Chemotactic Ionic Liquid Droplets: Striving to Mimic Nature

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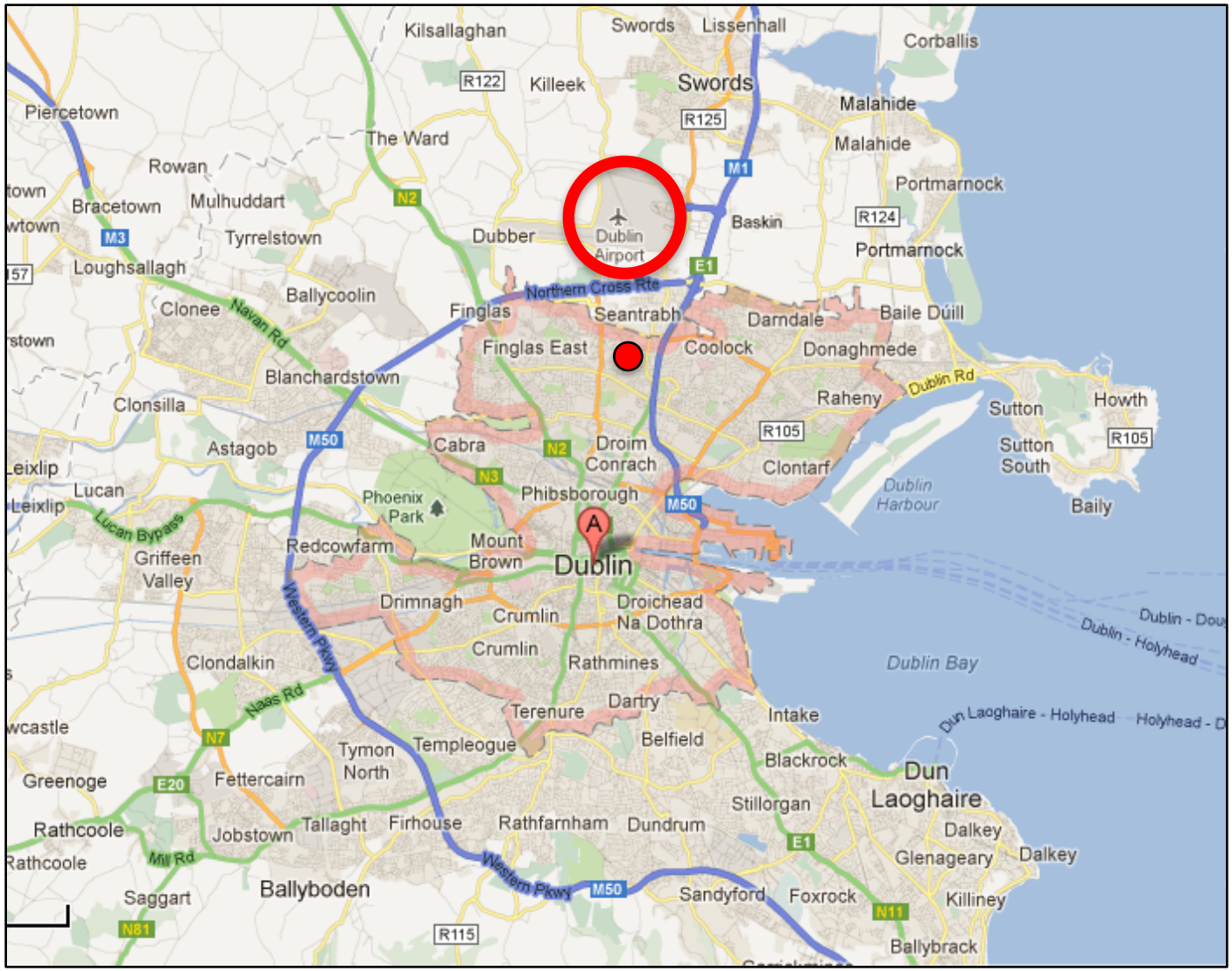
Insight Centre for Data Analytics, Dublin City University, Ireland

IC-ANMBES 2016

Dublin & DCU Location



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MINISTER BRUTON LAUNCHES €88 MILLION SFI RESEARCH CENTRE, BRINGING NEW INSIGHTS TO DATA ANALYTICS

Insight Centre for Data Analytics

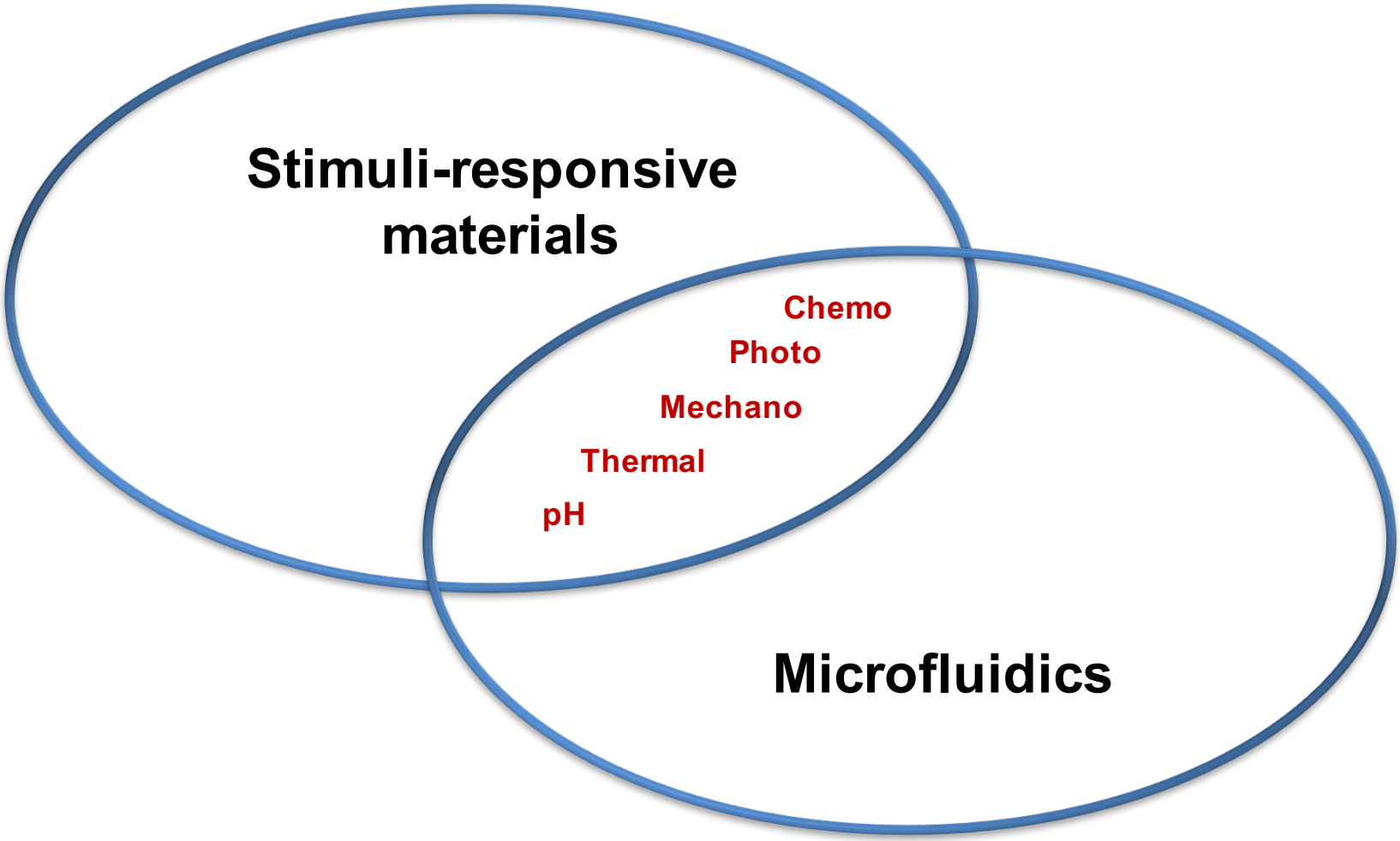
- **Biggest single research investment ever by Science Foundation**
- **Biggest coordinated research programme in the history of the state**
- **Focus is on 'big data' related to health informatics and pHealth**

- Insight, the Centre for Data Analytics, will position Ireland at the heart of global Data Analytics research
- Uniting 4 universities, 30 industry partners, and 200 researchers in one multi-location research centre
- Creating 300 direct jobs through 12 funded spin-outs, as well as creating indirect thousands of other job opportunities

Research and Innovation, Mr Sean Sherlock T.D. today officially launched Insight, a new **Science Foundation Ireland (SFI) Research Centre for Data Analytics**, in a joint initiative between DCU, NUI Galway, UCC and UCD, Insight, and other partner institutions, brings together more than 200 researchers from these and other Higher Education institutions, with 30 industry partners, to position Ireland at the heart of global data analytics research.

