COMPUTATIONAL STUDY OF TRANSITION OF OIL-WATER FLOW MORPHOLOGY DUE TO SUDDEN CONTRACTION IN MICROFLUIDIC CHANNEL

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PRESENTATION PLAN

- Introduction
- Application of microfluidics
- Motivation of the work
- Summary of the work
  - Use of COMSOL Multiphysics
  - Mathematical formulation
  - Results and discussion
- Conclusion
- Future scopes

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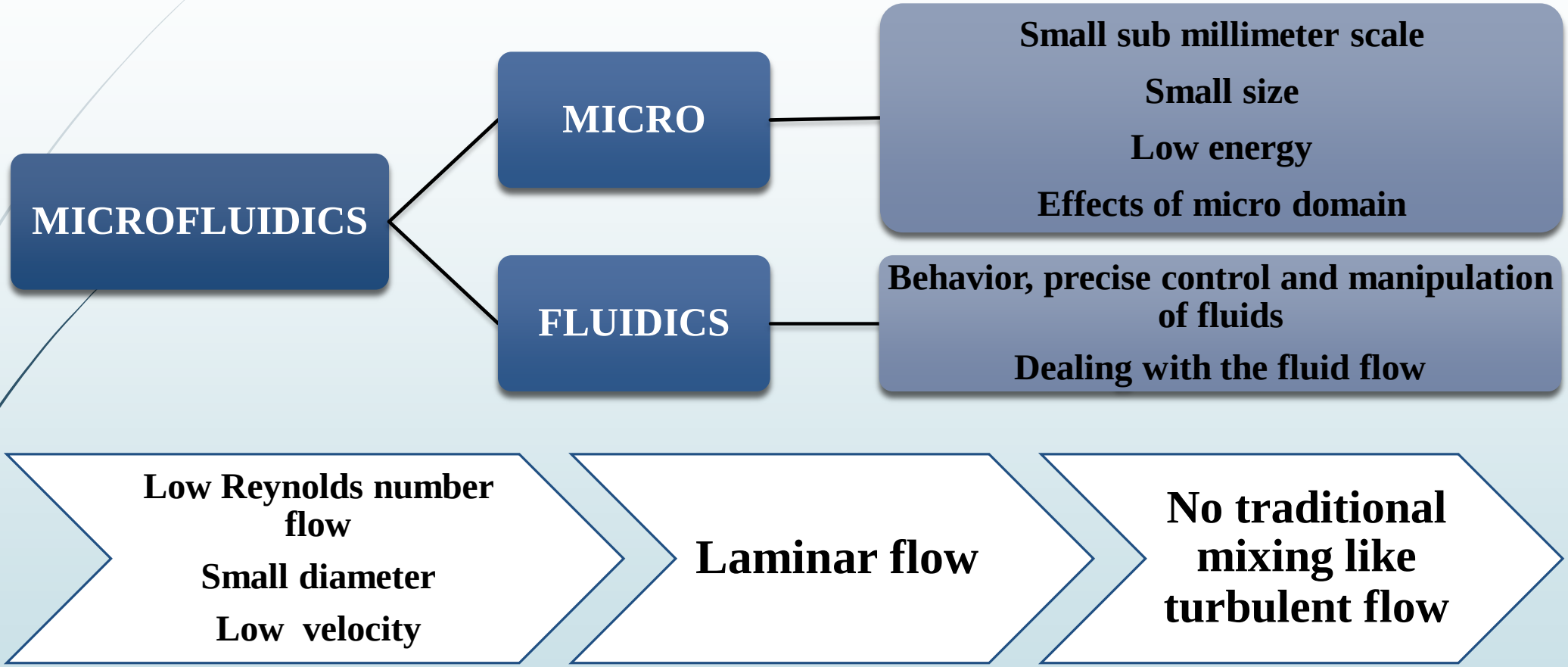
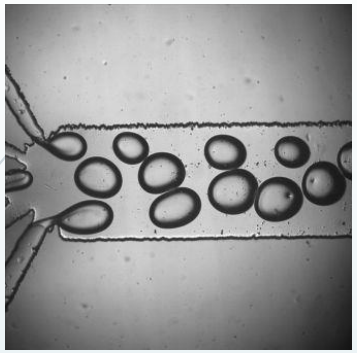
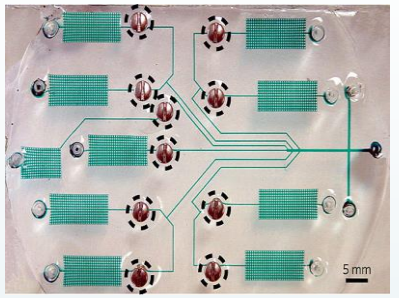
INTRODUCTION



