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量測原理與機工實驗

V. More on Micro/Nano Fluidics

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Relevant Subjects

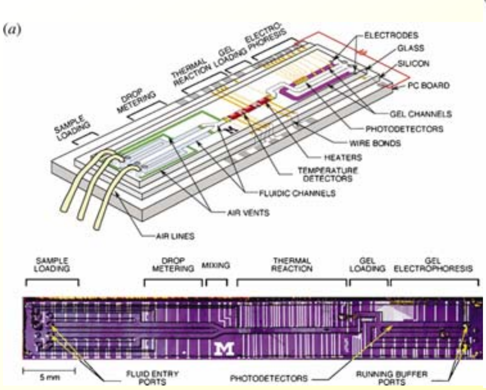
- MEMS/Lab on a chip
  - Biotechnology
  - Pumps, valves, mixers
  - Transport, manipulation
  - Screening, sensing, encapsulation
- Digital (planar) and droplet microfluidics
  - Device fabrications
  - Droplet formation
  - Droplet manipulation and sorting
  - Droplet coalescence, splitting, and mixing
  - Interfacial instabilities and fluid-wall interactions
- Droplet based microfluidics
  - Micro-drop physics
  - Forces and external fields
  - Fabrication
- Applications
  - Fabrication of materials
  - Biology and biophysics

<u>References</u> (major):

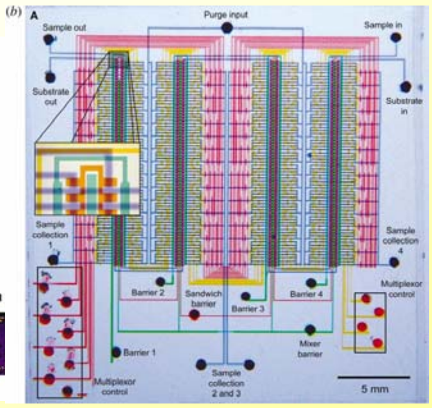
J. Berthier, *Microdrops and Digital Microfluidics*, William Andrew, 2008
Seemann et al., *Rep. Prog. Phys.*, Vol. 75, 016601 (2012).

Development of Microfluidics

- History: ink jet printing, space applications (micro motors)
- Boosting interest today: biology, biotechnology, microchemistry
- Advantages → lab on a chip
  - Reduced volumes of sample and reagents, costs, time
  - Increased sensitivity due to higher precision and selectivity
  - Lower risks with manipulation of toxic or dangerous products
  - Automation, parallelization → screening and systematic testing in the domain of drug discovery
  - Portability → diagnostic, bio-analysis



Scheme of a complex microflow system involving flow and transport necessary for multiple chemical analyses, mixing, detection, separation, and so on. Burns et al. *Science*, Vol. 282, p. 484 (1998).

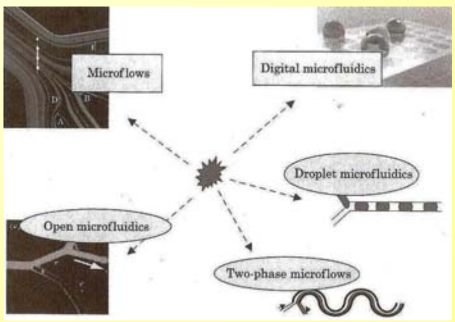


Scheme of a complex microflow system governed by pressure actuated microvalves. Photocopied from Thorsen et al., *Science*, Vol. 298, p. 580 (2002).