The Centre will receive funding of €58 million from the Department of Jobs, Enterprise and Innovation through SFI's Research Centres Programme, along with a further contribution of €30 million from 30 industry partners. Insight represents a new approach to research and development in Ireland, by connecting the scientific research of Ireland's leading data analytics researchers with the needs of industry and enterprise.

Adaptive Sensors Group



The Irish Invasion

The Irish Invasion

Contactless Conductivity Sensor for Wearable Sweat Monitoring

Solvent Sensing Fluorescent poly(Ionic Liquid) Ionogels

Two-Component Fluorescent Sensing of Saccharides

Stimuli-responsive Materials for Self-reporting Micro-fluidic Devices

Photo-Responsive Hydrogels with Enhanced Volume Changes due to Local pH alterations

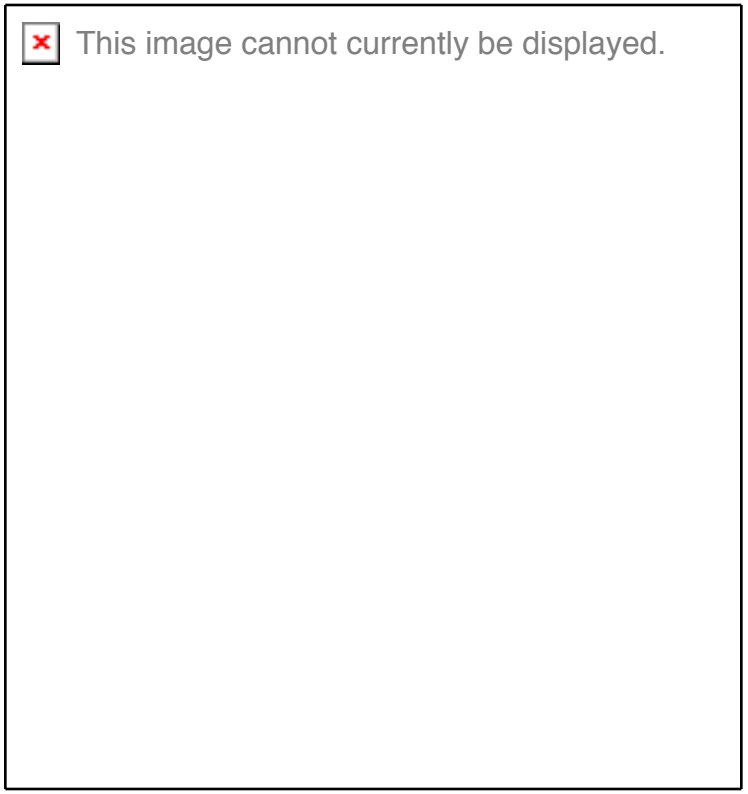
Outline

- Background to chemotaxis
- Use of Ionic Liquids as smart vehicle droplets
- Means to transport droplets
- Work towards leak detection in microfluidics
- Moving past binary systems to multicomponent synthesis

Chemotaxis

- Movement of an organism in response to a chemical stimulus
- Certain single and multicellular organisms have this ability
- Bacteria, Virus' and even some somatic cells i.e white blood cells
- Chemoattractant: to food source
- Chemorepellent: away from toxin

Neurophil



Synthetic Systems-Our Goal

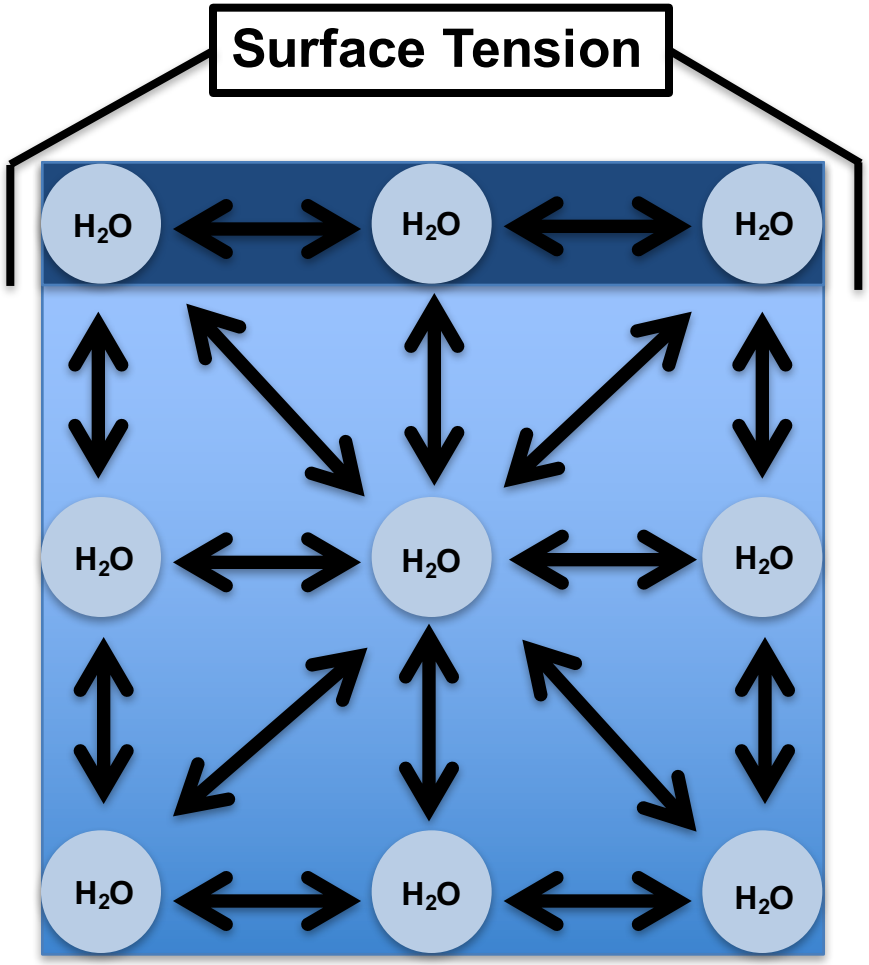
- Development of synthetic biomimetic “vehicles”
- These “vehicles” move in response to external stimuli
- Designed to move across the liquid/air interface
- Application: *Bridging microfluidics and autonomous sensing*
  - micro-vehicles for chemical reactions
  - cargo transport to desired destinations
  - dynamic sensing
  - leak detection
  - drug delivery

The Paper Boat

- Propelling a paper boat by applying a small amount of liquid soap.
- “Vehicle” movement achieved through the use of surfactant molecules