APPLICATIONS OF MICROFLUIDICS



Fluid thread breakup under microfluidic confinement with applications in oil recovery and biology, **João T. Cabral,** Polymers & Microfluidics Group, Imperial College, London



The origins and the future of microfluidics **George M. Whitesides**, *Nature* **442**, 368-373, 2006

Electronic

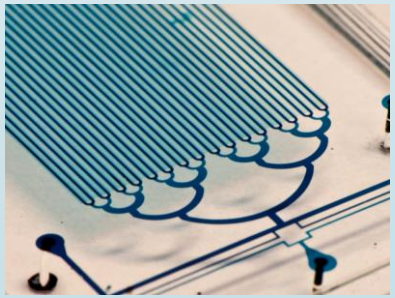
- DNA
- Drug delivery
- MEMS/ NEMS
- Micromixers
- Cooling of electronic devices
- Microreactors
- Digital microfluidics
- Microbial behavior
- Bio chips

Reaction Engineering

Microfluidics

Biological

Lab on a chip devices



Bio pixel microfluidic bacteria chip, http://www.extremetech.com/extreme/111617-glowing-bacteria-biopixels-the-sensor-displays-of-the-future

Parallel screening of an in situ "click" chemistry library in integrated microfluidics **Hsian-Rong Tseng, UCLA**

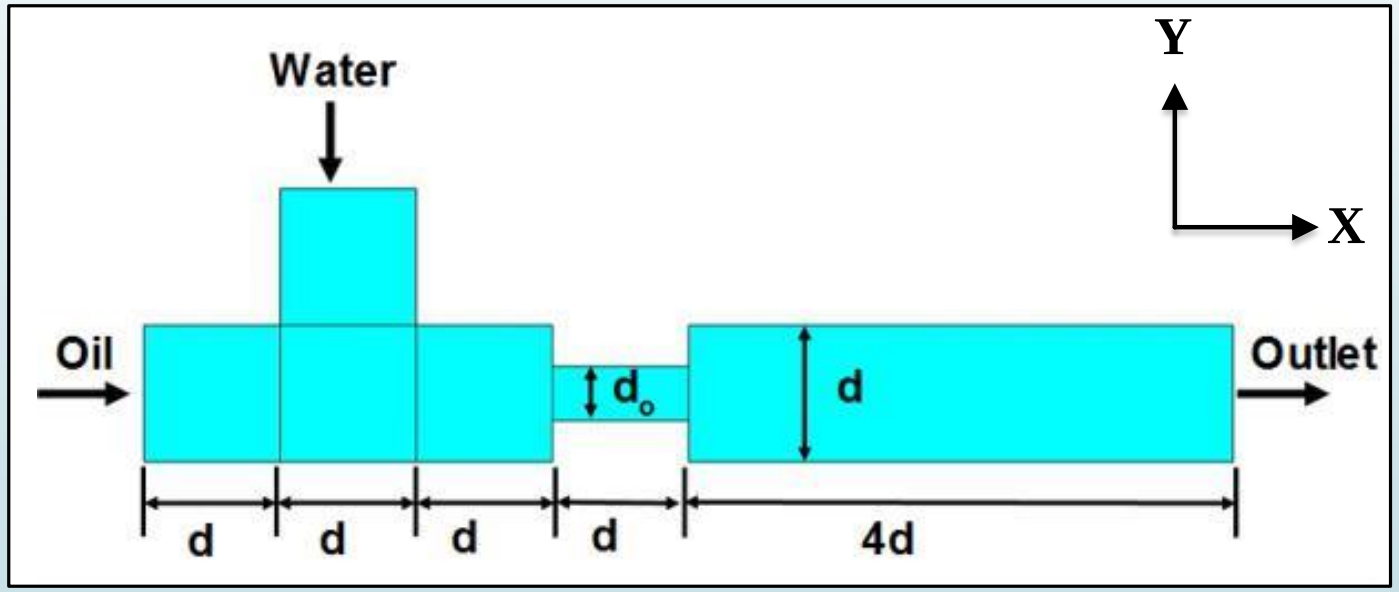
MOTIVATION OF THE WORK

- Achieve droplet driven flow from any type of flow pattern
- Study the effects of interfacial tension of the two phases (oil and water) and the contraction/orifice diameter
- Tuning of the droplet diameter by changing the orifice position and the diameter
- Droplet formation in an economic way i.e. without using any external force fields

