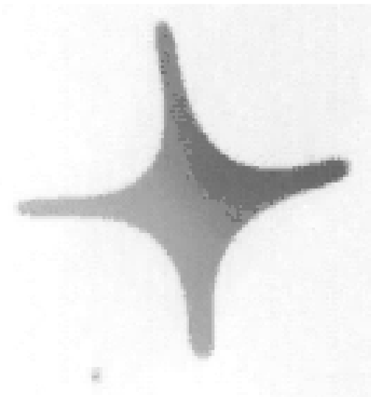
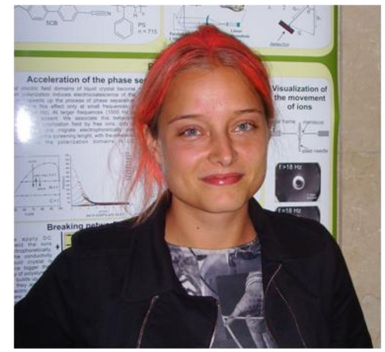
Dynamiczna kontrola separacji ładunków elektrostatycznych w układach miękkiej materii





Tomasz Szymborski, Natalia Ziębacz, Piotr Korczyk, Jan Tobiś,
Olgierd Cybulski, Stefan Wieczorek, Andrzej Żywociński,
Robert Hołyst i Piotr Garstecki

Department of Soft Condensed Matter
Institute of Physical Chemistry
Polish Academy of Sciences

- controlling soft matter with electric fields

- dynamic **separation of charge in LC**

  can we see the motion of ions with an optical microscope?

- **electrocoalescence**

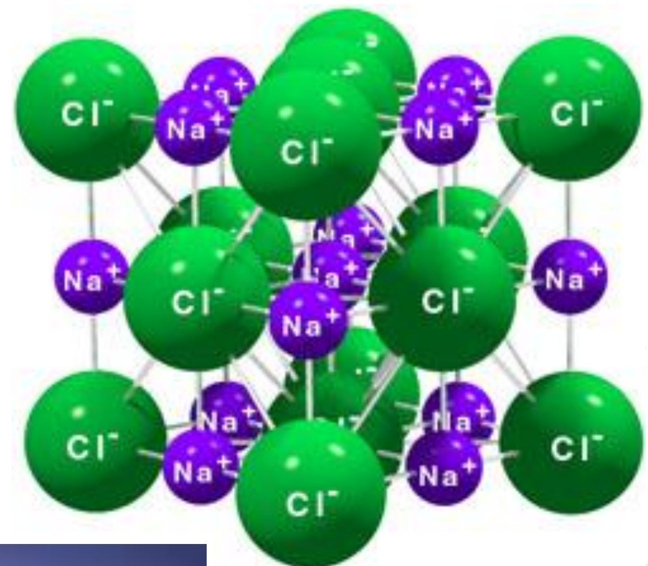
  ionic contribution to polarization of droplets

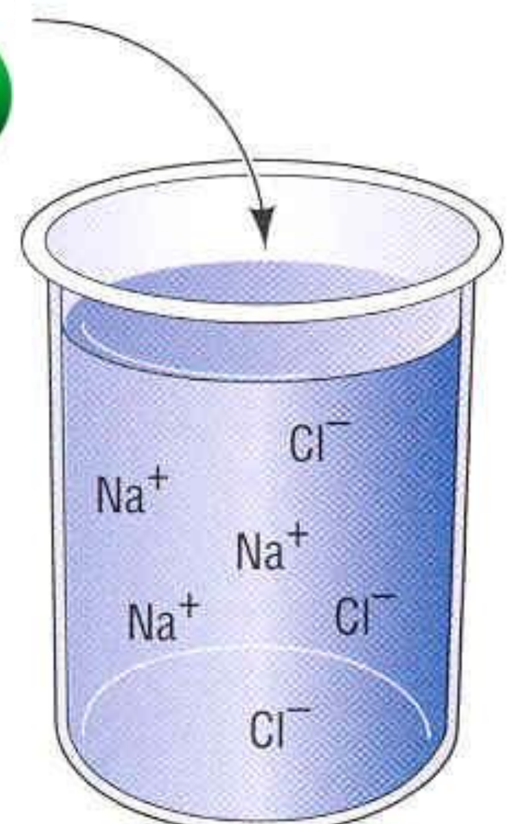
- **phase separation in a blend of LC and PS**

