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Simulation of a Pressure Driven Droplet Generator

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Outline

1) Overview of microfluidics

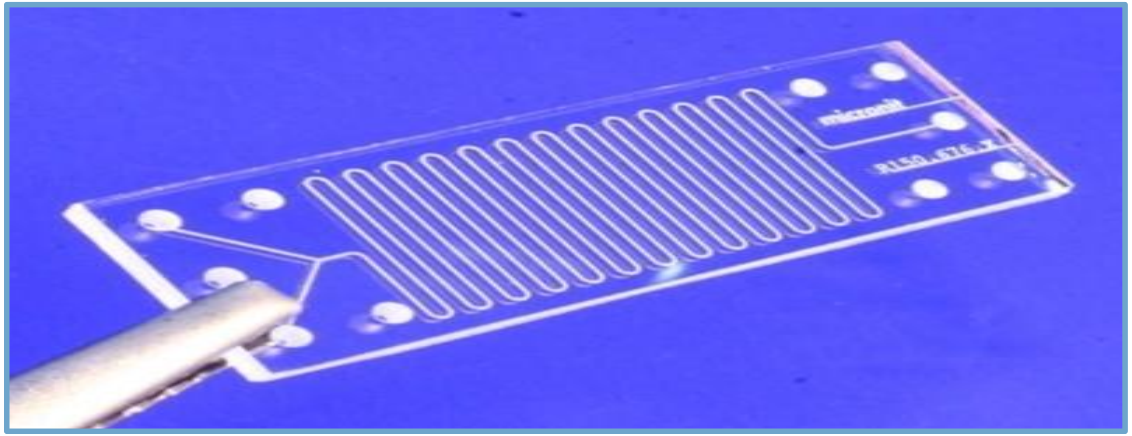
2) Presentation of the process

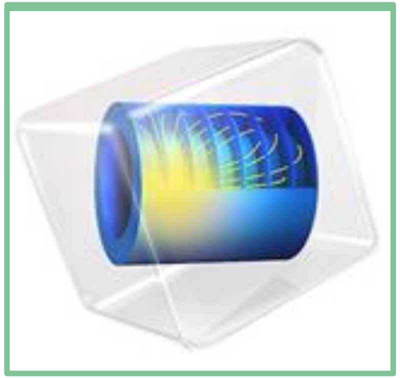
3) Model

4) Results

5) Outlook

1) Overview of microfluidics

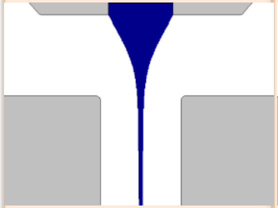
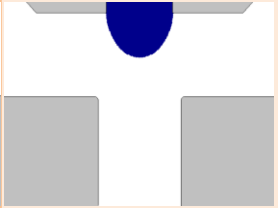


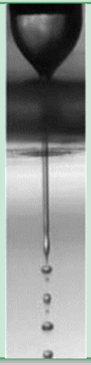


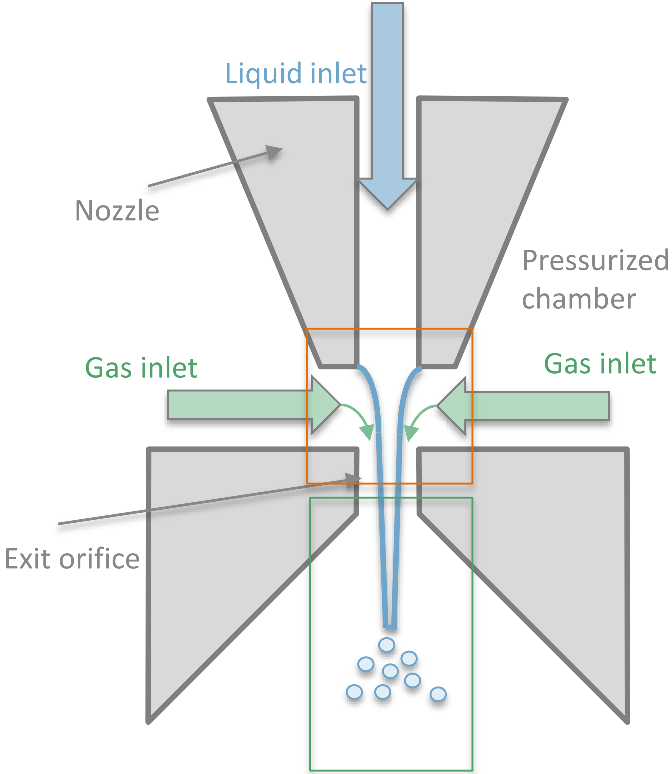
Pictures: potomac-laser.com, upperton.com, comsol.com

