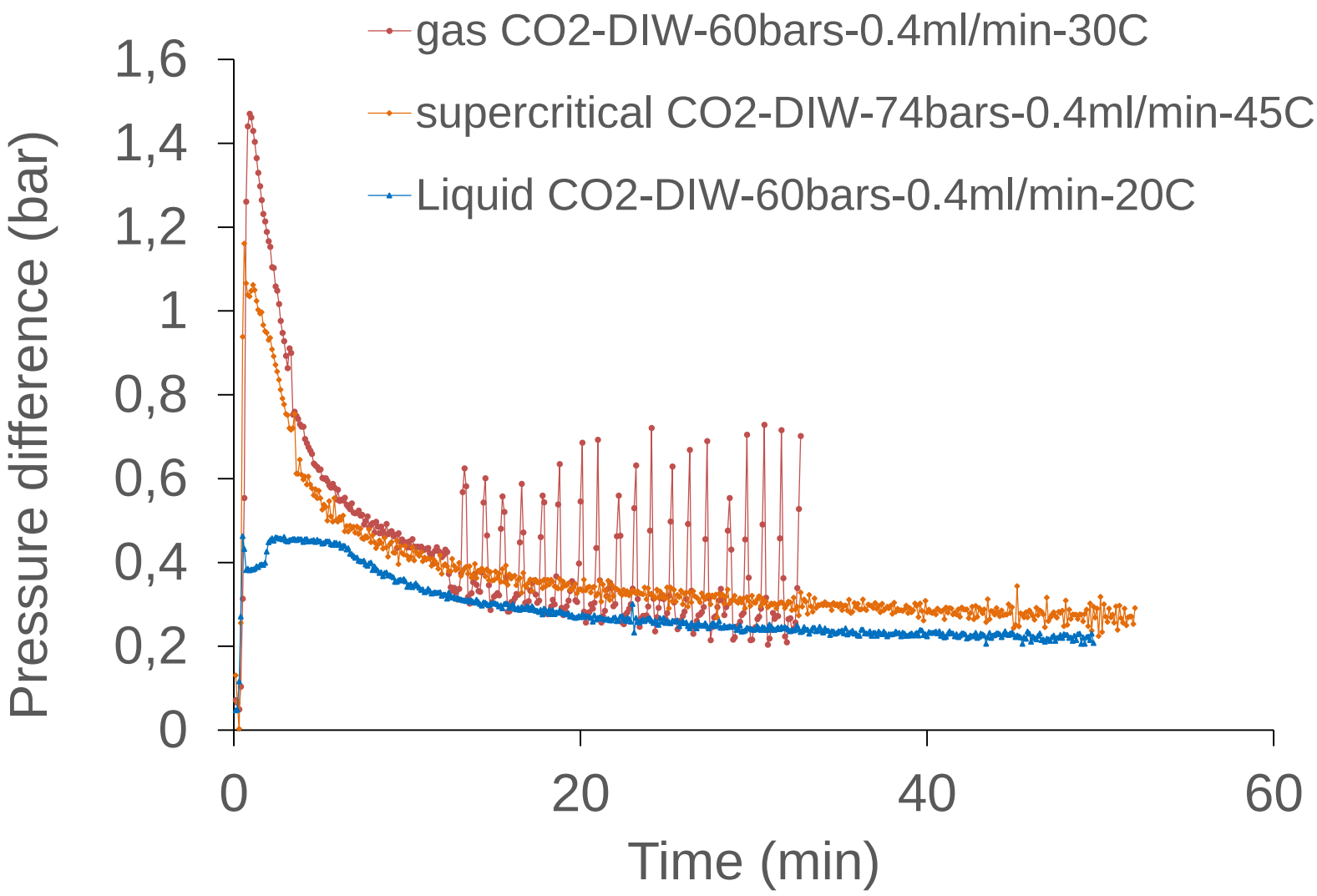




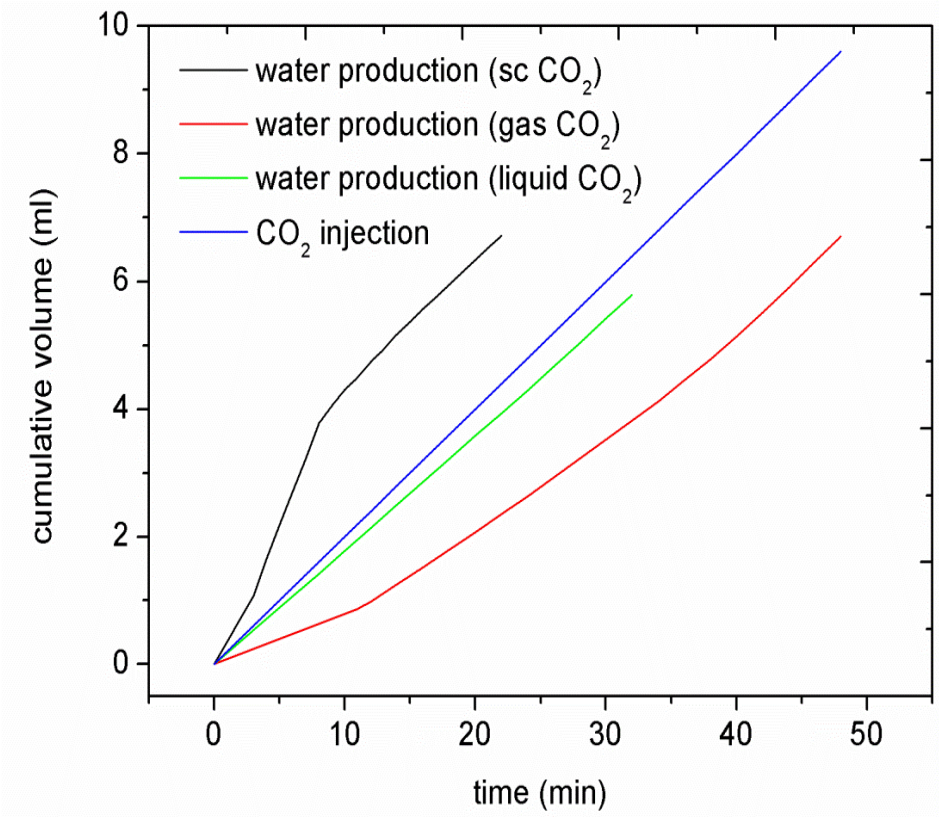
CO_2 Phase


10,000
1,000
100
10
1
pressure
P (bar)
solid
liquid
supercritical
