

Droplet microfluidics: fundamentals and applications

Dr Jan Guzowski

Group of Soft Granular Matter and Tissue Engineering (Team 19)

Institute of Physical Chemistry PAS

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- tentative day/time of the lecture: Thursdays 12:00-13:35,
- first lecture: March 21st 2024, last lecture: June 6th 2024,
- register until March 14th 2024 via email (jguzowski@ichf.edu.pl).

LECTURE SYLLABUS

I. Fluid mechanics at the microscale.

1. Navier-Stokes equation, incompressible flows, laminar flows, Stokes equation, lubrication theory.
2. Confined single-phase flows: Darcy's law, hydraulic resistance in channel networks - electric circuit analogy.
3. Liquid-liquid interfaces: basics of capillarity and wetting phenomena.
4. Emulsions: stability, role of surfactants; single-, double- and higher-order emulsions.

II. Microfabrication of microfluidic devices.

1. Materials: glass, polycarbonate, PMMA, PDMS, resins, etc.; their advantages and disadvantages (resistance to solvents, swelling).
2. Microfabrication methods: soft lithography, micromilling, etching, capillary pulling, 3D printing, other microfabrication methods.
3. Surface properties and functionalization of channel walls: hydrophobic, hydrophilic, fluorophilic, solvent-resistant coatings.

III. Multi-phase flows in microfluidics.

1. Confined two-phase flows: generation of droplets, bubbles and jets, dynamics of a single bubble in a channel (Bretherton problem), dynamics of multiple bubbles – from microfluidic networks (branched '1D' systems) to microfluidic crystals ('1.5D' systems).
2. Confined three-phase flows: generation of double emulsions, compound jets, soft-granular dripping and jetting, capillary-arrested states.

IV. Applications.

1. Miniaturization + automation: lab-on-a-chip devices, active vs. passive control: valves, switches, rails, traps, etc..
2. Material science: from fabrication of porous materials to granular materials and fibers.
3. Physics and chemistry in droplets: droplets as microreactors (mixing problem), from protein crystallization to colloidal self-assembly, phase separation, self-assembly of lipid bilayers, liposomes (artificial cells), multisomes, droplet networks (artificial tissues).
4. Single-cell encapsulation: encapsulation statistics, cell barcoding, single-cell sequencing.
5. Microbiology: encapsulation of bacteria, PCR in droplets, antibiotic susceptibility testing.
6. Tissue engineering: microfluidic fabrication of hydrogel scaffolds, 3D cell culture in hydrogel droplets and fibers.