  1000 fold increase of the rate of phase separation

- **summary**

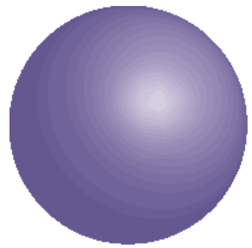
electrostatic forces

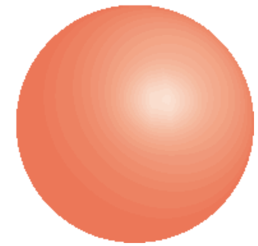




electrostatic potential

$$\frac{1}{R}$$

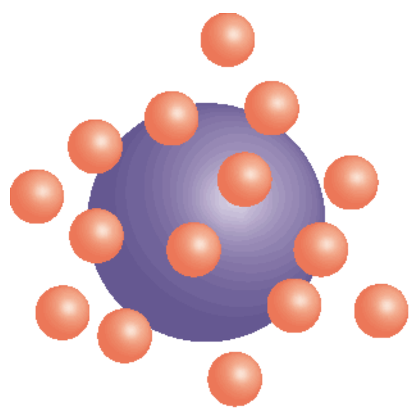


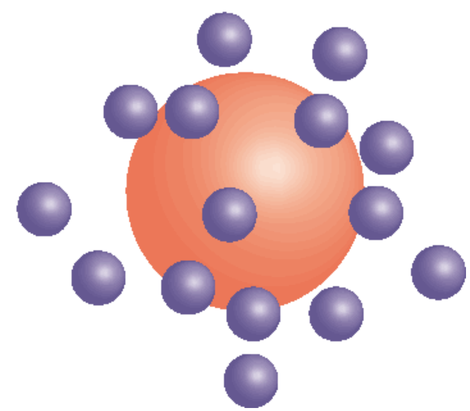


- **any other behavior?**

- **control the electrostatic interactions with electric fields?**

$$\frac{\exp(-R/d)}{R}$$





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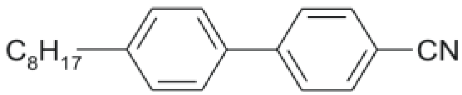
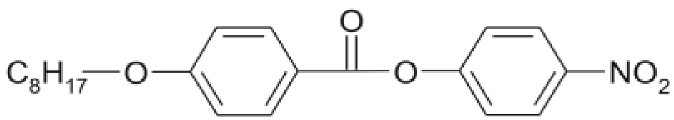
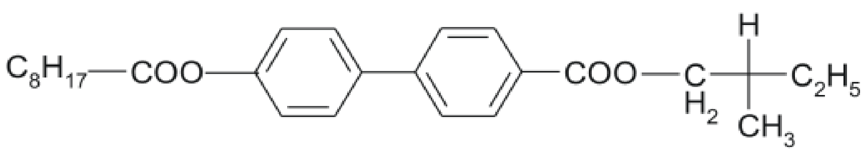
dynamic separation of charge in LC