fluid
critical point
triple point
gas
200
250
300
350
400
temperature
T (K)

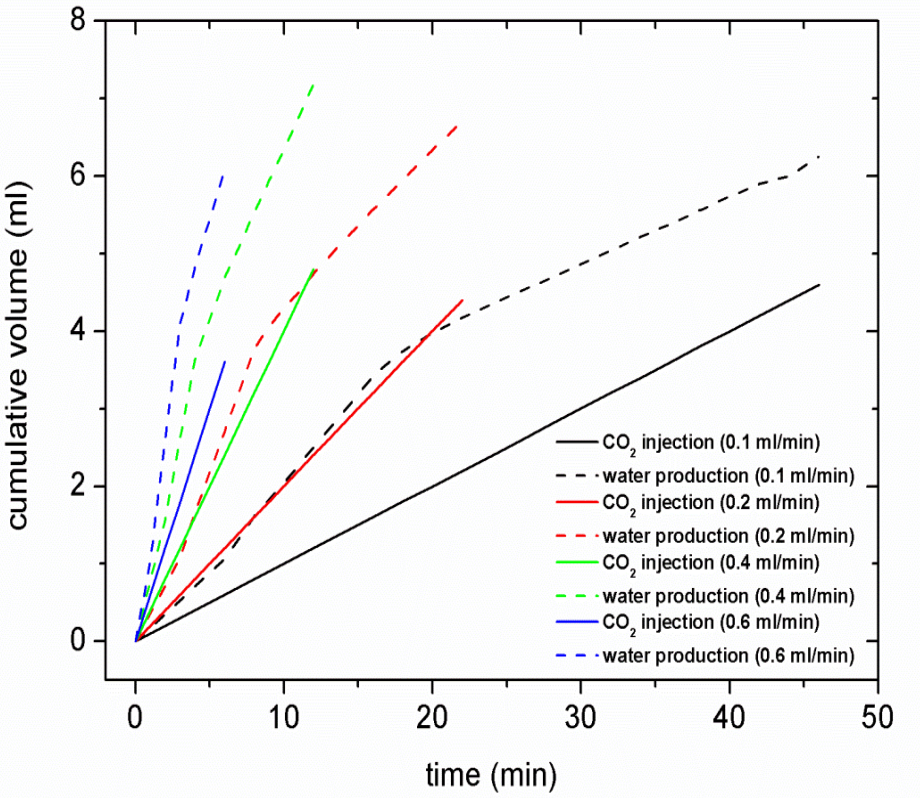
Effect of CO_2 phase on CO_2-water displacement



