NON-NEWTONIAN FLUID DISPLACEMENT IN MICROCHANNEL

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Introduction

Definition: Removal of a fluid inside a containment by means of another fluid. In this case, Non-newtonian fluids are considered.

Variations: Gas-gas, gas-liquid, liquid-gas, liquid-liquid

**Convention: First fluid=Displaced fluid, Second fluid=Displacing fluid*

Of the four displacement types, the **viscosity ratio** between the two fluids will **determine** the resulting parameters like **interface shape and film thickness.**

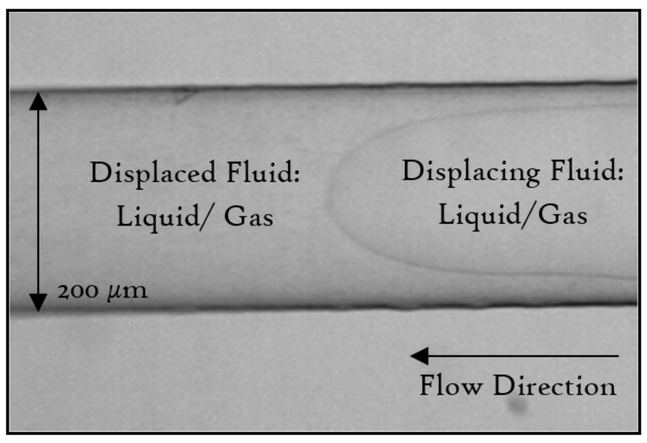


Figure 1: Viscous fingering during displacement flow inside a microchannel

If the **displacing fluid is more viscous** than the displaced fluid, **complete removal** of the initial fluid can be achieved quickly as no instability occurs.

When a **less viscous fluid displaces a more viscous one**, a finger-like interface forms leaving **a film of the displaced fluid is left on the channel wall** (Figure 1). This phenomenon is also commonly known as **viscous fingering.**

Hydrodynamic properties of interest: Displacement efficiency (m_g) & geometric mass fraction (m_e)

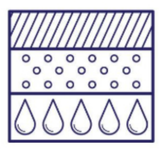
$$m_g = 1 - \frac{R^2_{displacing}}{R^2_0} \qquad m_e = 1 - \frac{\bar{U}_{displaced}}{\bar{U}_{mean}}$$

Applications

Cleaning of equipments
- Lab and pharmaceutical equipment often has small to micro-sized channels.

Flow of high viscosity waste
- Industrial waste with high viscosity, especially high MW polymer waste and solvents.

Enhanced oil recovery (EOR)
- Removal of trapped crude oil in reservoir that is unobtainable normally



Spread of contaminants in soil
- Movement of groundwater in reservoir rocks with micro pores.

Predicting volcanic eruption
- Understanding the movement of magma inside the porous rocks.

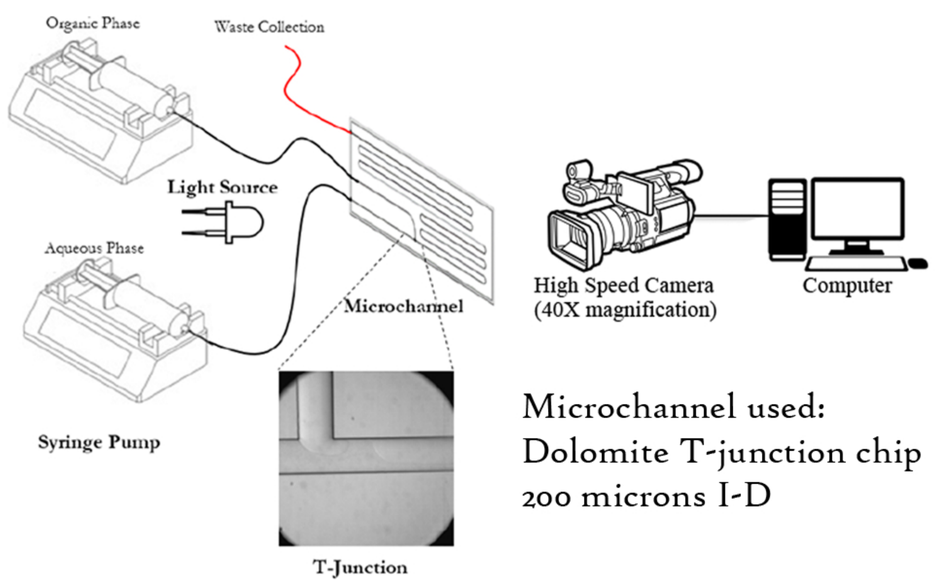
Administration of medication
- Dispensing of drugs into blood vessel of patients