2) Presentation of the process

❑ *Flow regimes & modes*

Flow regimes	
Stationary Dynamic (SD)	Transient (T)
Constant shape over time	Periodic flow
	

Modes	
Dripping	*Jetting*
Production at the exit orifice	Thread break up
	



Si, Li, Yin and Yin, 2009, *Modes in flow focusing and instability of coaxial liquid-gas jets*

3) Model

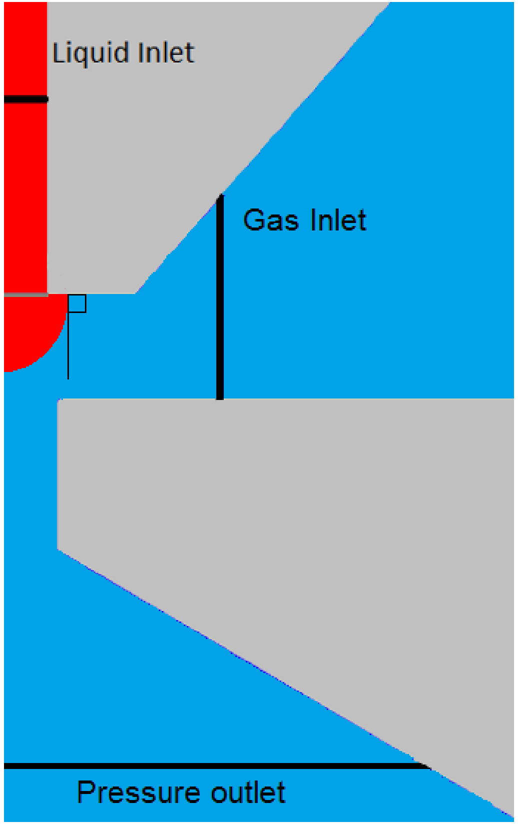
❑ *Assumptions*

- Rotational symmetry → 2D-axi consideration
- Neglecting the influence of temperature
- No chemical reactions

❑ *Fluids & interfacial properties :*

Property	Liquid (DP)	Gas (CP)
Density (kg/m^3)	957	1.225
Viscosity (Pa.s)	1.8e-3	1.8e-5

Surface tension (N/m)	35.6e-3
Contact angle (rad)	$\pi/2$



3) Model

❑ *Governing equations*

✓ Liquid & gas flows governed by the Navier-Stokes equations for incompressible flows

$$\nabla.\boldsymbol{u} = 0$$

$$\rho\frac{\partial \boldsymbol{u}}{\partial t} + \rho(\boldsymbol{u}.\nabla)\boldsymbol{u} = \nabla.[-pI + \mu(\nabla\boldsymbol{u} + \nabla\boldsymbol{u}^T)] + \rho\boldsymbol{g} + \boldsymbol{F}_{st}$$

✓ Interface motion of the multiphase flow: simulated with COMSOL module Two-Phase Flow, Phase Field approach.