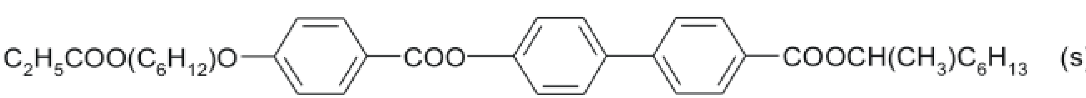
8CB



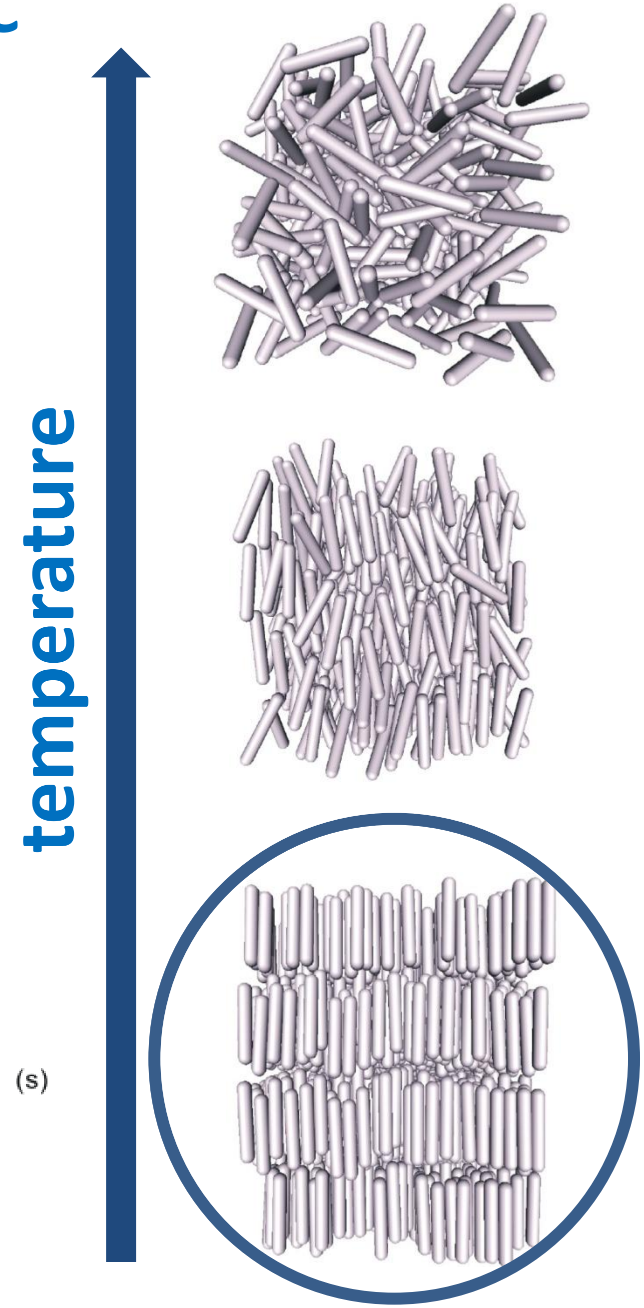
NPOB



MBOBC

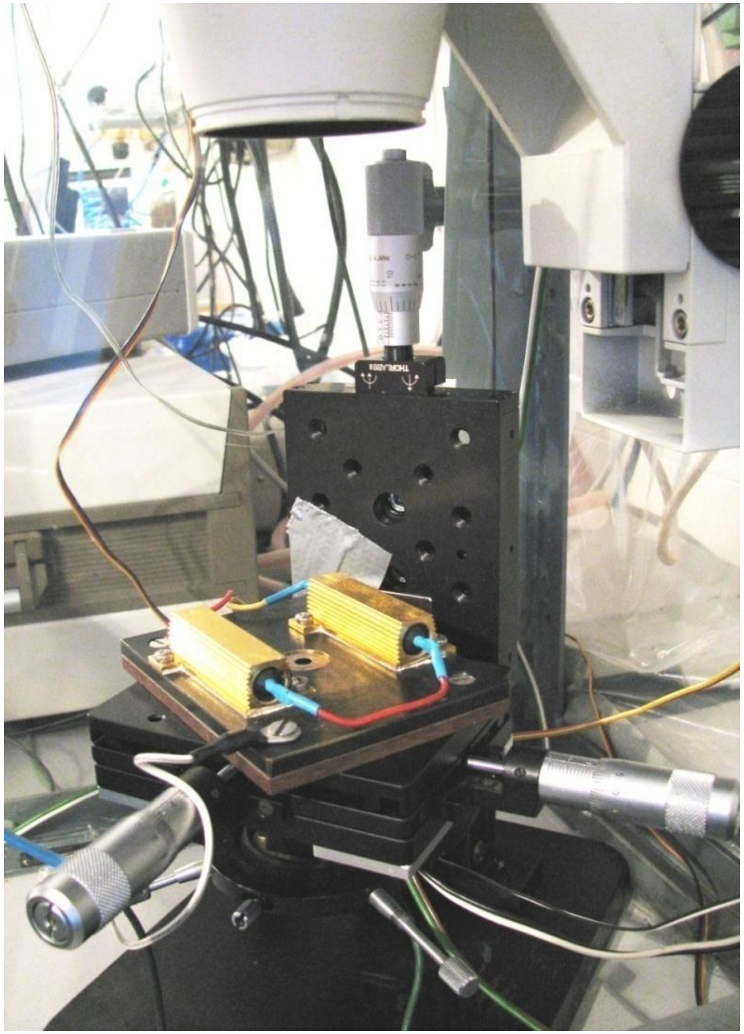


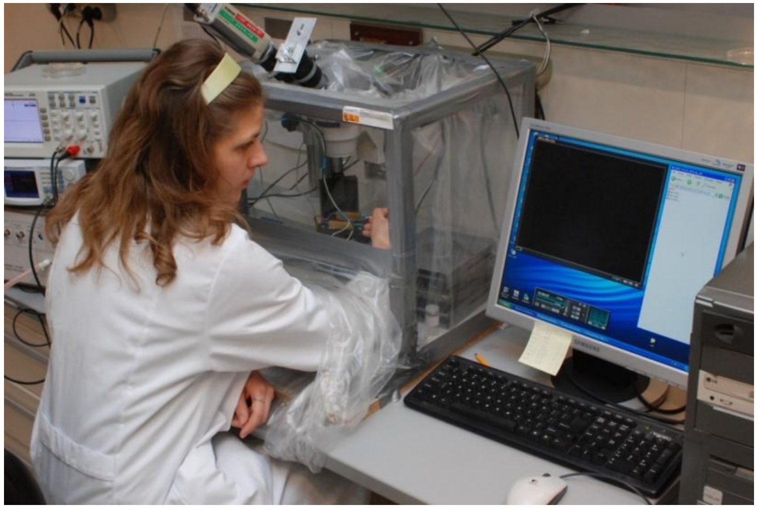
MHPPHBC

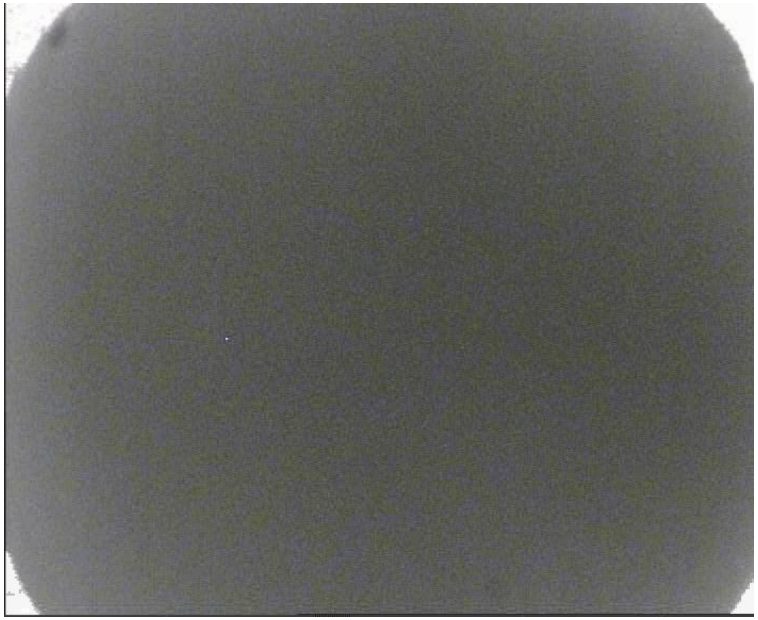


dynamic separation of charge in LC