Experimental Setup

Materials

Chemicals	Manufacturer	Concentration Added	Phase
Glycerol	Sigma-Aldrich	55 wt%	Displacing
Xanthan gum powder	Sigma-Aldrich	1000 & 2000 ppm	
FluoSpheres particles	Life-Technologies	Droplets (N/A)	
Distilled water	-	-	
Silicone oil	Sigma-Aldrich	99.9%	Displaced

Experimental Configuration



Microchannel used:
Dolomite T-junction chip
200 microns I-D

Figure 2: Experimental schematics for optical imaging of the displacement process

Results and Future Works

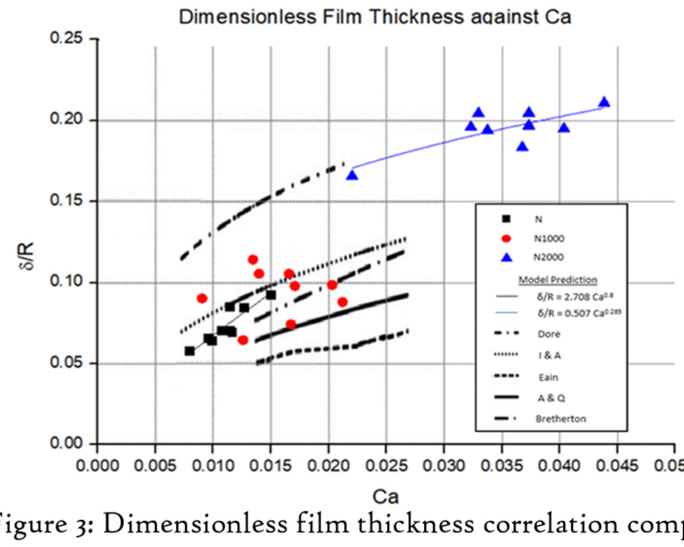


Figure 3: Dimensionless film thickness correlation comparrison

Power law fitting

$N1000$ $y = 0.187x^{-0.4719}$

$N2000$ $y = 0.978x^{-0.6177}$

Film Thickness Correlation

N $\frac{\delta}{R} = 2.708\,Ca^{0.8}$

$N2000$ $\frac{\delta}{R} = 0.507\,Ca^{0.285}$

Future works

- Complex fluids (viscoelastic)
- Multiple microchannel configuration (constrictions, junctions, bends)
- Other channel shapes (semi-circular, square)
- Higher measuring precision techniques (two colour μ-PIV, LIF)

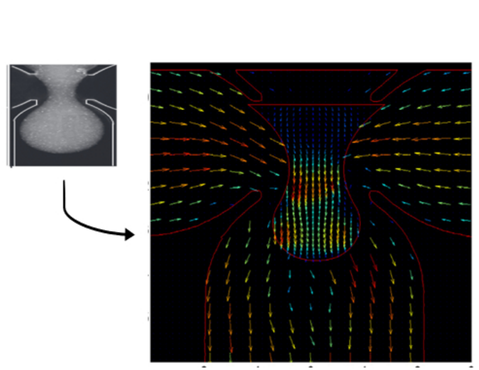
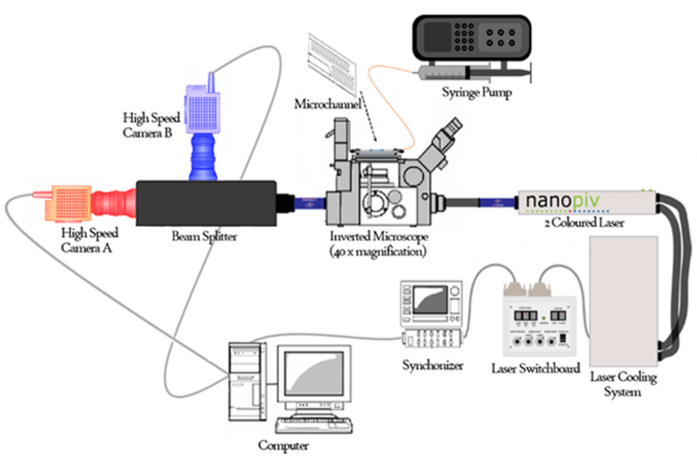


Figure 4: Velocity field from PIV



Acknowledgement

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