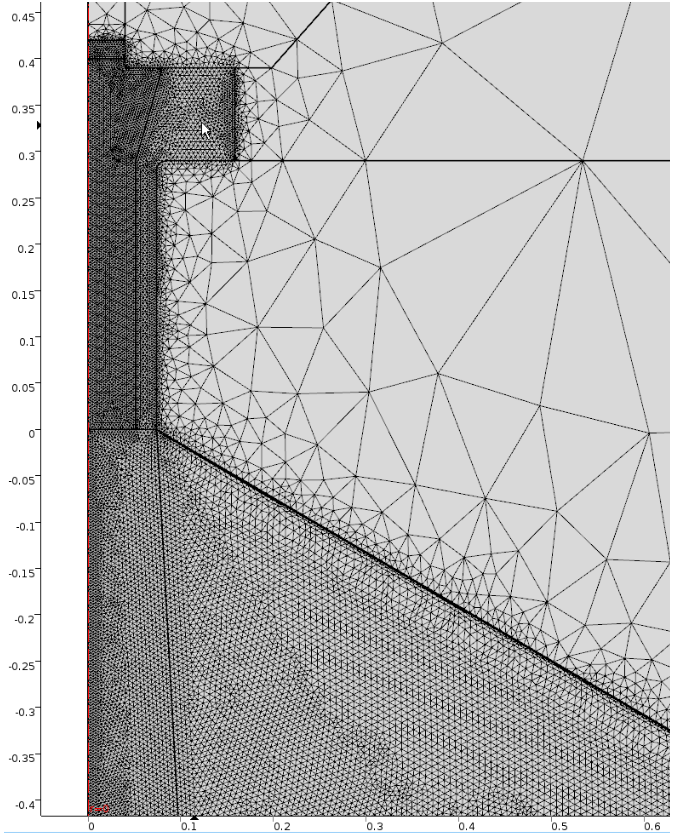
→ Resolution of the Cahn-Hilliard equation

$$\frac{\partial \phi}{\partial t} + \boldsymbol{u}.\nabla\phi = \nabla.\frac{3\epsilon\sigma}{2\sqrt{2}}\chi\nabla[-\nabla.\epsilon^2\nabla\phi + (\phi^2 - 1)\phi]$$