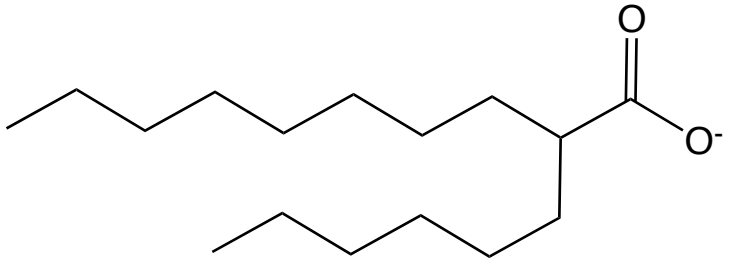
Surface Tension

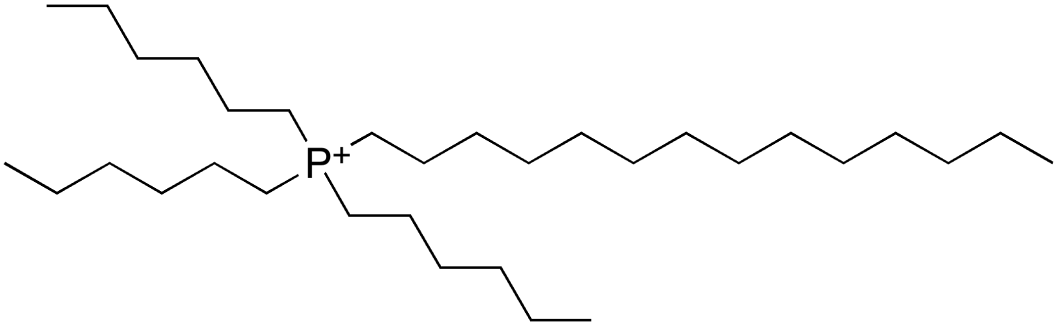
- Surface molecules experience greater attraction to neighbours compared to bulk molecules
- Liquid flows from low to high surface tension
- Results in Marangoni effect



Surfactants

- Long chained molecules
- Charged hydrophilic “head”
- Hydrophobic “tail”
- Surface active
- Alter surface tension



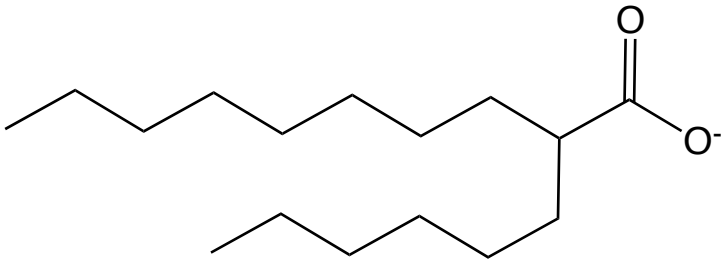


Chemotactic Droplet:

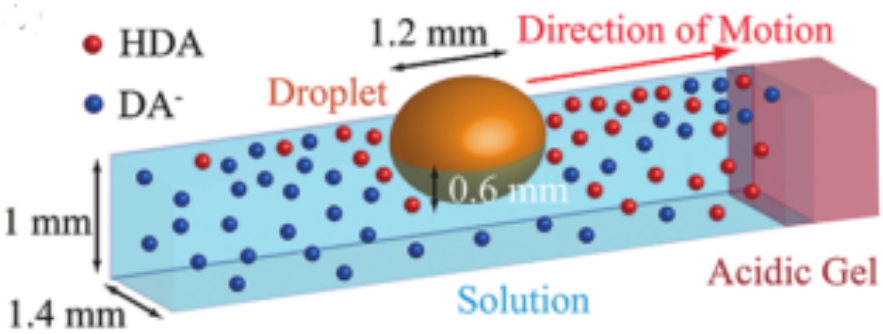
A. Grzybowski. *J. Am. Chem. Soc.*, 2010, 132 (4), 1198–1199

Grzybowski's Droplet

- Can 'solve' complex maze
- pH sensitive surfactant
- Surfactant in dichloromethane droplet
- Follows pH gradient to exit