Effect of CO_2 phase on CO_2-water displacement

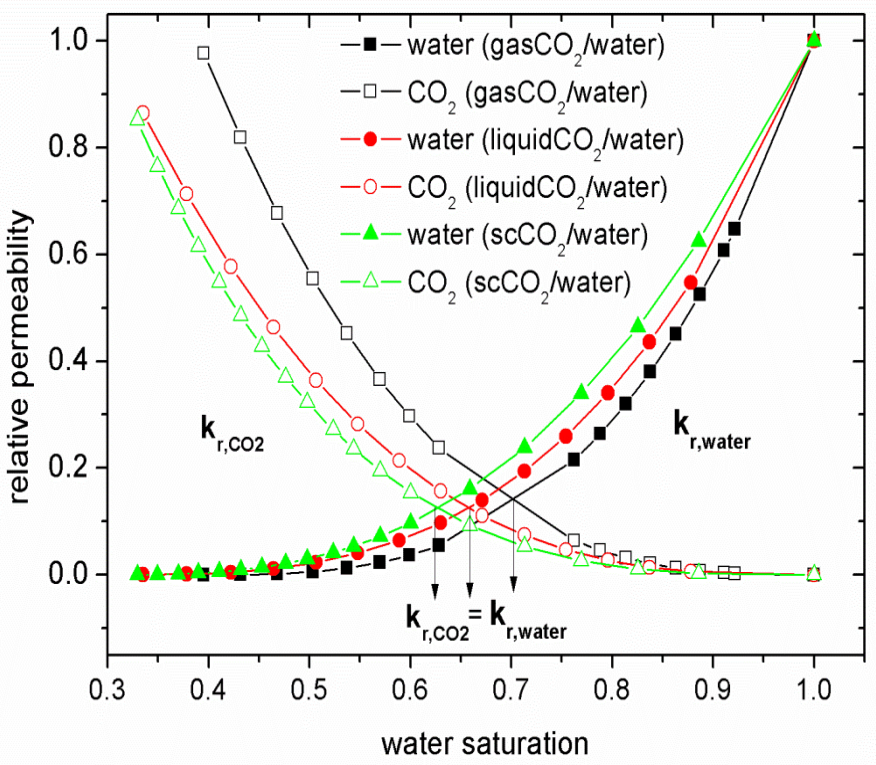


Water production of gas CO_2-water, liquid CO_2-water and supercritical CO_2-water systems