APPLICATION OF COMSOL MULTIPHYSICS

GEOMETRY

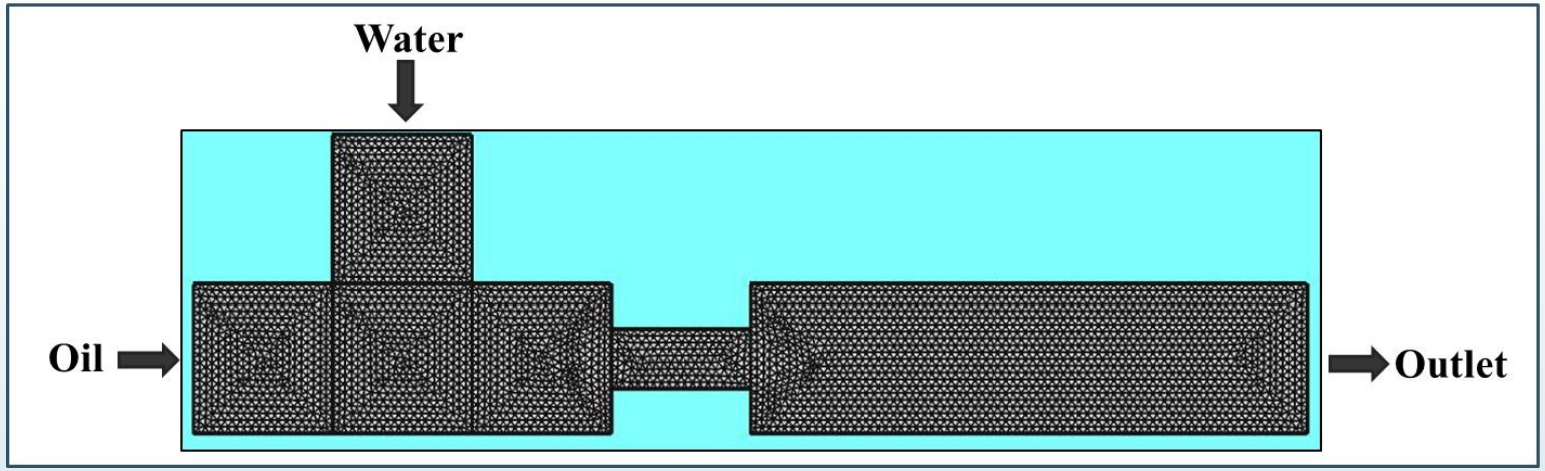
- Selection of appropriate coordinate
- Determining of the domain shape and size
- Simplifications, if possible



d_o = orifice diameter
d = micro channel diameter

d_o = 100 μm-200 μm
d = 500 μm

MESH



- **6770 – 6924** number of mesh elements
- **Physics controlled mesh**
- **Triangular mesh**

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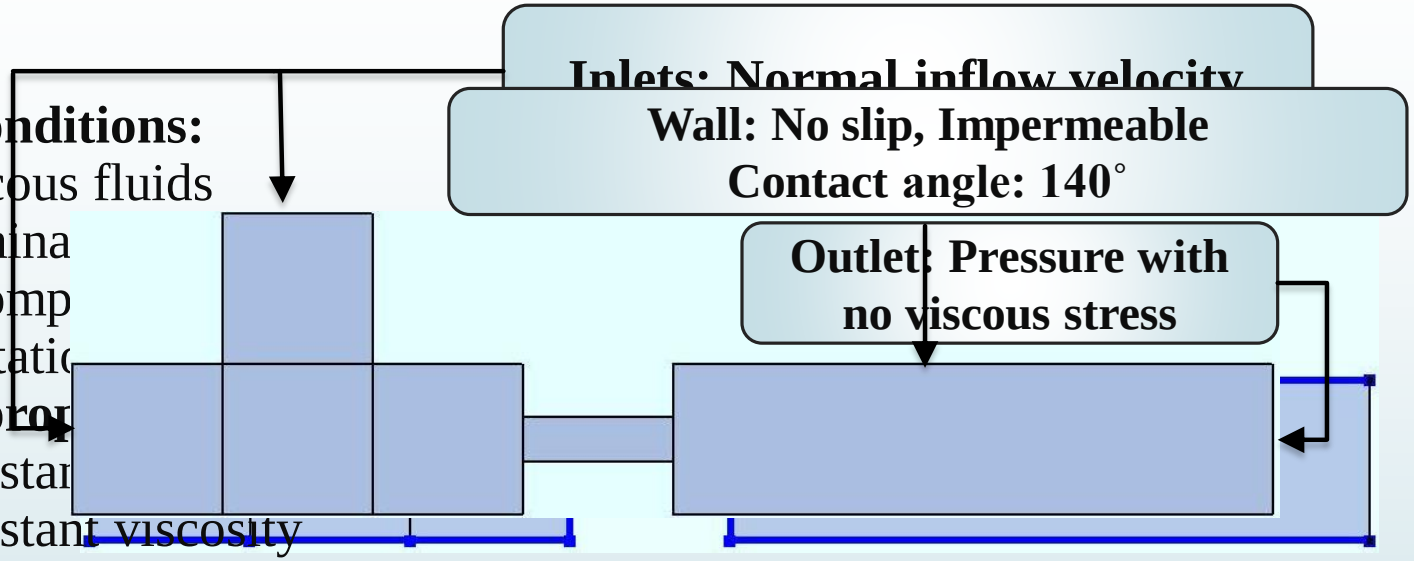
PHYSICS