experiment

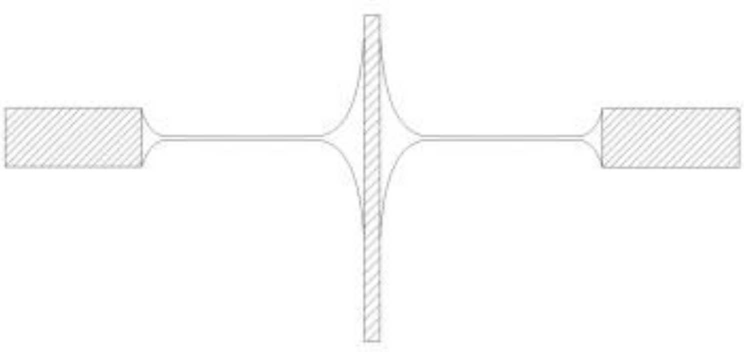


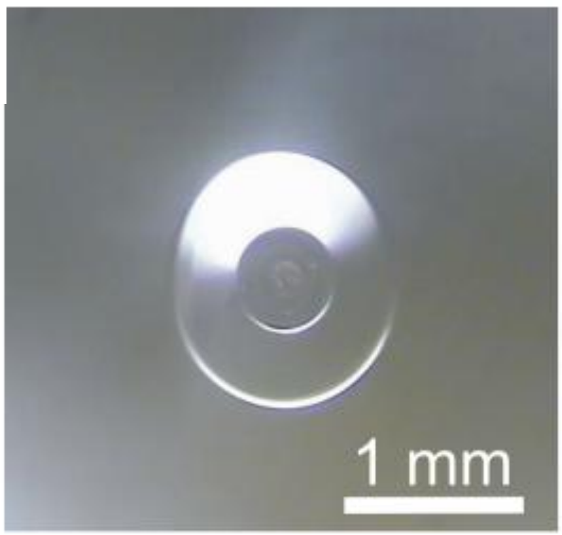




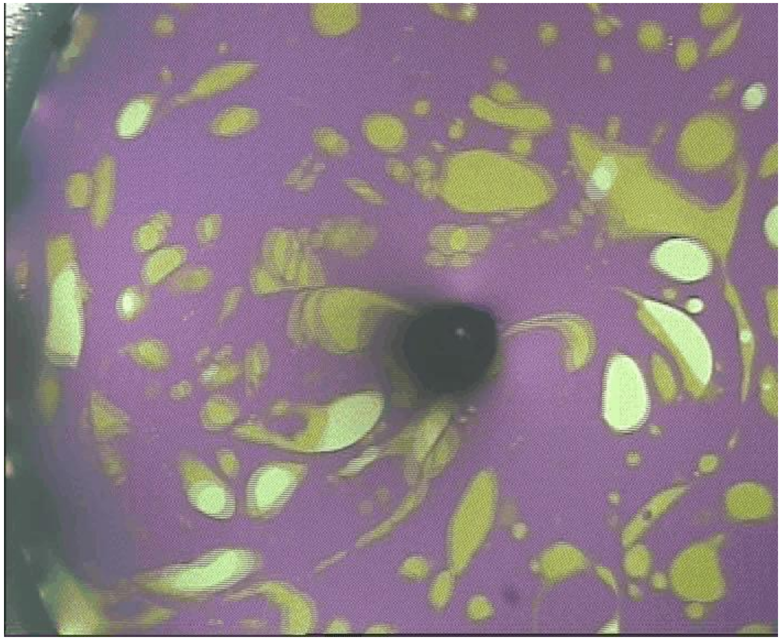
dynamic separation of charge in LC

needle through



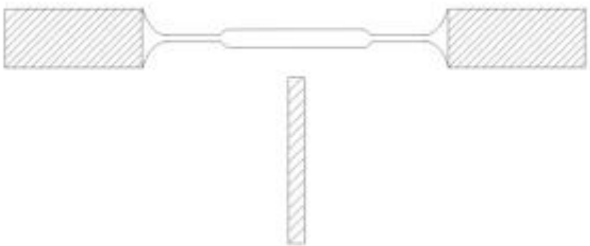