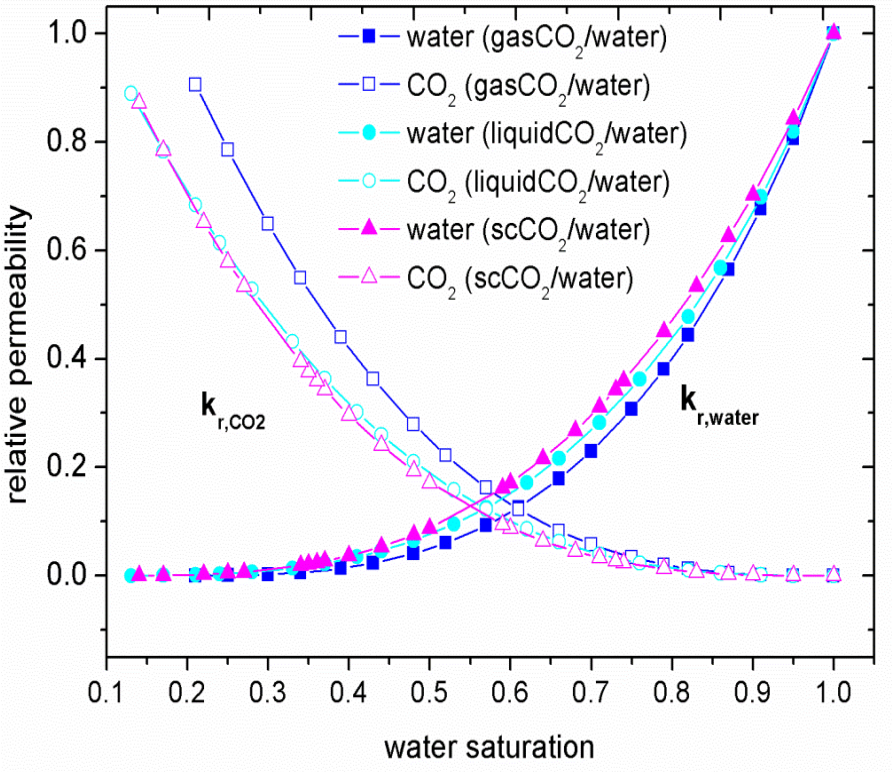


Cumulative water production for the supercritical CO_2-water system at supercritical CO_2 injection rates of 0.1, 0.2, 0.4 and 0.6 ml/min

Effect of CO_2 phase on CO_2-water displacement



Relative permeability curves for gas CO_2-water, liquid CO_2-water and supercritical CO_2-water displacements



Relative permeability curves predicted based on Plug and Bruining's experimental data for gas CO2-water, liquid CO2-water and supercritical CO2-water displacement

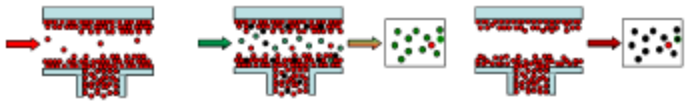
Development of a compact process for CO_2 capture

- Post-combust … ical absorption with aqueous … ercially available technology[1].
- However, the … apture process arise from the … onsumption for the desorption …
- Develop a co… CO_2 capture p… to deal with inc…

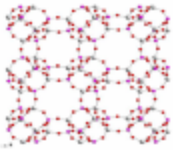
Combination of a rotating packed bed absorber and microwave (MW) assisted thermal regeneration.

Wetting Layer Absorbents

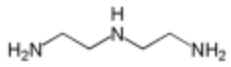
Develop a wetting layer absorption (WLA) carbon capture process based on chemical solvents



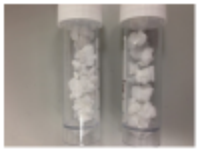
In comparison with liquid amine scrubbing processes, WLA has high working capacity and rate of mass transfer, and lower regeneration penalty