- **Flow conditions:**
  - Viscous fluids
  - Lamina
  - Incomp
  - Irrotatio
- **Fluid pro**
  - Constan
  - Constant viscosity
  - Newtonian fluids
  - Immiscible fluids
- **Flow models:**
  - Multi phase flow
  - Two phase flow, Phase field



GOVERNING EQUATIONS

- **Conservation of Mass – Continuity equation:**

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

$$\nabla \cdot \mathbf{u} = 0 \qquad \text{Incompressible flow}$$

$$\rho = 0.5\left[\rho_1(1+\phi) + \rho_2(1-\phi)\right]$$

$$\eta = 0.5\left[\eta_1(1+\phi) + \eta_2(1-\phi)\right]$$

- **Navier-Stokes Equation:**

$$\rho\left(\dot{\mathbf{u}}_i + \mathbf{u}_i \cdot \nabla \mathbf{u}_i\right) = -\nabla p_i + \nabla \cdot \boldsymbol{\tau}_i + \mathbf{f}_{st} + \rho \mathbf{g}$$

where, $\boldsymbol{\tau}_i = \eta_i\left(\nabla \mathbf{u}_i + \nabla \mathbf{u}_i^T\right)$ and $\mathbf{f}_{st} = G\nabla\phi$

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RESULTS

FLOW PARAMETER VALUES

- **Viscosity:**
  - Oil: 0.01 Pa s
  - Water: 0.001 Pa s
- **Density:**
  - Oil: 1000 kg/m^3
  - Water: 1000 kg/m^3
- **Velocity:**
  - Oil: 0.1 m/s
  - Water: 0.01 m/s
- **Interfacial Tension (γ):**
  - Varied from 0.0258 to 0.04 N/m
- **Contact angle (θ) :**
  - Equilibrium contact angle of a water droplet on the wall and embedded inside oil is set to 140°