- Challenges ~ revolution of fluidic micro-systems
  - Integration of all the components of a system on the same chip
  - – Active methods: efficient but difficult (to be small, energy…)
  - – Passive methods: easier to integrate, but less efficient
  - Growing complexity of micro-fabrication
  - Miniaturization of the whole chain of treatment: e.g., molecules/particles targeted from macro to micro system (bio)
  - Large surface/volume ratio → modified physics: adherence (of target molecules) to solid walls, effects of capillary forces (preventing fluid from entering microchannels …)
- Driving forces: ∇p, capillary, electric, magnetic, acoustic, rotation

Digital and Droplet Microfluidics

- Hierarchy
  - Conventional system: microplate ~ 10 μl
  - Microfluidic (microflow) system ~ 100 nl – 1 μl
  - Microdrops ~ 1 pl – 10 nl
  - – parallel systems:
    digital microfluidic system
  - – serial systems:
    droplet microfluidic system



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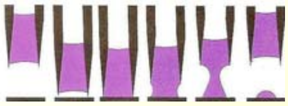


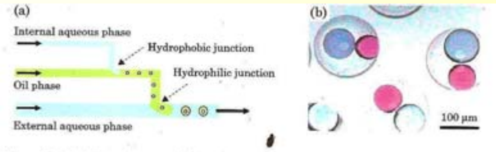


Figure 2.3 (a) Successive use of T-junctions with wetting and non-wetting walls results in the encapsulation of two liquids in a droplet [5]; (b) clever use of T-junctions can be used to obtain simultaneous encapsulation; reprinted with permission from [5]. © 2004 American Chemical Society.

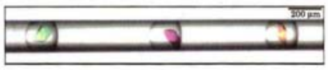


Figure 2.4 Droplets in a glass capillary: crystals of proteins were grown under microbatch condition in these droplets, from [6]. © 2004 Wiley, reprinted with permission.

Photocopied from Berthier (2008)

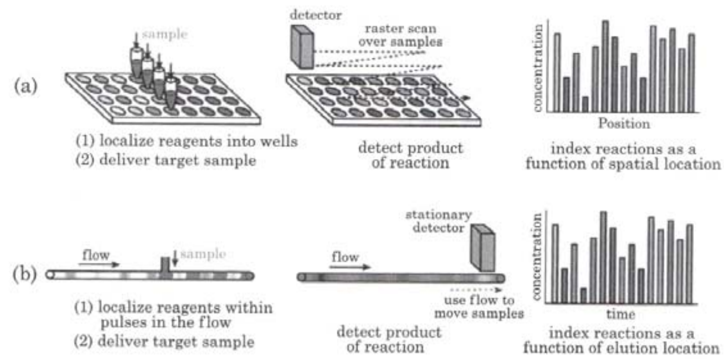
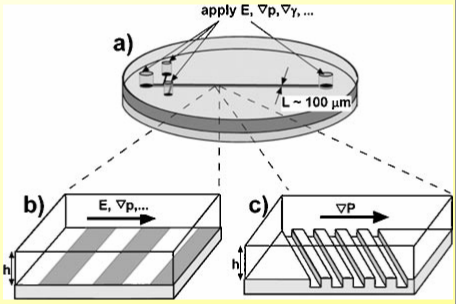


Figure 9.44 Comparison between digital and droplet microfluidics. From [46]. © 2006 Wiley; reprinted with permission.

Photocopied from Berthier (2008)

Droplet Based Microfluidics

- Functions: screening, sorting, encapsulation, (bio/chemical) reaction, analysis/detection
- Techniques
  - Device fabrications
  - Droplet formation
  - – T-junction: on-line reactions
  - – Flow focusing: encapsulation
  - – Carrier phases and surfactants
  - – Bulk/step emulsifications



Photocopied from Stone et al., Annu. Rev. Fluid Mech. , Vol. 36, p. 381 (2008)

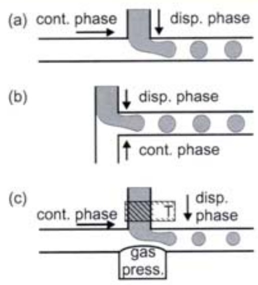


Figure 4. Schematic of various T-junction geometries. (*a*) 'regular T-junction' geometry where the dispersed phase is injected perpendicular into a stream of continuous fluid. (*b*) 'Head on' geometry where the dispersed and the continuous phases are injected from opposite sides. (*c*) 'Active T-junction' allowing variations of the geometry by air pressure and temperature control of the dispersed phase.