Zeolites



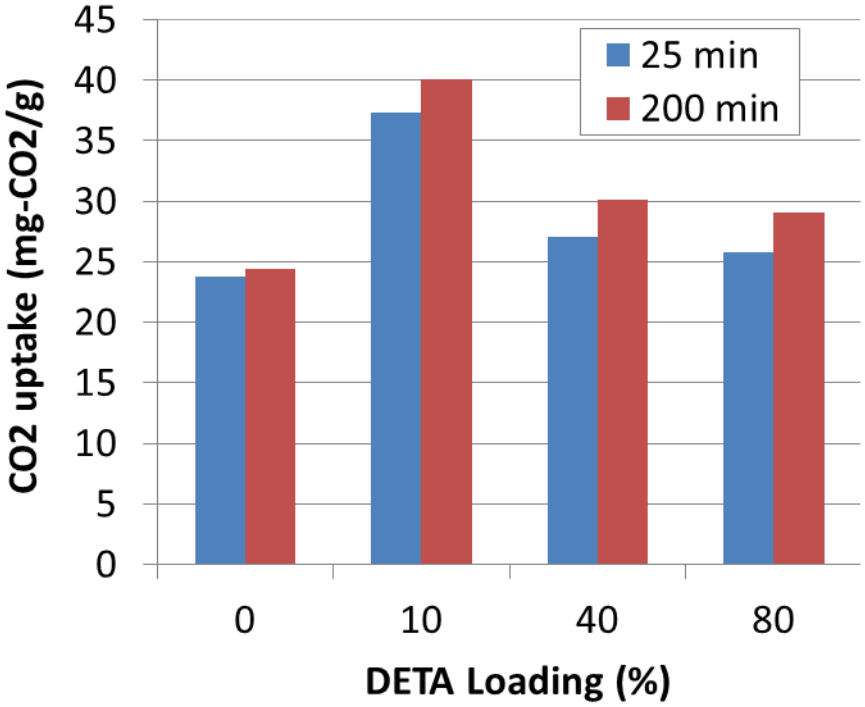
Dyetilenetriamine (DETA)

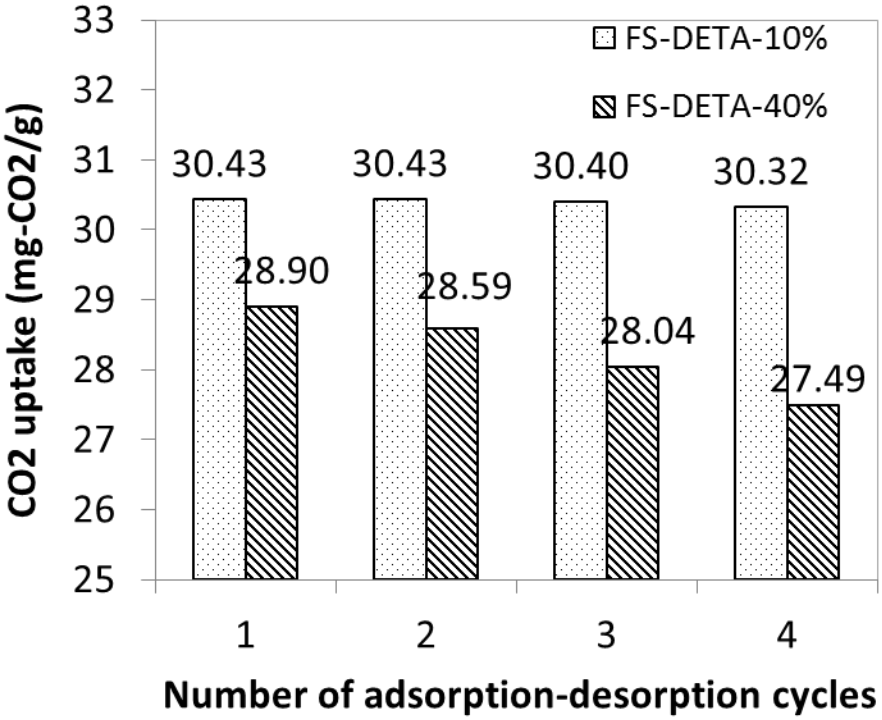


micro and mesoporous silica gel

Fig. 1 Illustration of compact CO2 capture system

CO_2 adsorption and regenerability





TGA test results

Development of Fluidization Technique for CO_2 Capture and Combustion