NIOR Wettability Estimation by Oil Adsorption

Visit NIOR to Wintershall (Barnstorf) and BASF (Ludwigshafen)
May 22nd – 24th, 2017

PhD-student Samuel Erzuah
Supervisor Ingebrit Fjelde
Co-supervisor Aruoture Voke Omekeh
Introduction

- Representative wettability conditions in SCAL and EOR-experiments
  (e.g. smart water and polymer flooding)
- SCAL data not early available
- Early more reliable potential estimates for water flooding will reinforce early focus on EOR-methods
Objectives

• Develop method for estimation of wettability condition of reservoir rock based on wettability of minerals mainly in contact with the flowing fluid phases
Secondary objectives

• Develop Quartz Crystal Micro-Balance with Dissipation (QCM-D) method to determine oil adsorption on mineral surfaces

• For selected rock examples, determine wettability and oil adsorption for minerals mainly in contact with flowing fluids in reservoir rock

• Develop method for estimation of wettability conditions in reservoir rock based on wettability of minerals and mineral distribution.

• Compare these wettability estimates with results from reservoir wettability studies using standard methods
Dissemination


Main results

• Development of QCMD method for oil adsorption measurements, more challenging than expected

• Flotation tests
  – Cheap and fast wettability screening
  – Small amounts of rock/minerals required

• Surface complexation modelling (SCM) promising cost-effective technique to estimate wettability of minerals at reservoir conditions
Result examples

• QCM-D development
• Flotation experiments
• Surface complexation modelling
Quartz Crystal Microbalance with Dissipation (QCM-D)

• Nanoscale technique for analyzing surface phenomena including thin film formation, interactions and reactions

• Frequency
  • Related to mass/thickness

• Dissipation
  • Related to rigidity
QCM-D measurements

1. **Binding of a small globular molecule**
   - Moderate frequency change $\Delta f$ (mass change).
   - Low dissipation change, $\Delta D$ (indicating rigid film).

2. **Binding of a large elongated molecule**
   - Large $\Delta f$ (more mass).
   - Large $\Delta D$ (soft film).

3. **Rinsing with regenerating buffer removing elongated molecule**
   - $f$ back to phase 1 (mass removal).
   - $D$ back to phase 1 (back to rigid film).
QCM-D in EOR/IOR

- Sensor of different materials

- Several possible EOR/IOR applications, e.g.
  - Dissolution and precipitation minerals
  - Adsorption/retention of chemicals
    - Polymer, surfactant, production chemicals
    - Crude oil
  - Crystal growth
Development QCM-D flow-cell method

- Cooperation with supplier
- New flow cell
  - Reservoir temperature and **pressure (NEW)**
    - i.e. back-pressure possible
  - Change in design to allow displacement of different fluid phases
  - Testing of prototype flow cell
- Sensors
  - Mainly quartz sensors during method development
  - Kaolinite sensors prepared and used in some tests
QCM-D experimental set-up

Injection fluid → Flow cell with sensor
Stainless steel
Temp. & pressure → Back pressure regulator
QCM-D Challenges

- When formation water injected, corrosion of stainless steel flow cell
  - Deposition of corrosion products on sensors
  - New flow cell in titanium prepared by supplier
  - Change to titanium piston cell and peak tubing

- Dissolution of quartz sensor and kaolinite sensor by formation water
  - Necessary to saturate fluids with mineral before injection
New QCM-D experimental set-up

Injection fluid → Mineral column → Flow cell with sensor (Titanium, Temp. & pressure) → Back pressure regulator

Oven
QCM-D quartz sensor without and with mineral column
Next steps:

- Oil injections
- Kaolinite
Flotation experiments

- Affinity of minerals to their respective fluid phases
- Mainly determined by wettability, particle, particle size, temperature and interfacial tension
- Experiments at same temperature and interfacial tension
- Reference with n-decane to isolate effect of wettability
Flotation Mineral examples

Amount oil-wet particles (w%) for different brines and oils

Quartz

Kaolinite

Calcite
Flotation example Reservoir rock
Simulations PHREEQ-C

- Ion-exchange
- Solubility minerals
- Surface complexation modelling (SCM)
  - Estimating attractive electrostatic pair linkages between oil-water interfaces and mineral surfaces
  - Bond product
    - Product of mole fraction of oppositely charged oil-water and mineral surfaces
    - Used to quantify tendency of oil adhesion on mineral surfaces
SCM Quartz

Figure 1: The bond product of the dominant electrostatic pair linkage in quartz.

Water-wet
SCM Kaolinite

Less water-wet than quartz
SCM Calcite

Less water-wet than both kaolinite and quartz
Comparison Flotation and SCM

Similar ranking of minerals by SCM as wettability characterized by flotation tests
Summary

• Development of QCM-D for measurement of oil adsorption more challenging than expected
  – Appears promising also for other EOR/IOR studies, but further development required

• Flotation
  – Cheap and fast method for wettability screening
  – Only smaller quantities of rock/mineral required

• Simulations SCM
  – Cost-effective technique of estimating wettability of minerals in reservoir rocks
  – In agreement with flotation ranking of minerals
  – Information about dominating adsorption mechanisms