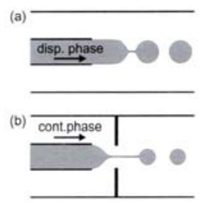


Figure 6. Schematic of co-flowing devices with flow focusing (*b*) and without flow focusing (*a*).

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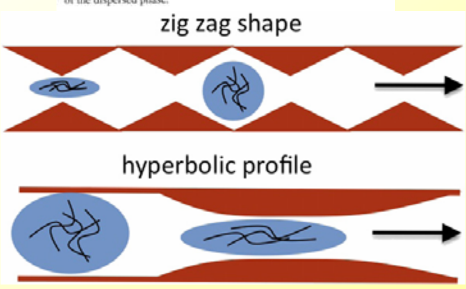
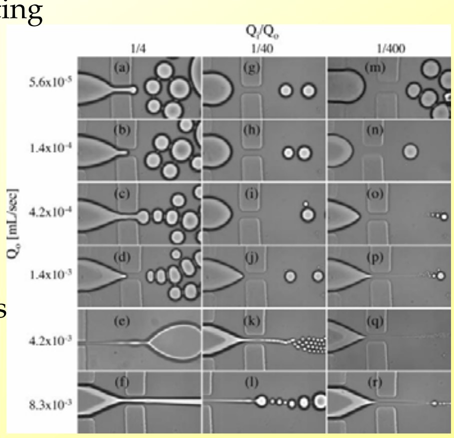
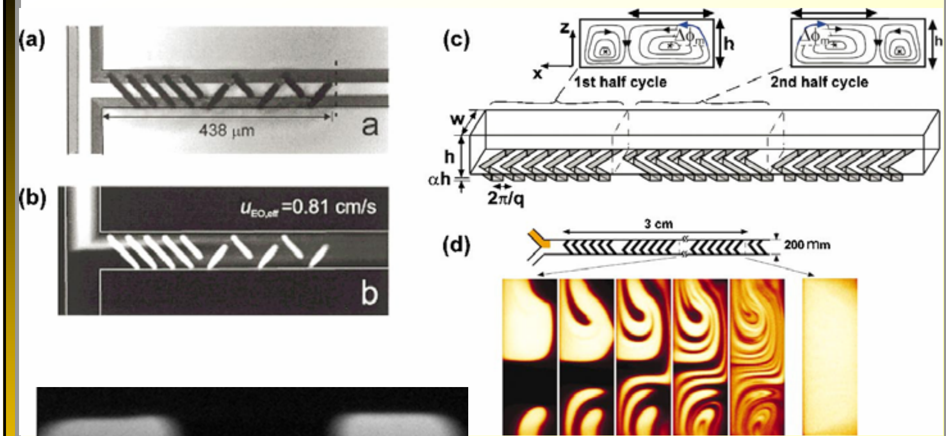


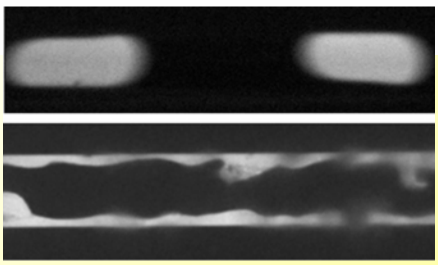
Schematic representation of geometric microchannel designs probing the elastic properties of protein networks encapsulated in droplets. Seeman et al., *Rep. Prog. Phys.*, Vol. 75, 016601 (2012).

- Techniques (cont'd)
  - Droplet manipulation and sorting
  - Droplet coalescence
  - Splitting, mixing …
- Applications
  - Fabrication of special materials
  - Biology and biophysics



Anna et al., *Appl. Phys. Lett.*, Vol. 82, p. 364 (2003)





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