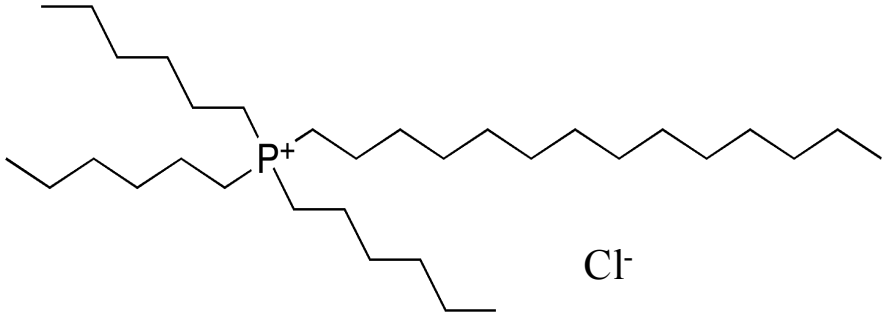
$pK_a \approx 8.3$

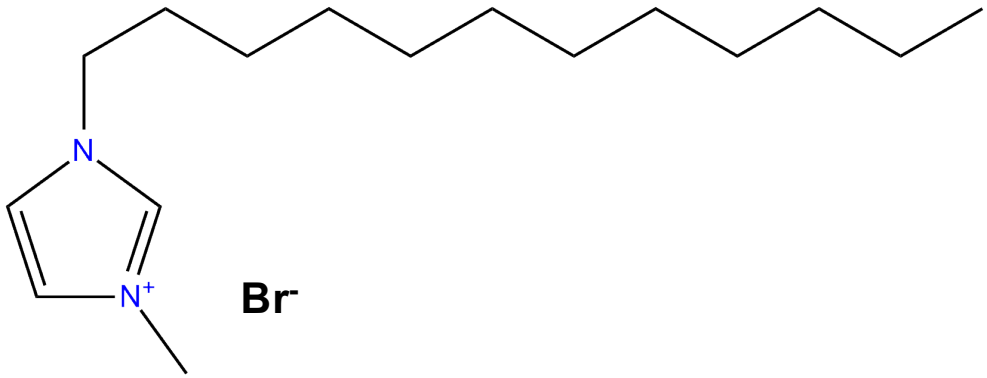


A. Grzybowski. *J. Am. Chem. Soc.*, 2010, 132 (4), 1198–1199

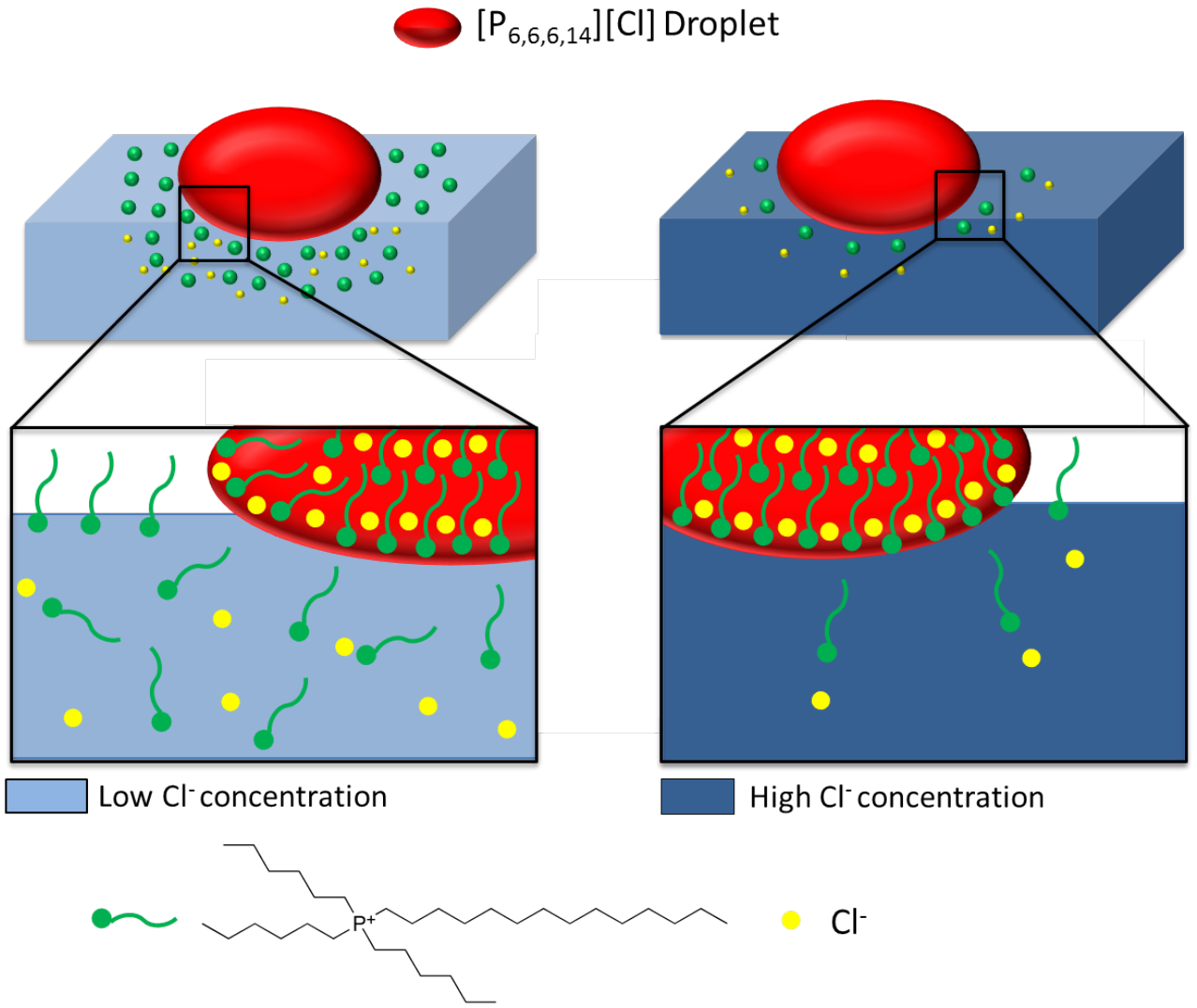
Ionic liquids

- High thermal stability
- High ionic conductivity
- Negligible vapour pressure
- Excellent solvents
- “Designer” solvents
  - Control of Anion and Cation properties

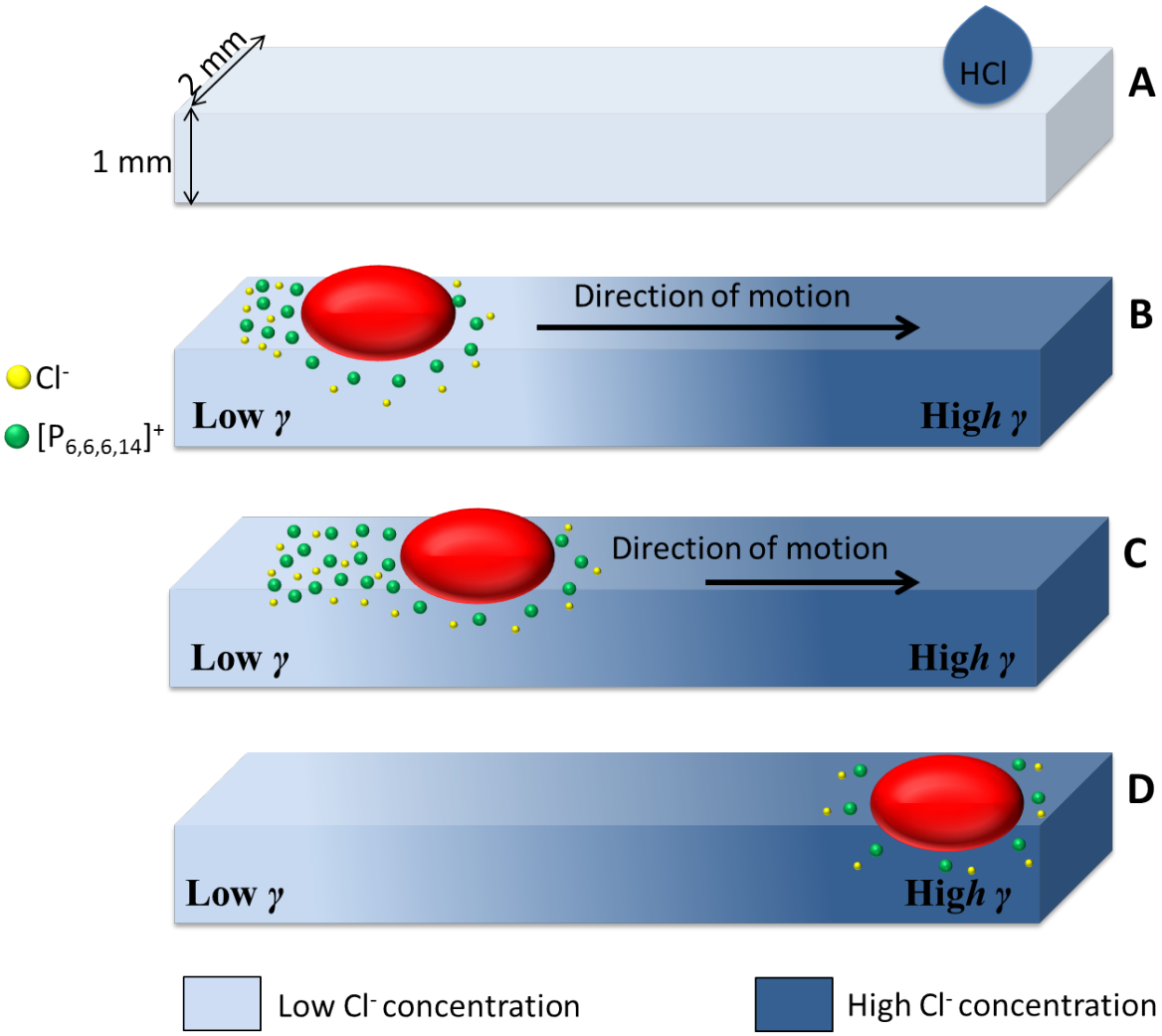




Droplet Composition



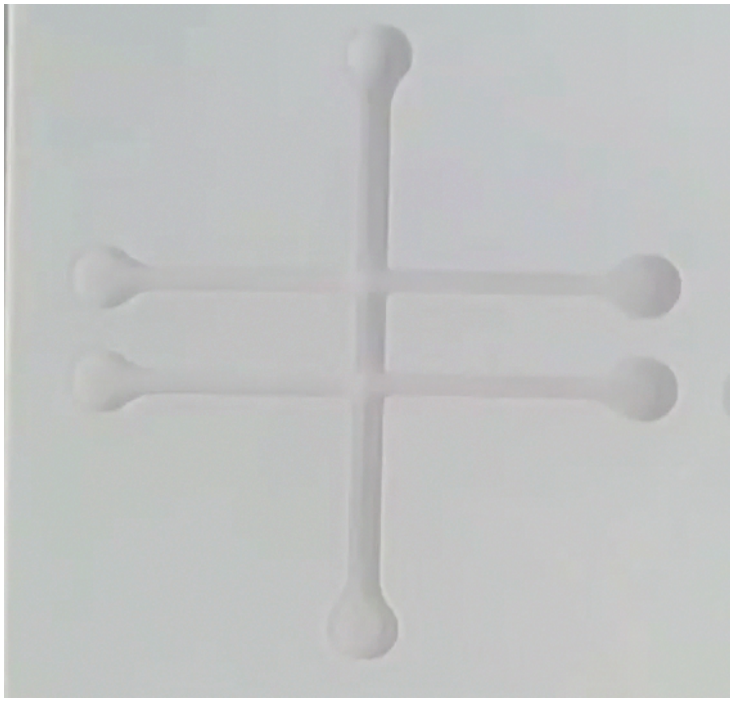
Droplet Movement



Gradient Generation

Acid – Base system:

Channel filled with a solution of 10^{-2} M NaOH, solution of 10^{-2} M HCl acts as the chemoattractant

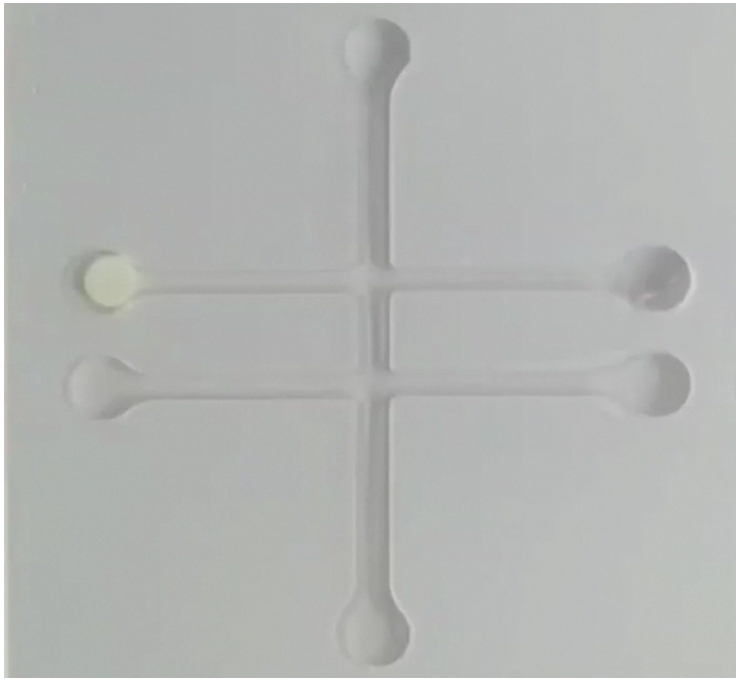


Speed x 2

Gradient Generation

Acid – Base system:

Channel filled with a solution of 10^{-2} M NaOH, polyacrylamide gel soaked with 10^{-2} M HCl acts as the chemoattractant

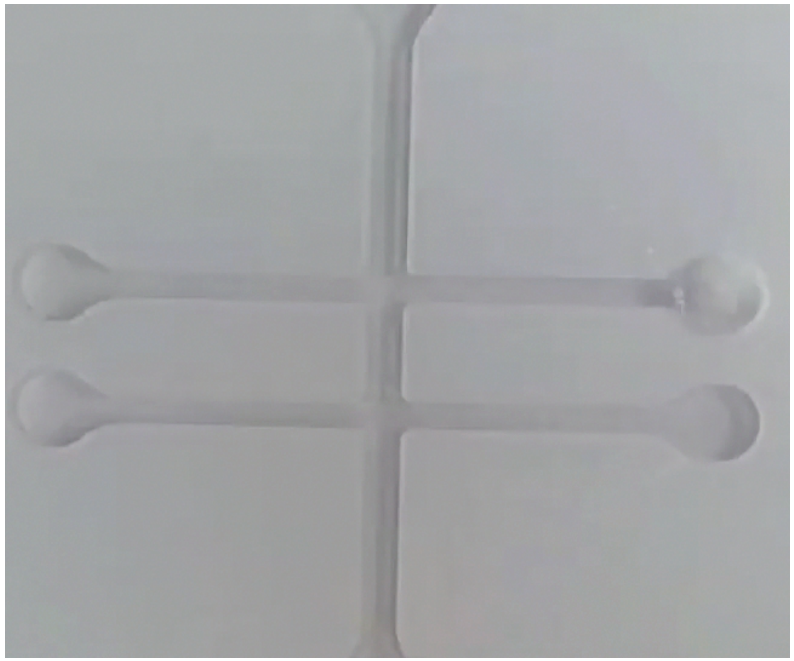


Speed x 4

Gradient Generation

Salt system :

Channel filled with a solution of 10^{-5} M NaCl, crystals of salt act as the chemoattractant

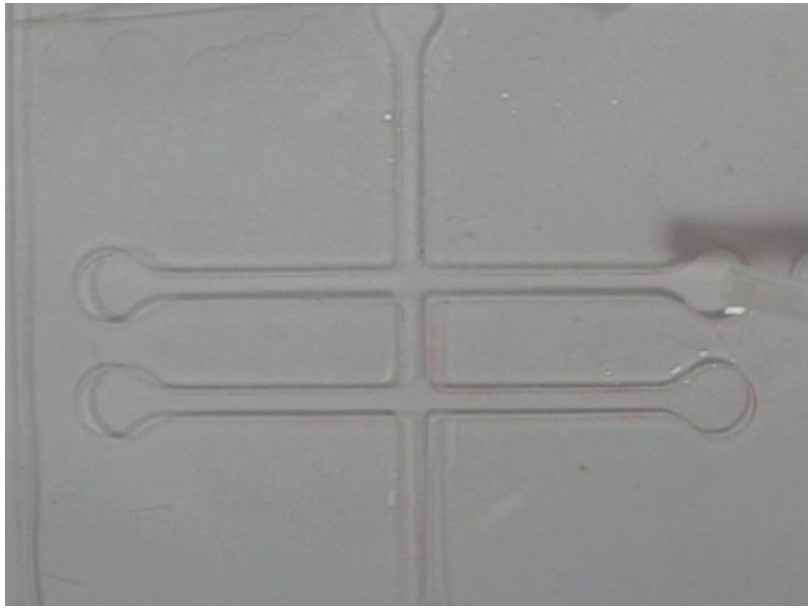


Speed x 4

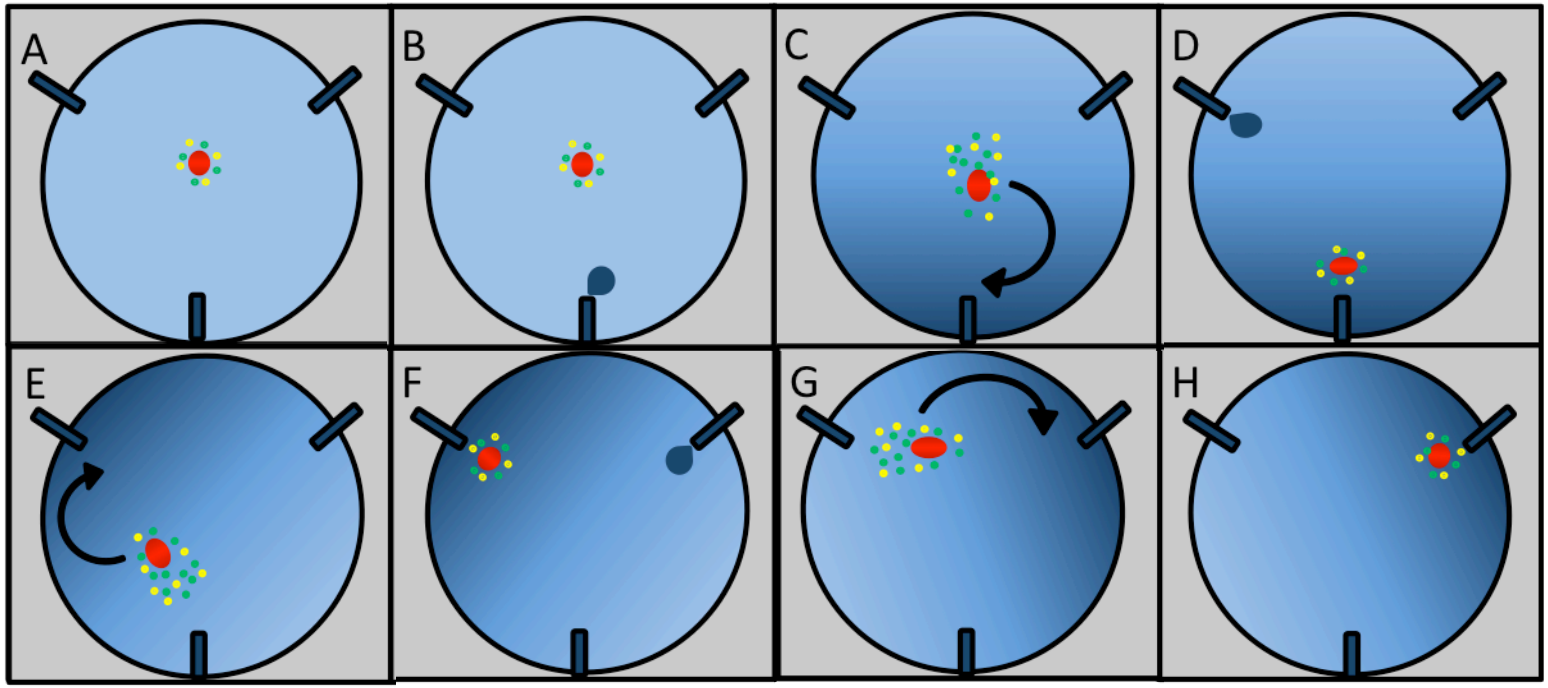
Multiple Droplets

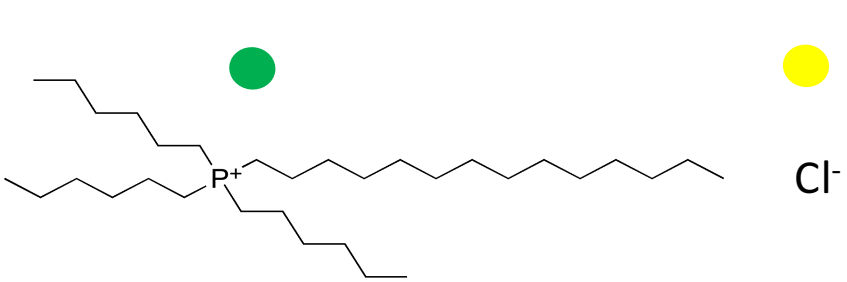
Acid – Base system:

Channel filled with a solution of 10^{-2} M NaOH, solution of 10^{-2} M HCl acts as the chemoattractant



Leak Detection





HCl 10^{-2} M

NaOH 10^{-2} M

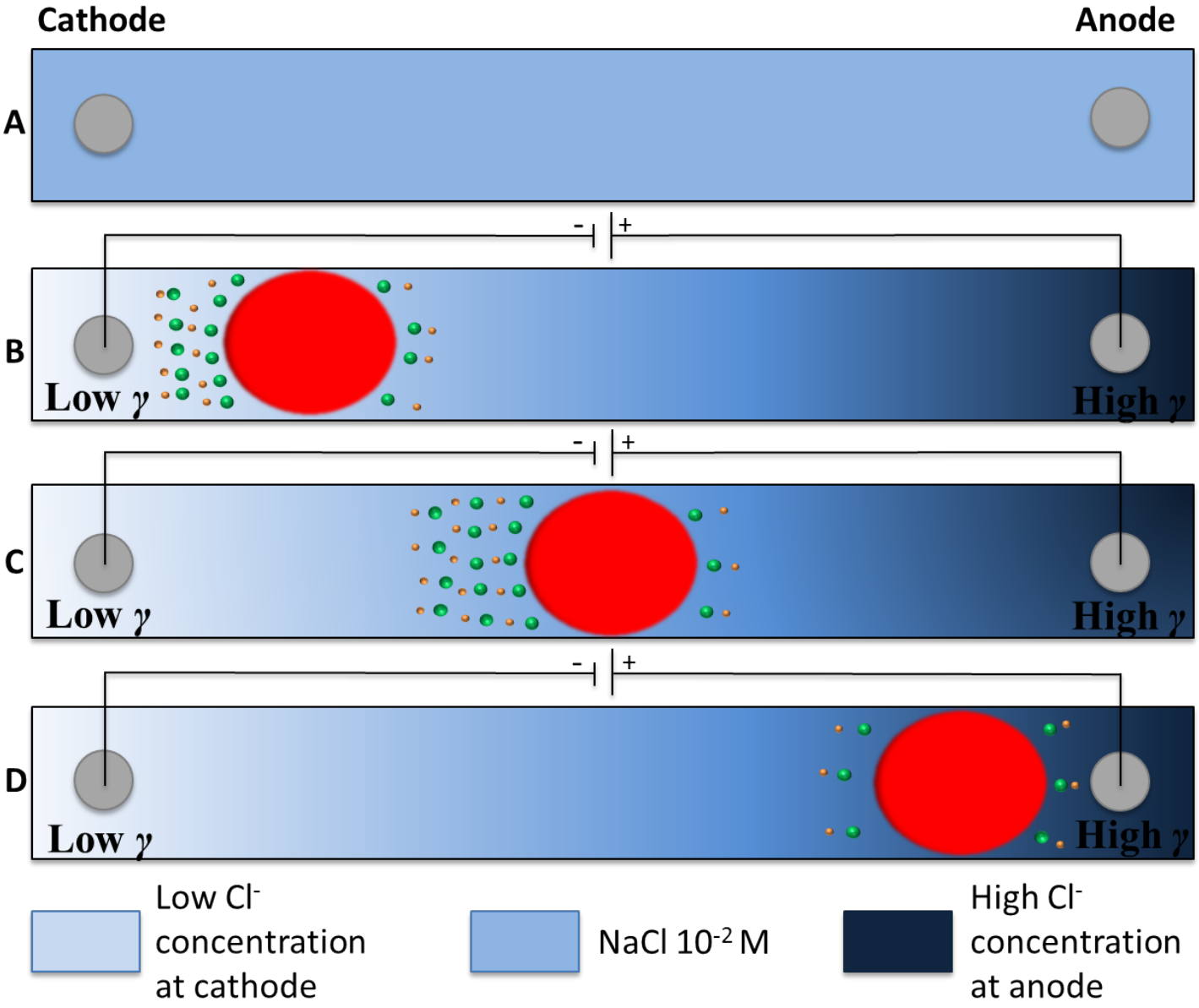
Speed x 5

Chemotactic Droplets

- Droplets follow a Cl^- gradient to desired destinations
- Droplet solely composed of IL
- Multiple droplets can be moved to destination
- Merging of droplets possible
- Chemical gradients quickly come to equilibrium

Francis, W.; Fay, C.; Florea, L. and Diamond, D. *Chem. Commun,* 2015, 51, 2342.

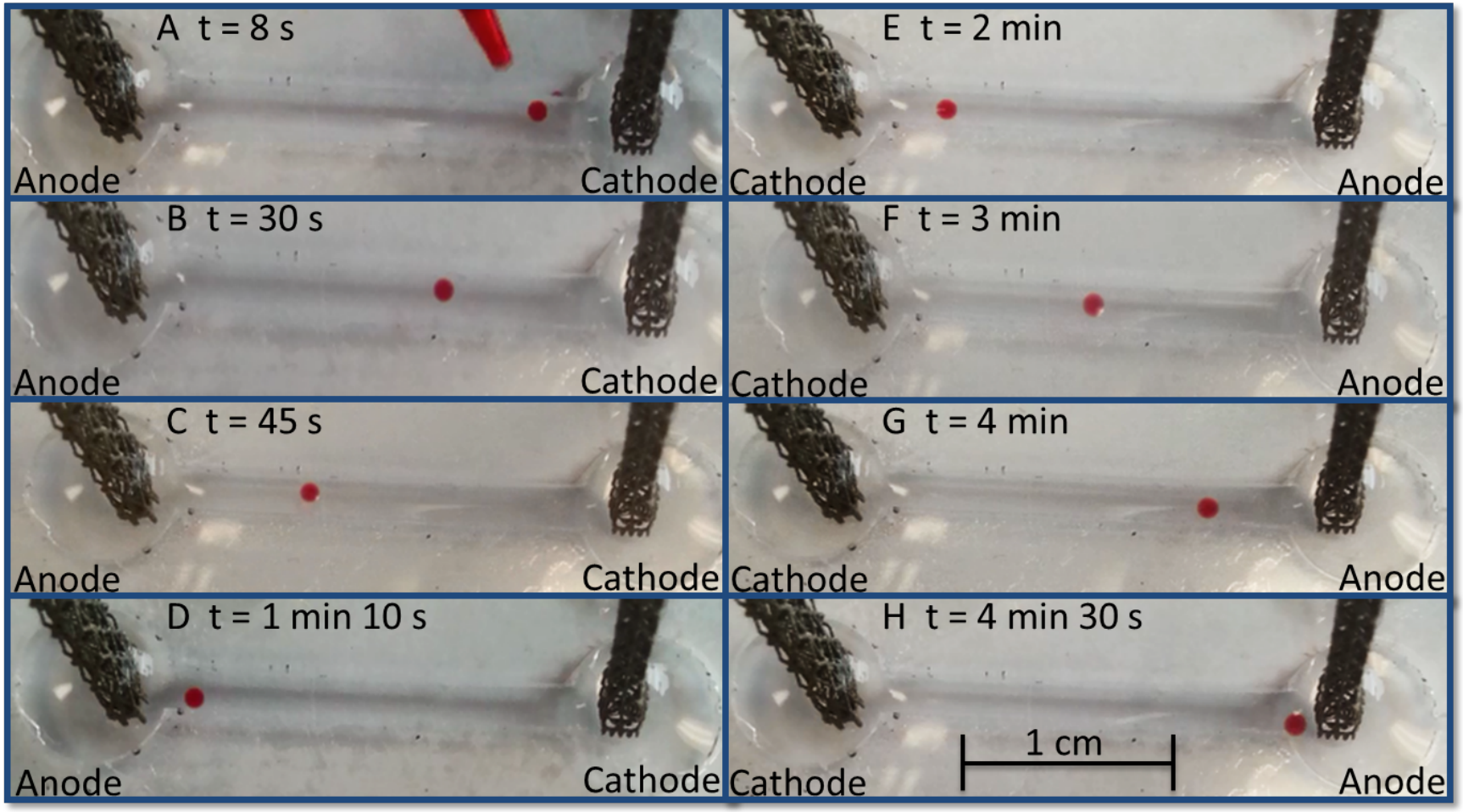
Droplet Movement



Electrotactic Droplets

- On demand generation of gradients at the electrodes
- Salt solutions used as electrolyte
- Control over length of gradients
- Reversible droplet movement
- Allows for droplet to be moved to several destinations

