Microscopic and Mesoscopic Polymer Adsorption in Enhanced Oil Recovery (EOR)

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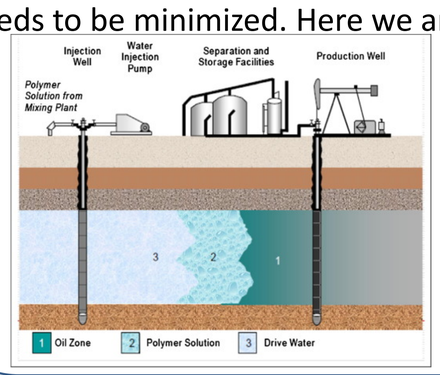
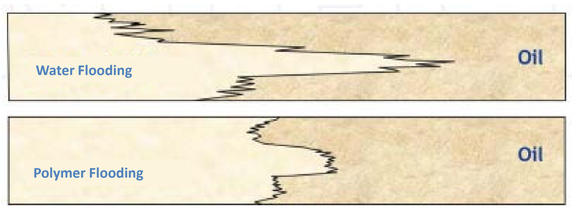
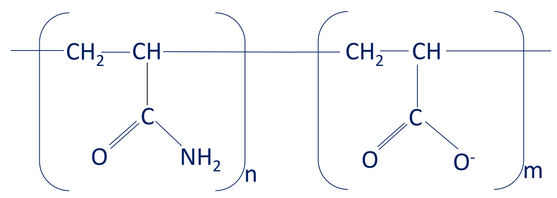
PROBLEM STATEMENT

The polymer EOR utilizes high molecular weight polymers to improve the viscosity of the displacing aqueous phase. This polymer-brine solution has a better sweep efficiency than the normal brine solution. But the polymers get adsorbed on the rock surface. Polymer adsorption on the pore surface has a negative impact and therefore needs to be minimized. Here we are investigating polymer adsorption fundamentally through QCM and SMFS.







Chemical formula of Flopaam: Random copolymer of Polyacrylamide (70%) (the left,n) and polyacrylic acid (30%) (the right,m)

Some factors affecting adhesion:

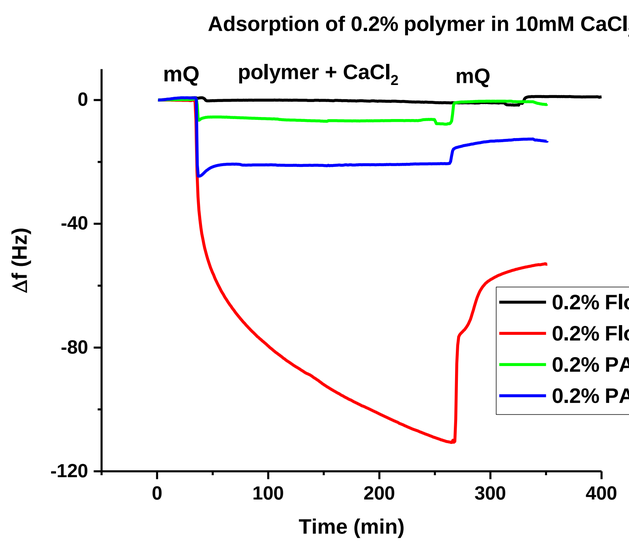
- ✓ Charge on the polymer
- ✓ Surface charge (charge on the clays)
- ✓ Ions present in the brine
- ✓ pH of the solution

QCM-D

Upon passing the polymer solution, the sensor undergoes frequency shift (Δf) and Dissipation shift (ΔD) due to adsorption, density and viscosity effects. The amount of polymer adsorbed can be extracted by using appropriate model. Polymer studied: Flopaam 3630 (20 MDa) and Polyacrylamide (PAM) (2 MDa).

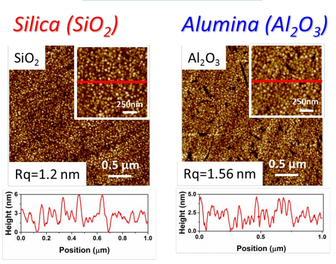
RESULTS

- Effect of substrates



More adsorption of Flopaam and PAM on alumina substrate

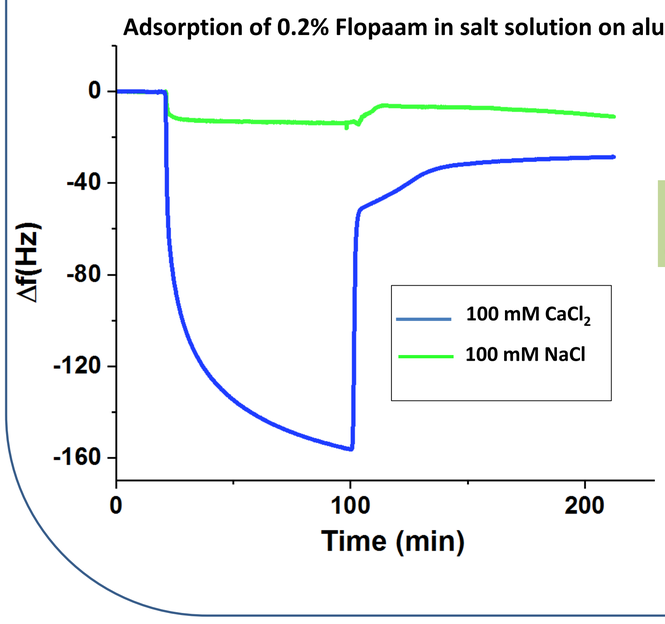
Substrate characteristics[1]