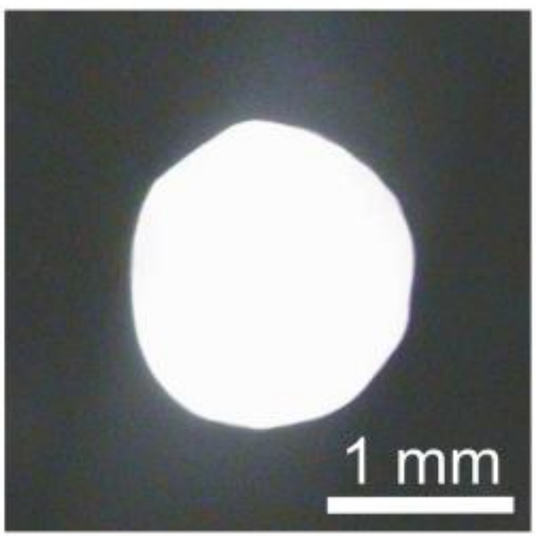
DC



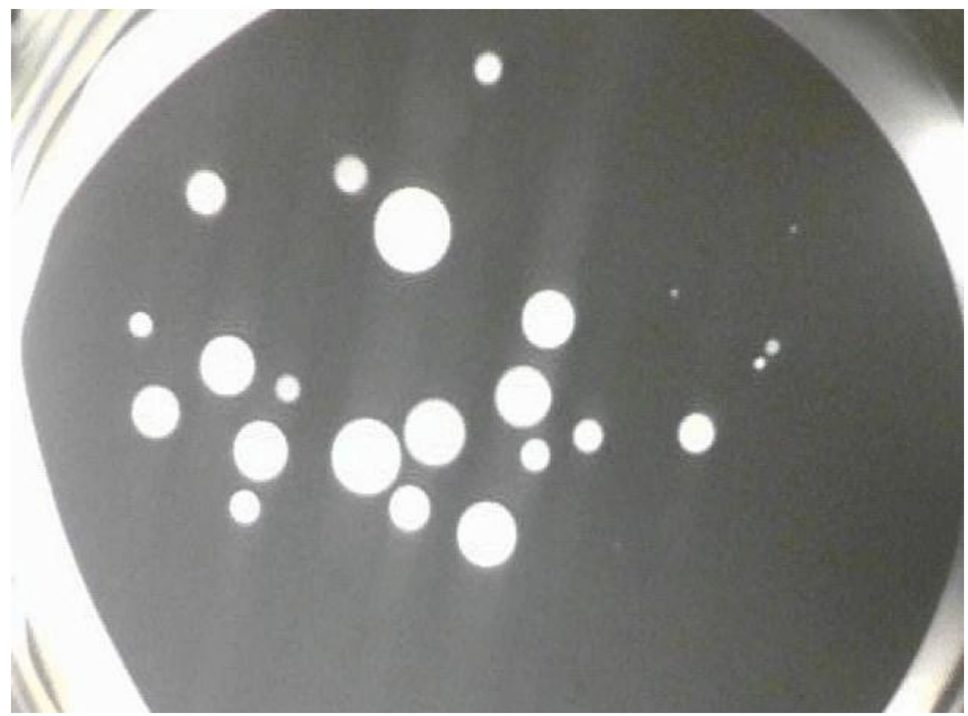
dynamic separation of charge in LC

needle below

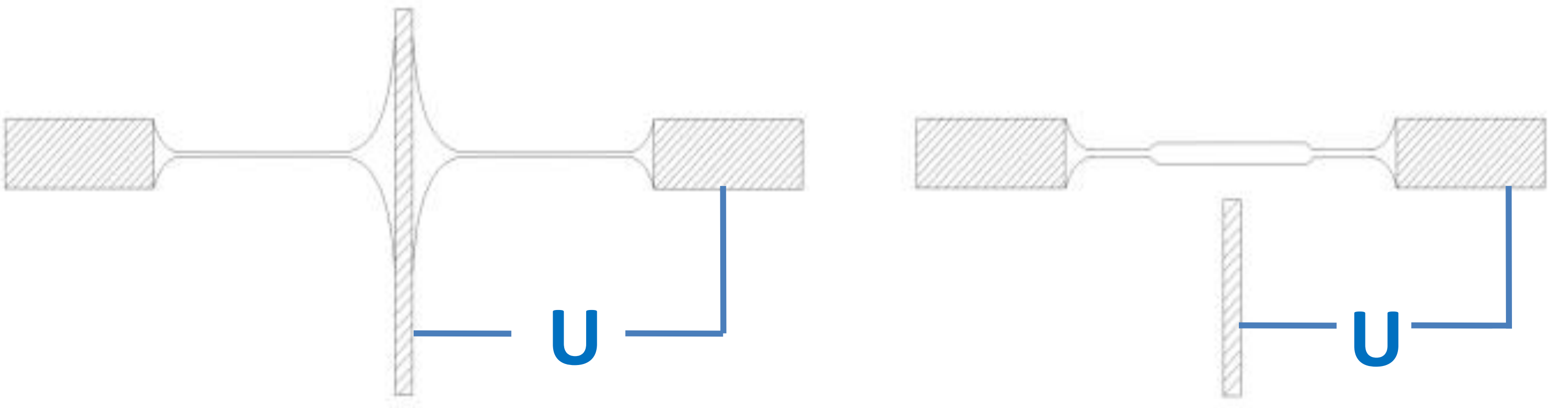




AC, high frequency



electric field



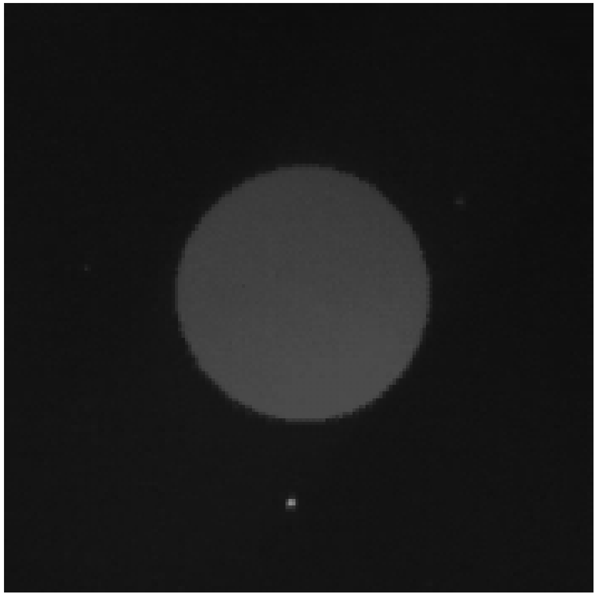
?