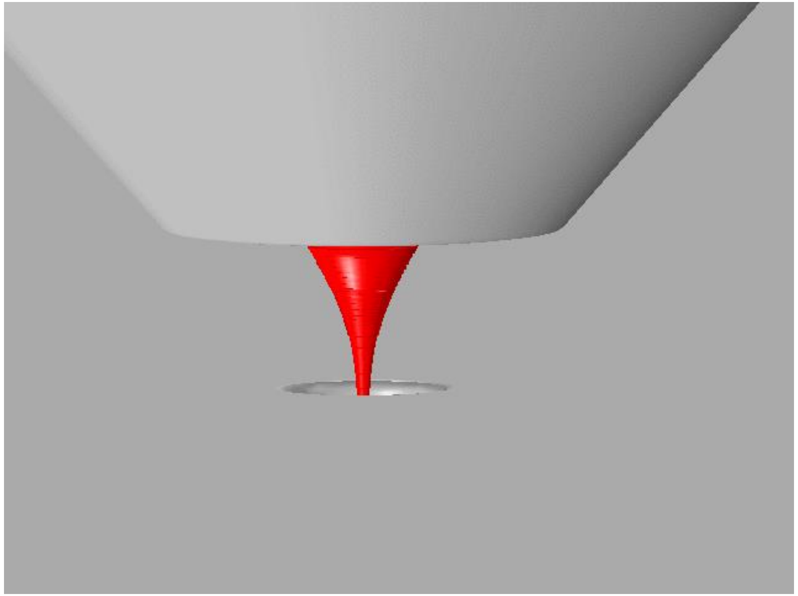
3) Model

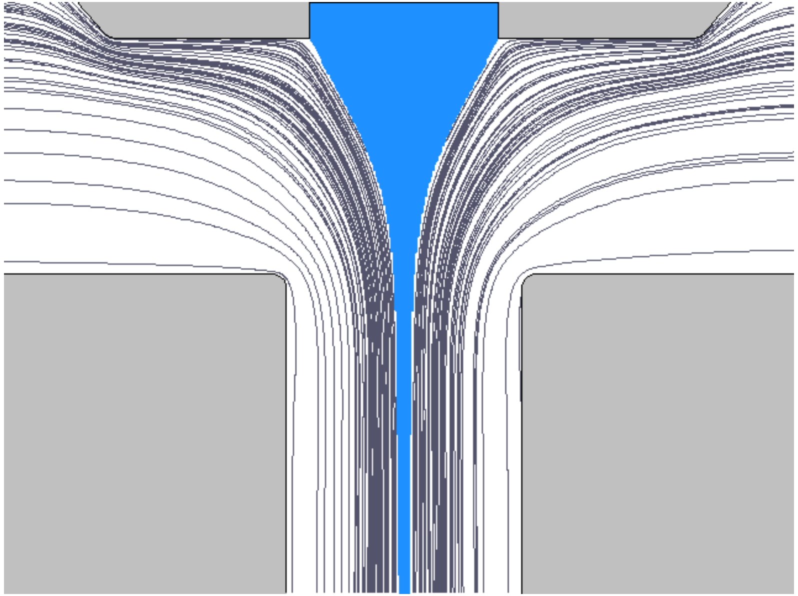
❑ ***Numerical details***

- Range of liquid flow rate : 1 to 10 ml/h
- Range of gas pressure : 0.02 to 1 bar
- Time setting : [0,0.01s] with timestep of 1e-4s
- BDF for the time-dependent study
- Newton-Raphson algorithm to linearize
- PARDISO as direct solver
- Calibration studies on mobility & phase field parameter



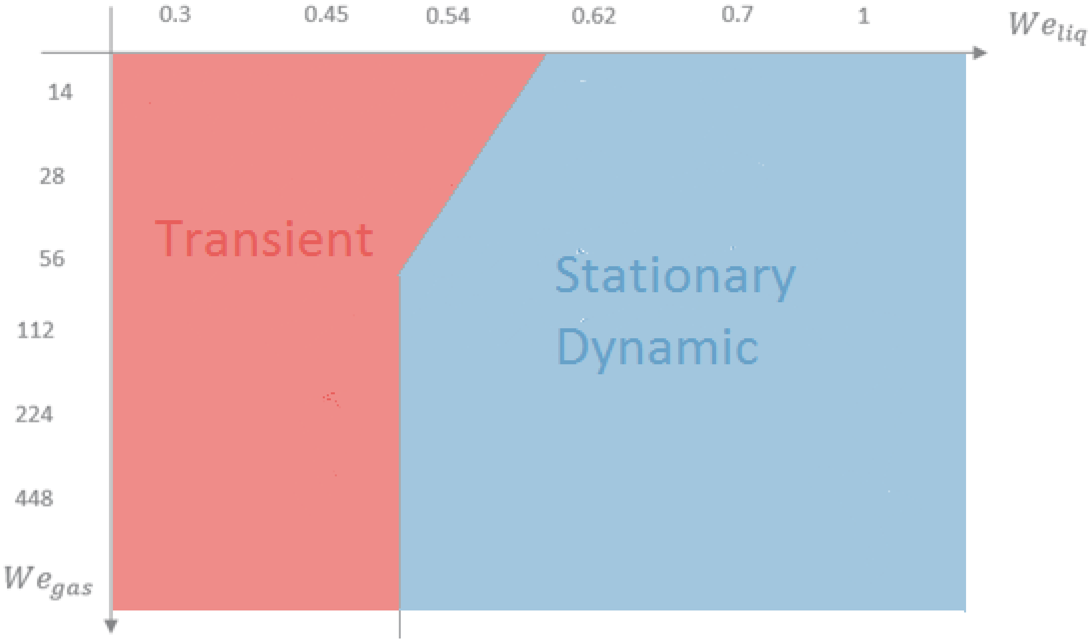
4) Results





Stationary Dynamic

4)Results



T: Transient
SD: Stationary Dynamic

→ Flow regimes as a function of the Weber number

- Liquid Weber :

$$We_{liq} = \frac{\rho u^2 R_{in}}{\sigma} = \frac{kinetic\ energy}{surface\ tension}$$

- Gas Weber

$$We_{gas} = \frac{2P_{gas}R_{out}}{\sigma} = \frac{pressure}{surface\ tension}$$

→ Good agreement with experimental data from Si *et al*.

→ Experimental validation in progress

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Si, Li, Yin and Yin, 2009, *Modes in flow focusing and instability of coaxial liquid-gas jets*

5) Outlook

❑ *Further work :*

- Simulation of droplets modes
- Study on the effect of geometry
- Optimization aiming the smaller monodispersion
- Phenomena underlying the spray : atomization, deposit, etc.

Thank you for your attention !

Any questions ?

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