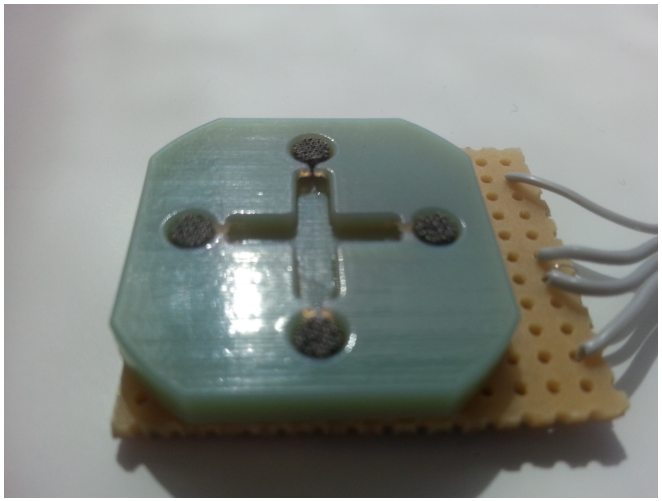
Reversible Movement



10^{-3} M NaCl used as electrolyte, 9 V applied across the solution.

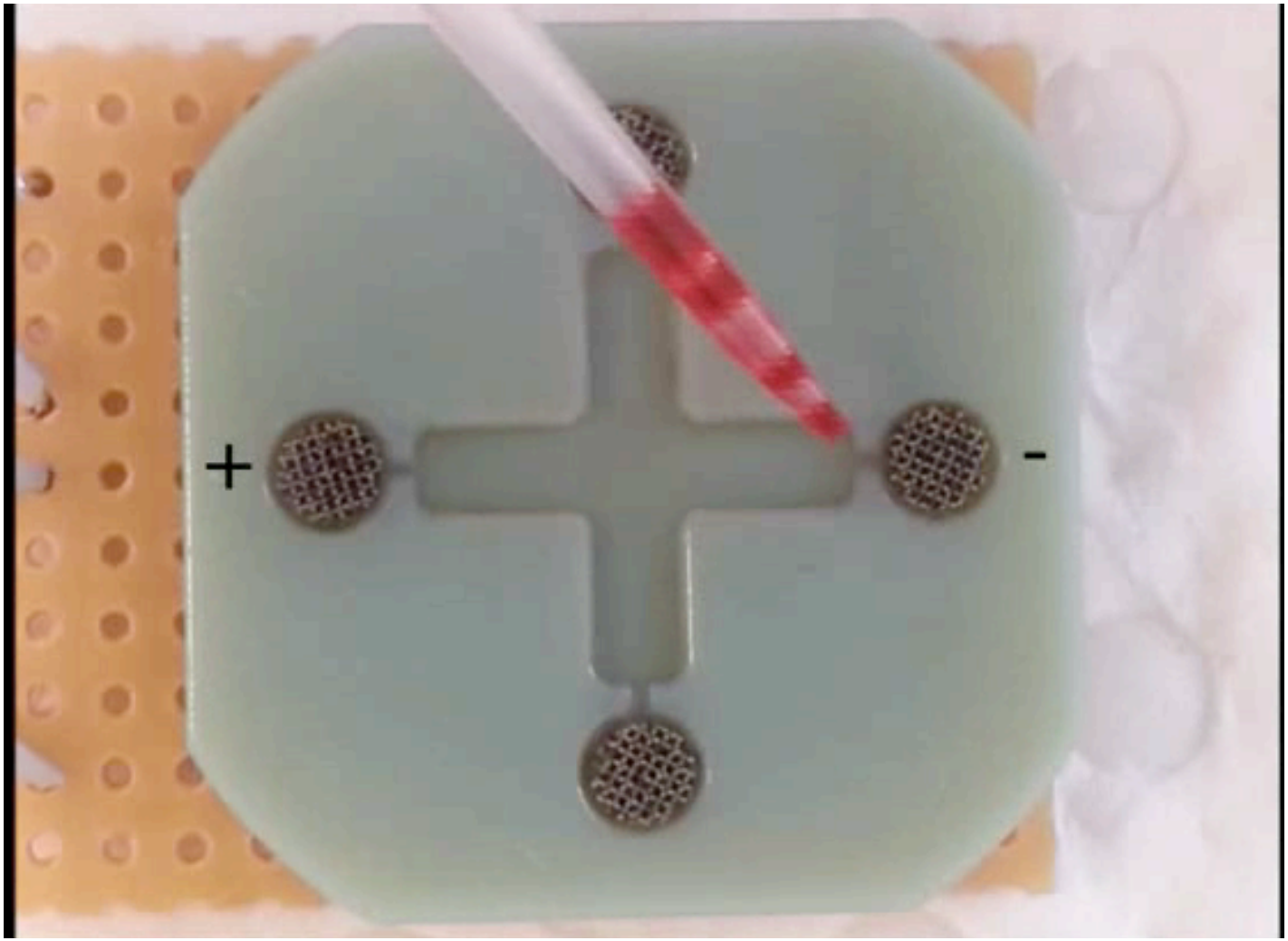
Chip Design

- **Chips 3D printed**
- **Electrodes - Realizer SLM-50 3D printer**
- **Channels - Objet350 Connex**
- **Electrodes embedded within the channels**



Electrotactic Ionic Liquid Droplets, W. Francis *et al.*, Sensors and Actuators **2016**, Accepted