dynamic separation of charge in LC

electric field

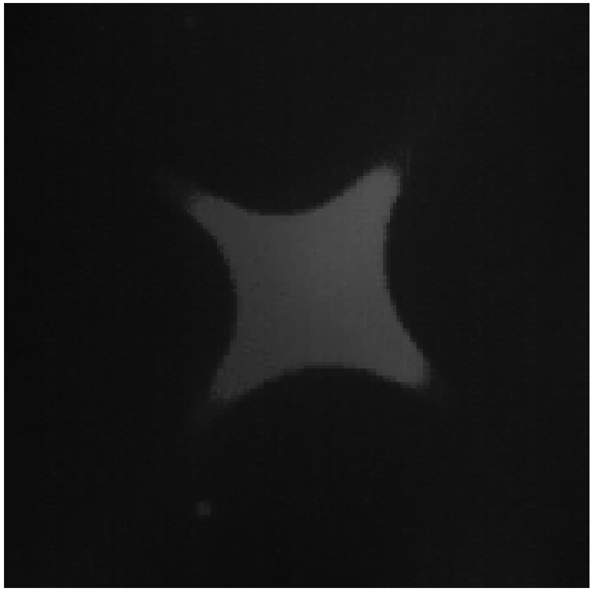
frequency

10^2 Hz



10^1 Hz

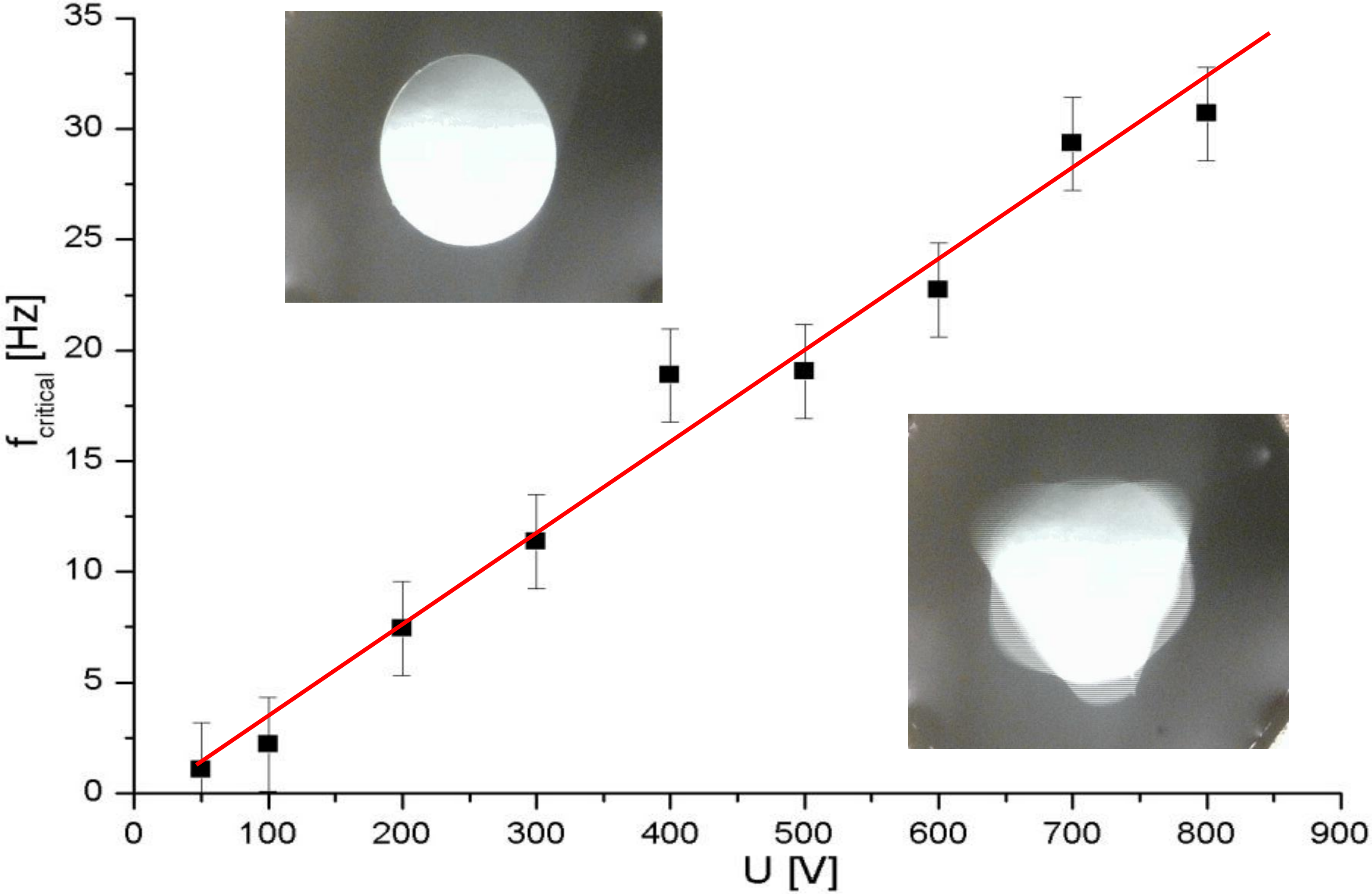
sharp transition at f_{CR}



10^0 Hz

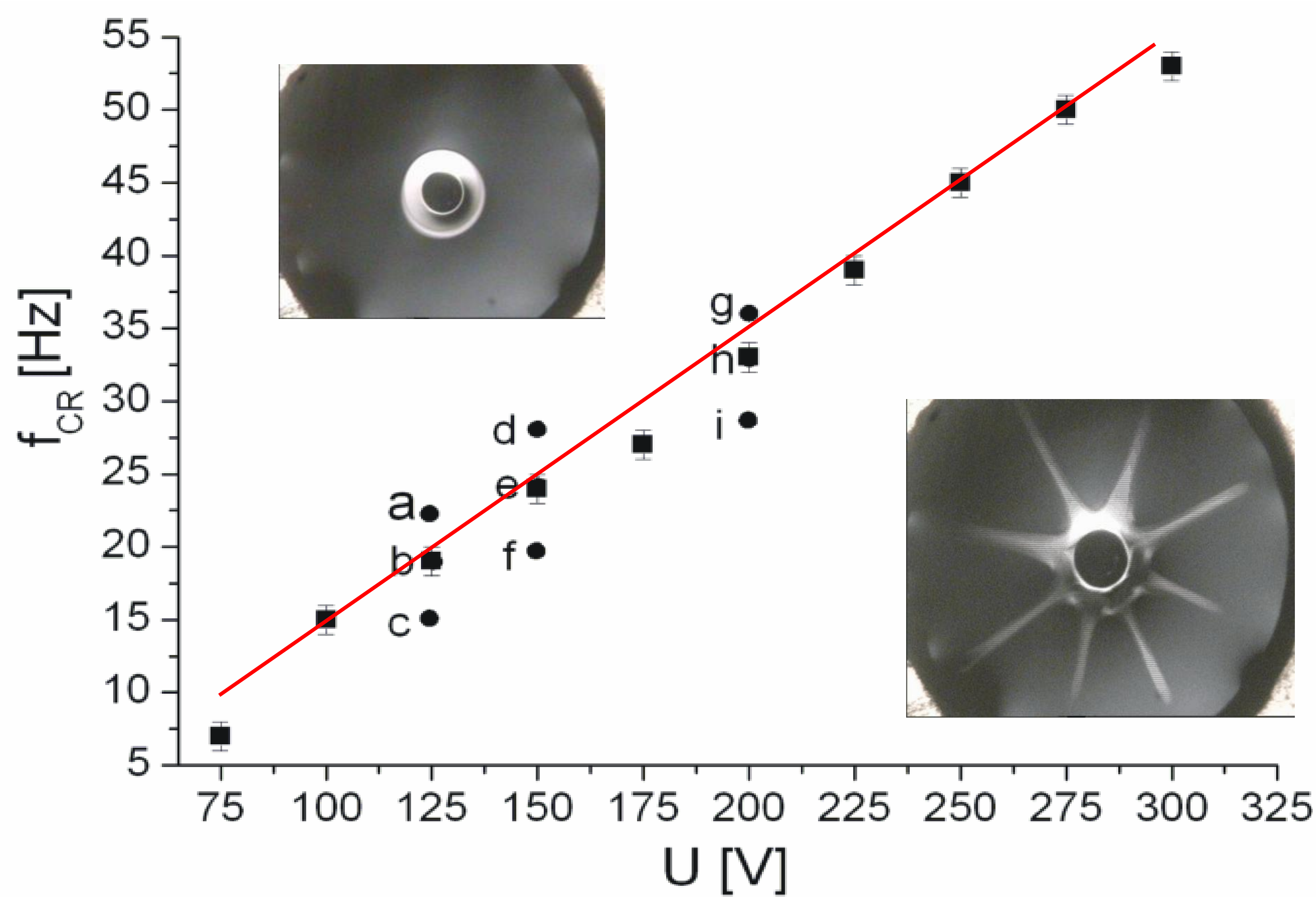