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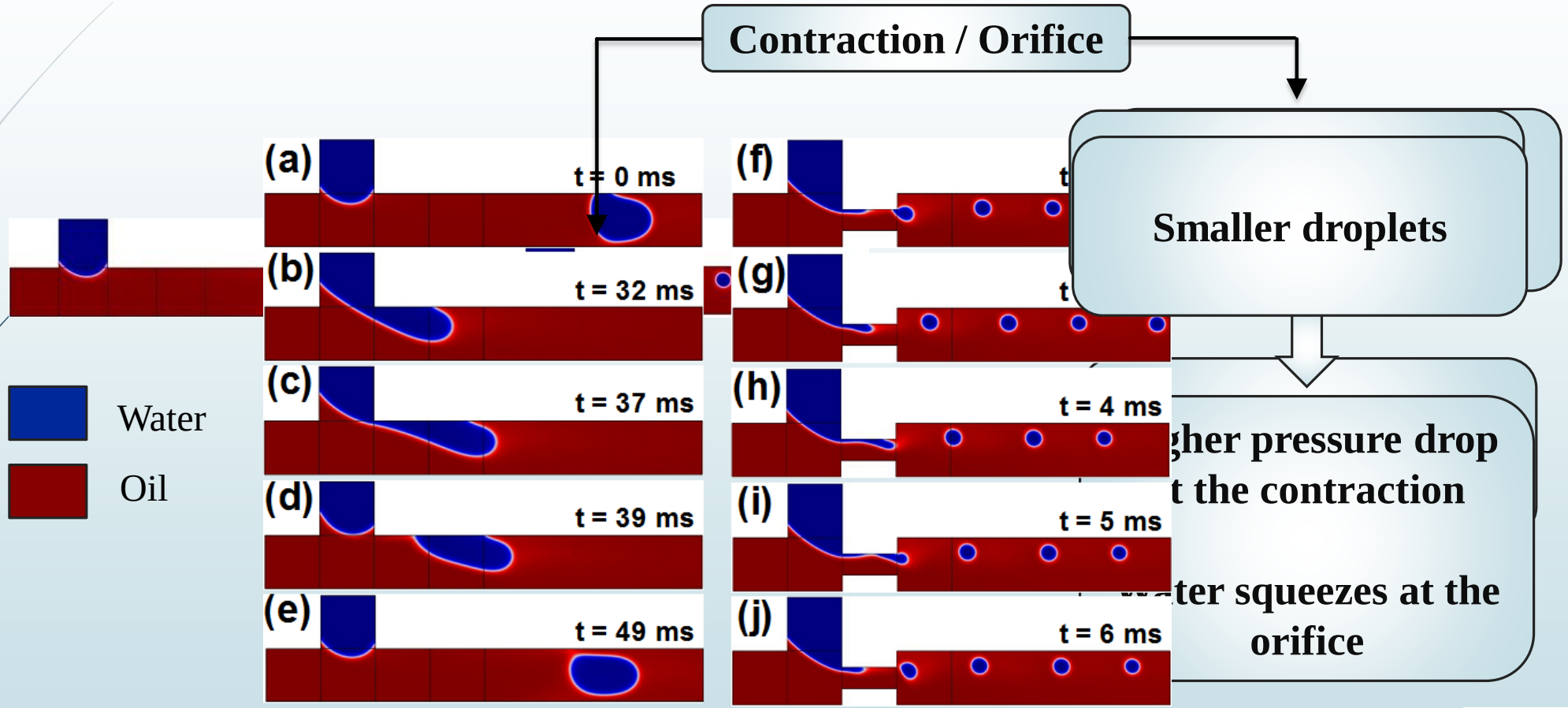
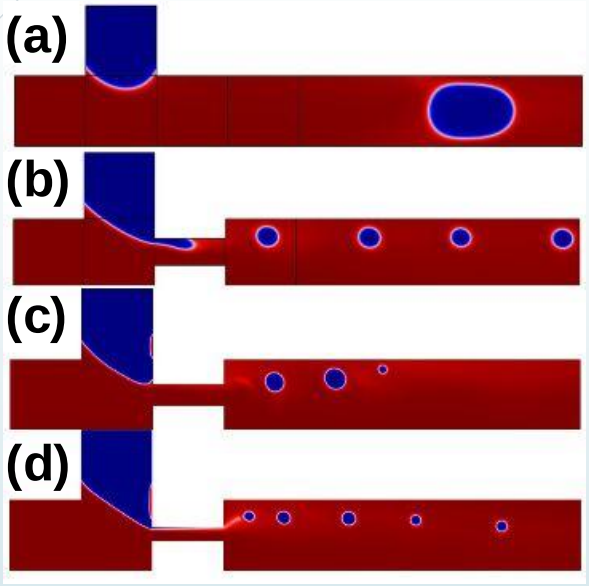
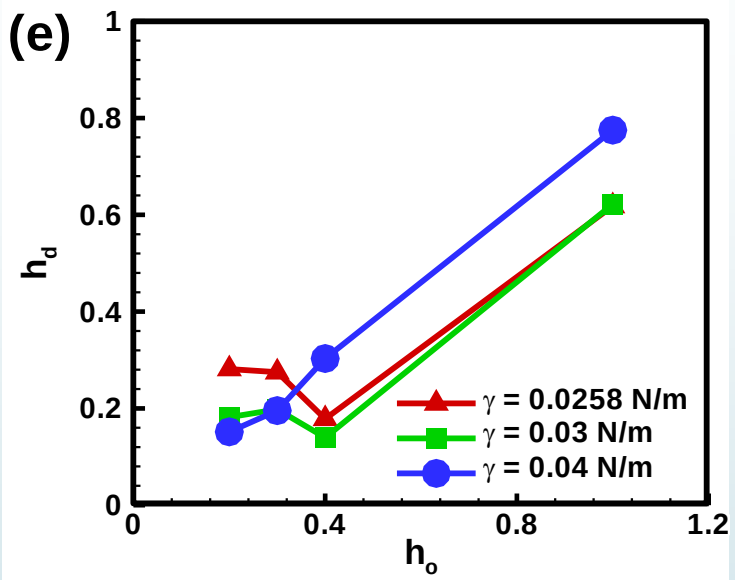
CHANGE IN FLOW MORPHOLOGY