Example of Electrotactic Ionic liquids

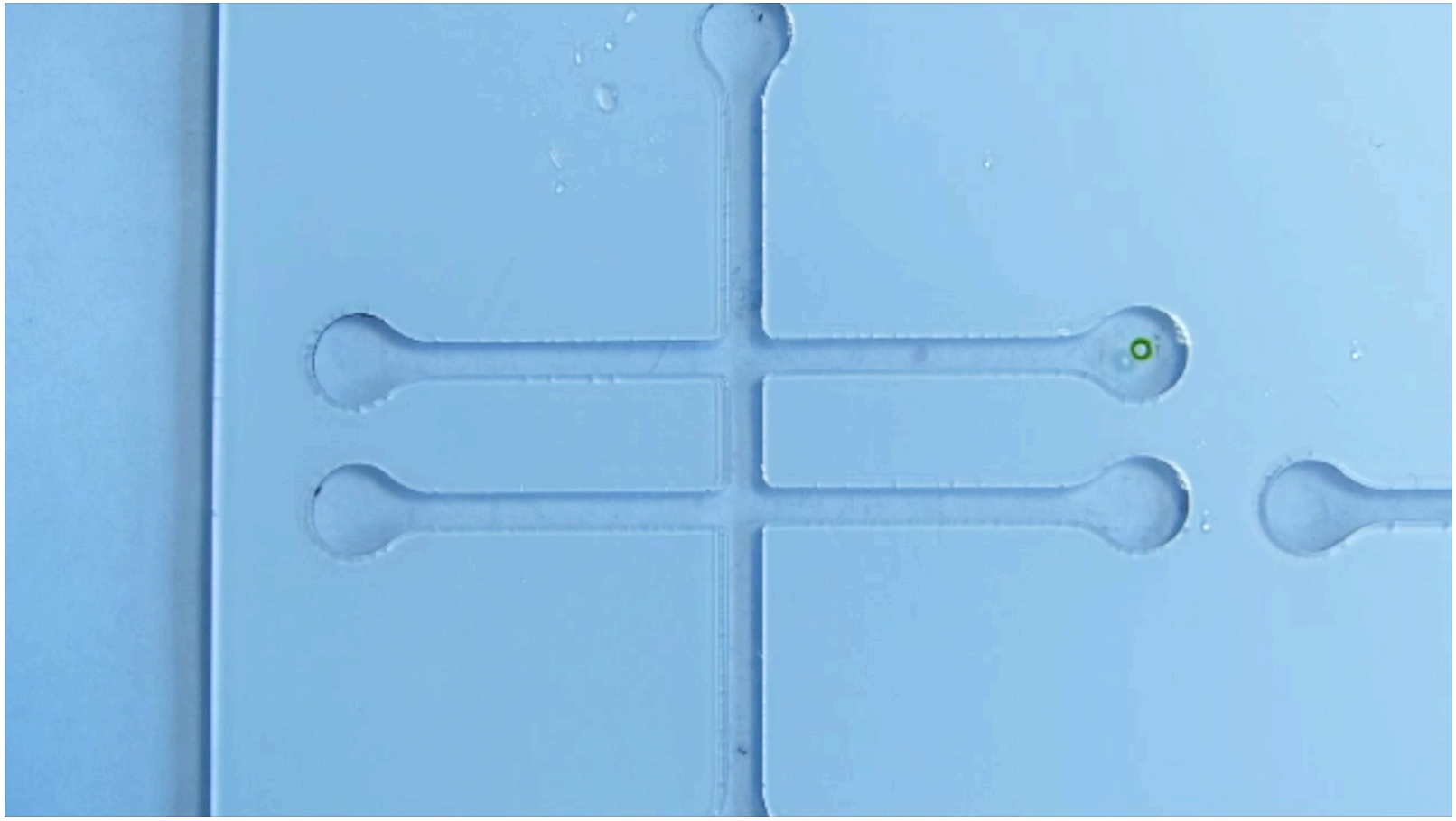


NaCl 10^{-3} M , 9 V, Speed x 5

Adding Functionality

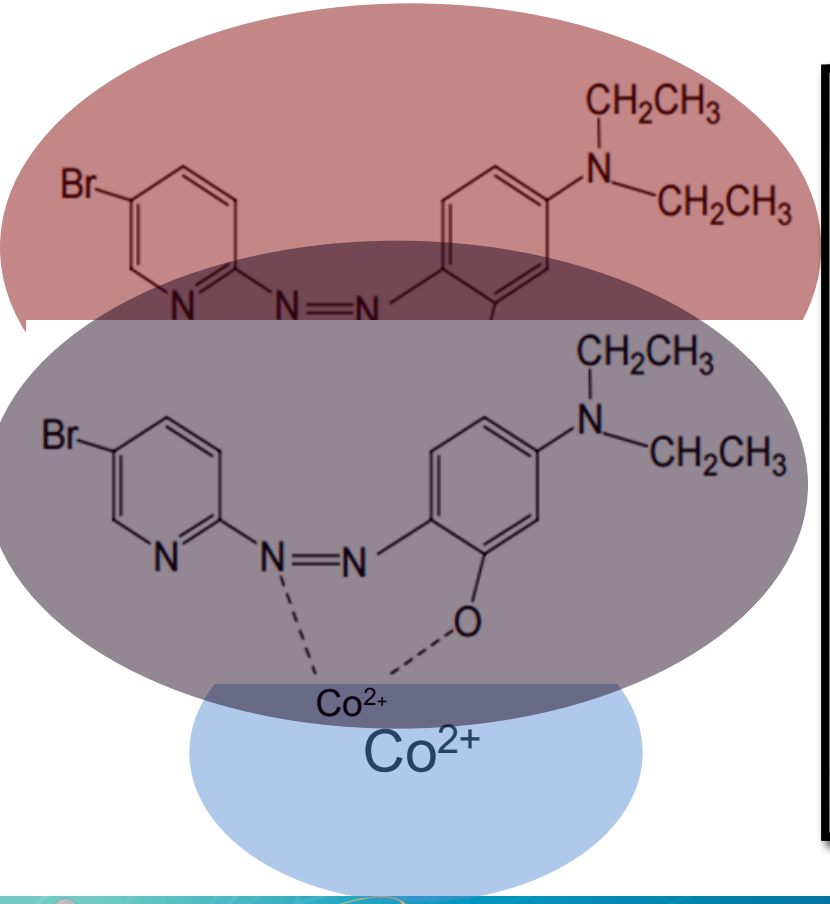
- Have droplets perform more sophisticated tasks
- Micro-vessels for chemical reactions
- Cargo transport to desired destinations
- Dynamic sensing units
- Leak detection

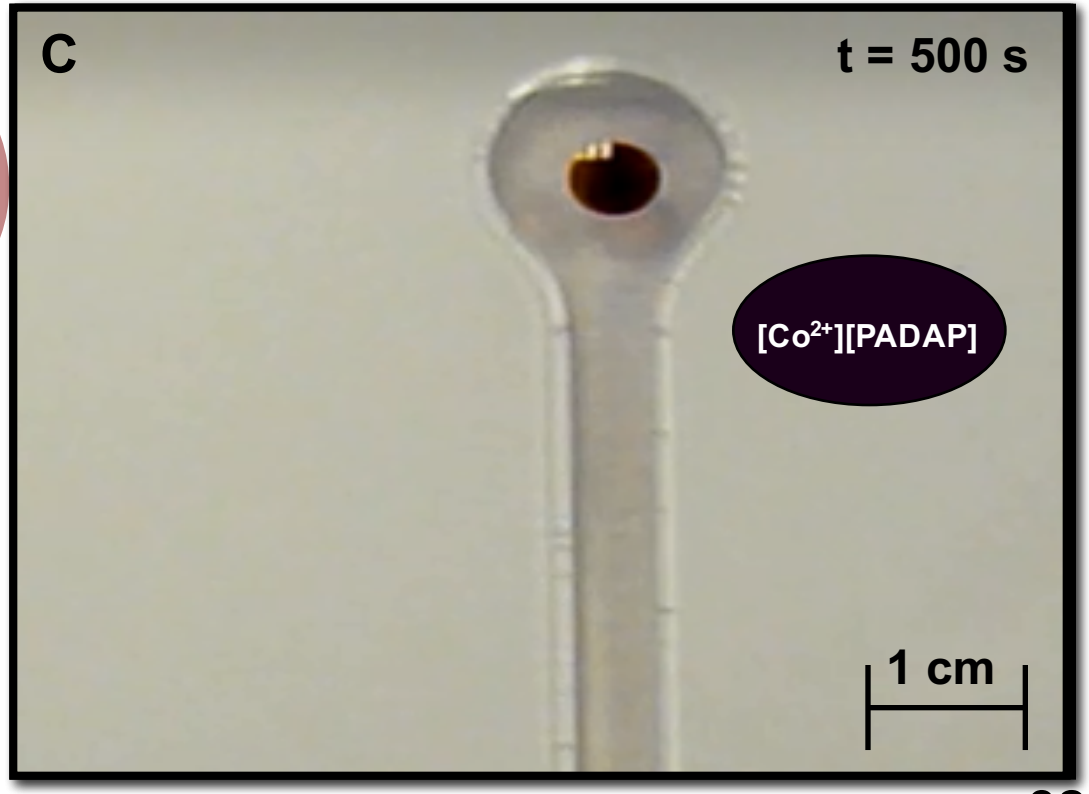
Adding Functionality



Chemical Reactions: Metal ion sensing

- Reactions take place inside droplet
- Predetermined locations
- Analytes: Co^{2+} and Cu^{2+}
- Metal sensing dye: PADAP





Recent Advances

1. **Optimisation of polymerisation reactions within droplets**
   - Transportation of separate monomeric mixtures to site of fault

2. **Biological applications**
   - Transportation of drugs upon immune response

3. **Extension to ternary/quaternary systems**
   - Ability programme varied parallel syntheses through compartmentalisation

Ionic Liquid Droplets: Striving to Mimic Nature

- Chemo and electro tactic droplets
- Autonomous movement
- Vessels for chemical reactions
- Transport cargo to desired destinations
- Leak detection

Vă mulțumesc

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