dynamic separation of charge in LC

MHPPHBC – ferroelectric LC

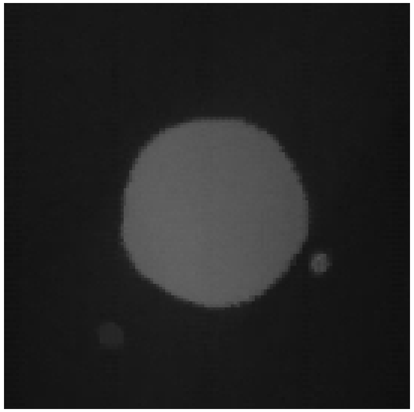


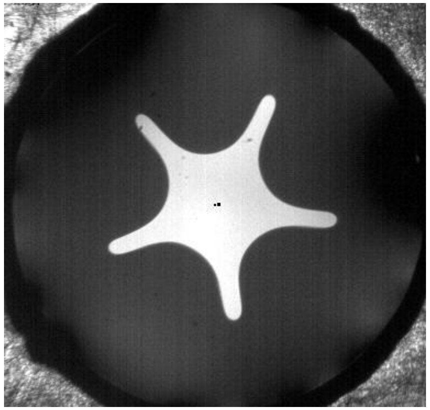
dynamic separation of charge in LC

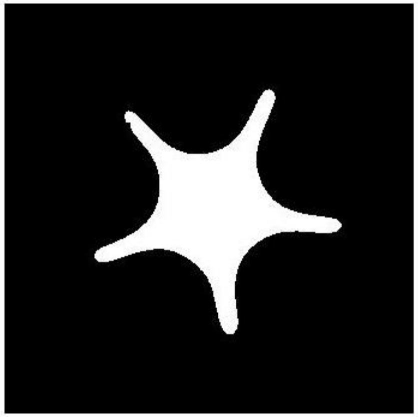
8CB – non-ferroelectric LC

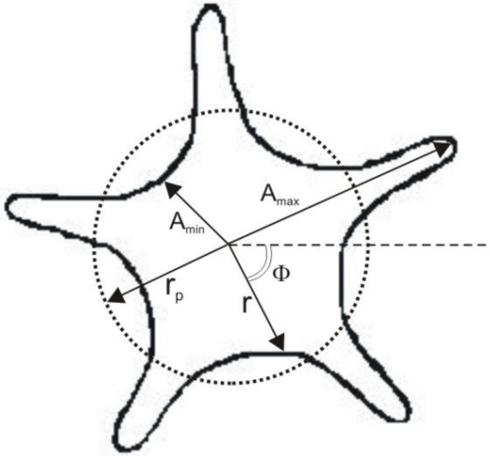