EFFECT OF ORIFICE DIAMETER





- From images (a), (b), (c) and (d) we can say

Orifice diameter decreased

Droplet diameter decreased

- Image (e) shows the variation of **dimensionless droplet diameter** with **dimensionless orifice diameter** upon changing the interfacial tension

$$h_d = d_d/d$$

Dimensionless droplet diameter

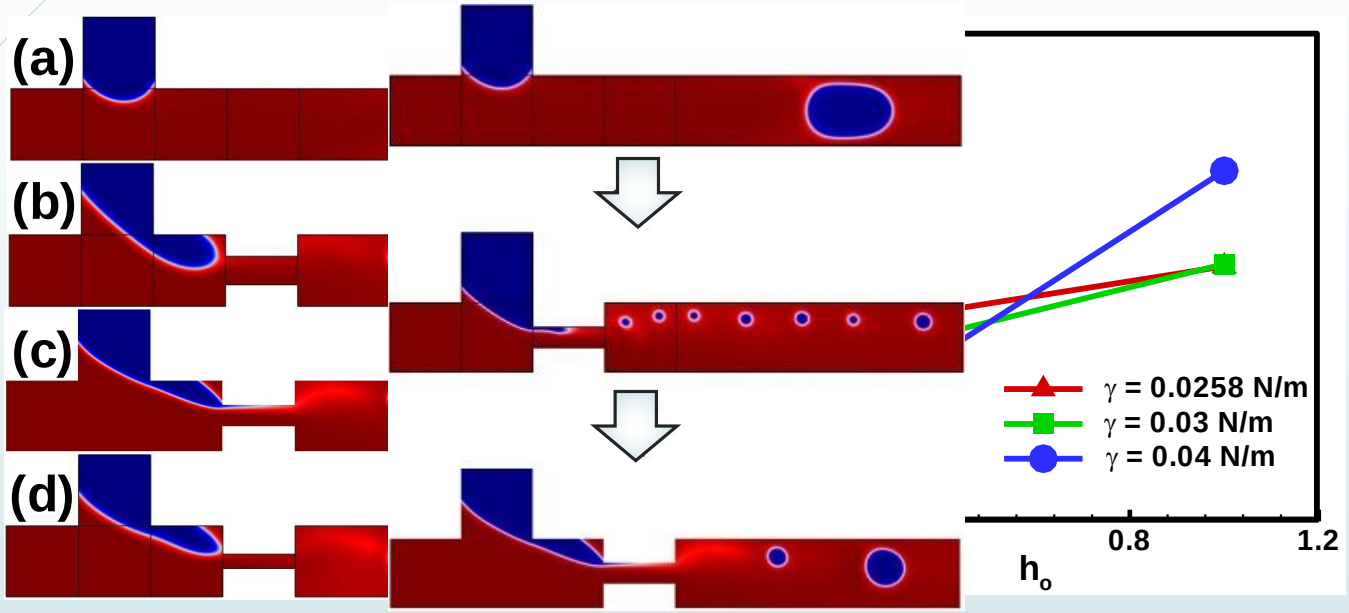
d_d = droplet diameter

$$h_o = d_o/d$$

Dimensionless orifice diameter

d_o = orifice diameter

EFFECT OF ORIFICE POSITION



- From images (a), (b), (c) and (d) we can say

Orifice diameter decreased

Droplet diameter decreased

- From this combined image it is also evident that the droplet diameter also depends on the position of the contraction

Shifting of contraction from T-junction towards right → Droplet diameter increased → Droplet frequency decreased

CONCLUSIONS

- Controlled oil-water flow patterns by using a contraction near a T-junction microchannel
- Smaller diameter orifice can facilitate smaller sized flow structures
- Frequency and size of droplets can be controlled by the size of orifices and also by their positions

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FUTURE SCOPES

- Effect in flow patterns by adding two or more contractions in the downstream of the T-junction
- Effect in flow patterns by adding orifice at the inlets
- Effect in flow structures by switching the inlets between oil and water
- Study the flow morphology by varying different other parameters like velocity ratio

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THANK YOU…