SiO_2; q = - 0.060 e/nm² Al_2O_3; q = 0.013 e/nm²

10 mM NaCl, pH=5.8

- Effect of ions on adsorption



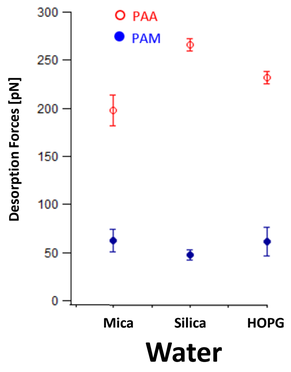
Divalent Ca^{2+} ions increase the adsorbed amount of Flopaam on Alumina[2]

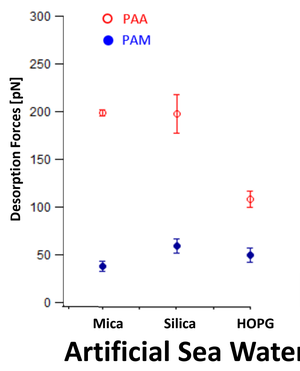
AFM BASED SINGLE MOLECULE FORCE SPECTROSCOPY (SMFS)

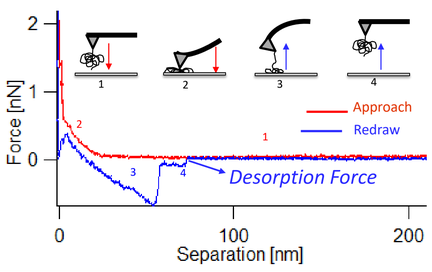
The polymer is grafted on to the cantilever and its interaction with the substrate is observed. The deflection of the cantilever and the piezo contractions (converted to force and separation respectively) give us information about desorption force and desorption length.[3]

RESULTS

- Study on Homopolymers: Polyacrylamide (PAM) and Polyacrylic acid (PAA)

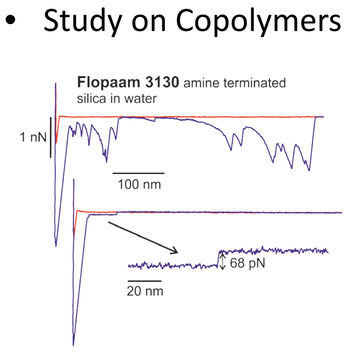


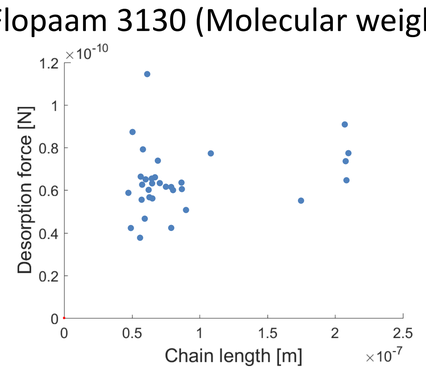




Polyacrylic acid is highly influenced by presence of ions

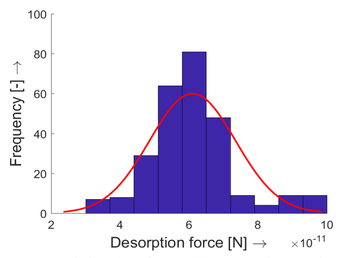
- Study on Copolymers : Flopaam 3130 (Molecular weight ≈ 2 MDa)



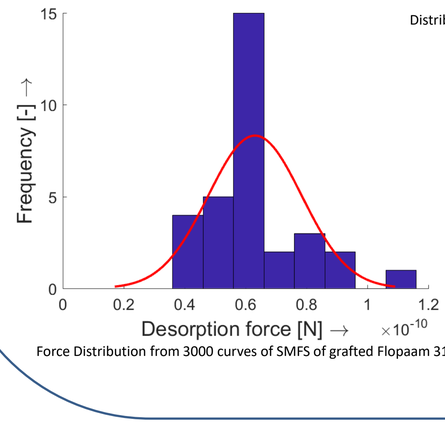


Distribution of desorption length for grafted Flopam 3130

Better statistics for shorter graft length



Force Distribution from 1000 curves of SMFS of grafted PAM (around 500 nm in length)



Force Distribution from 3000 curves of SMFS of grafted Flopaam 3130

- ✓ Stretching events are more due to the very long polymer grafted on to the tip.
- ✓ Statistics is poor when compared to the shorter grafted chain.
- ✓ Desorption length is not representative of the very long polymer attached.

➢ Need a lower molecular weight copolymer to study SMFS

CONCLUSIONS

- ➢ QCM-D and SMFS by AFM can be used to study the polymer adsorption at mesoscopic and microscopic level.
- ➢ QCM-D preliminary experiments suggest the effect of substrate and ions on polymer adsorption
- ➢ SMFS of homopolymers implies Polyacrylic acid is highly influenced by presence of ions.
- ➢ SMFS of copolymer requires a lower molecular weight system

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PCF TWENTE PHYSICS OF COMPLEX FLUIDS.

[1] Siretanu,I. *et al, Sci. Rep.* **2014**, *4.*
[2] Wang, L. *et al*, *Colloids Surf. A* **2016**, 494, 30-38.
[3] Giannotti, M.I. *et al, ChemPhysChem* **2007**,8,2290-2307

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DPI, P.O. Box 902, 5600 AX Eindhoven, the Netherlands

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