dynamic separation of charge in LC

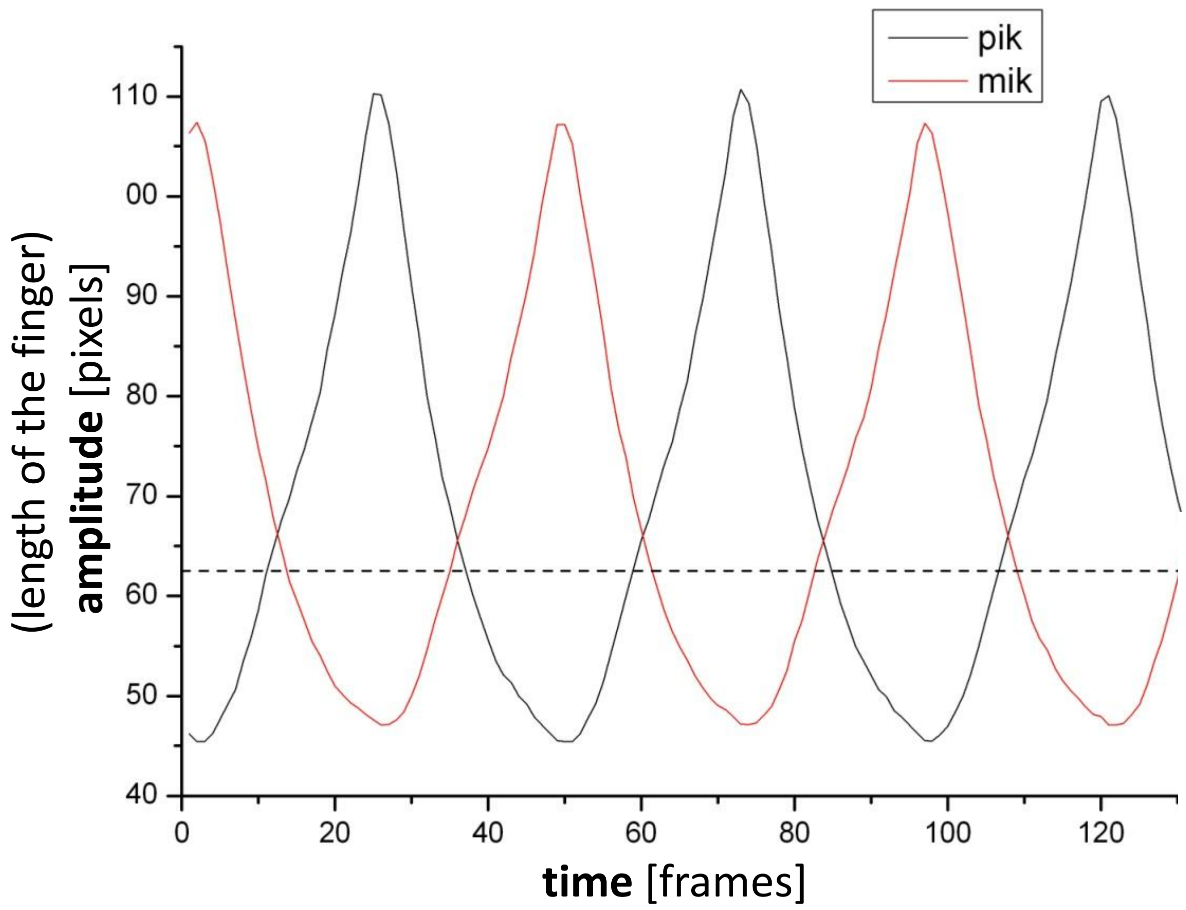


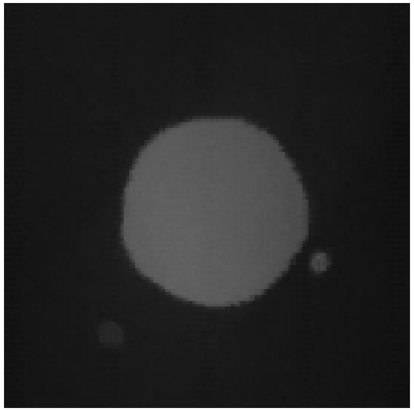


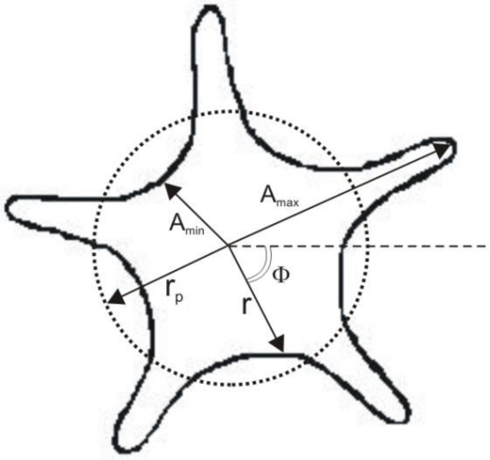




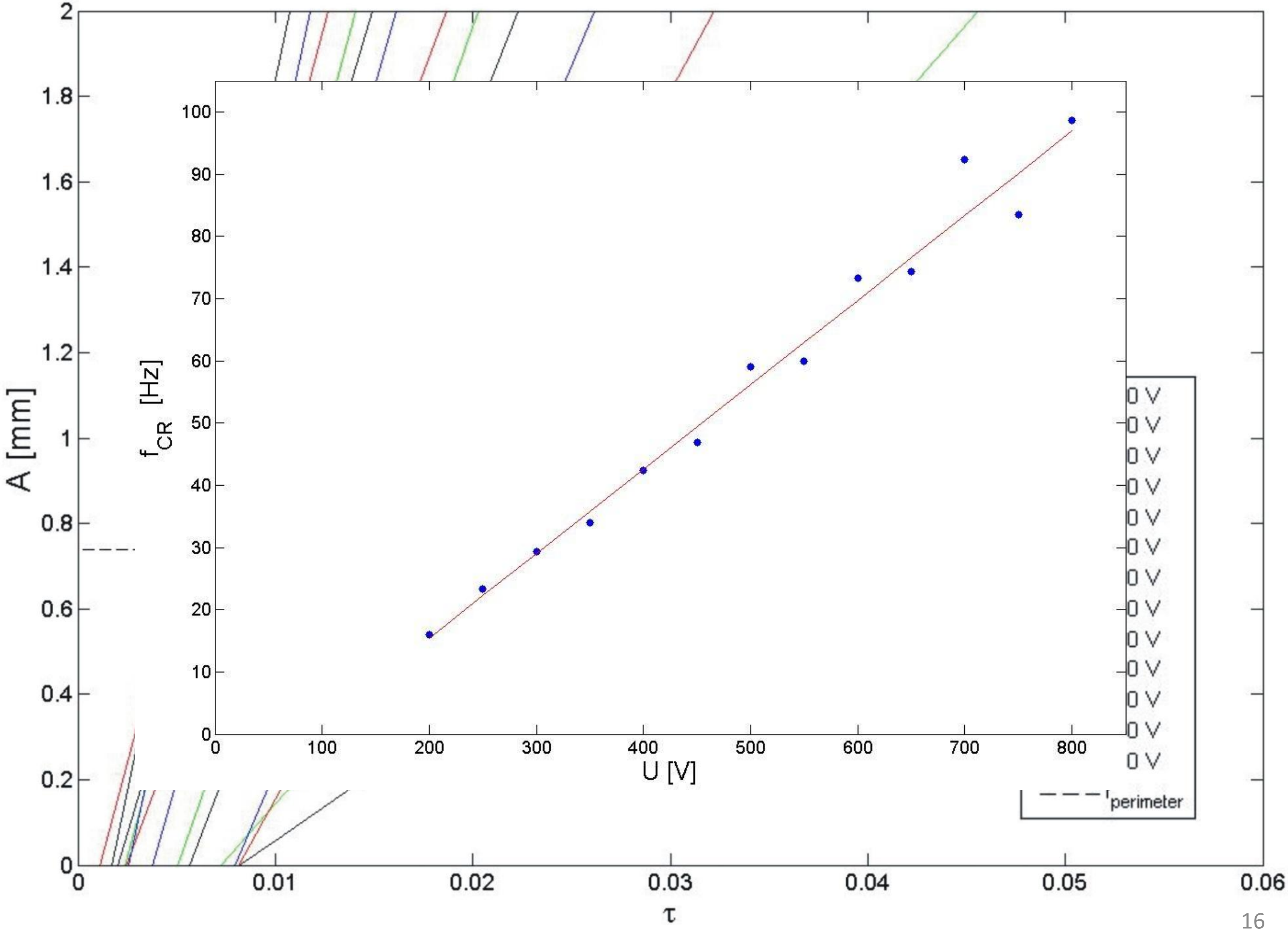
dynamic separation of charge in LC





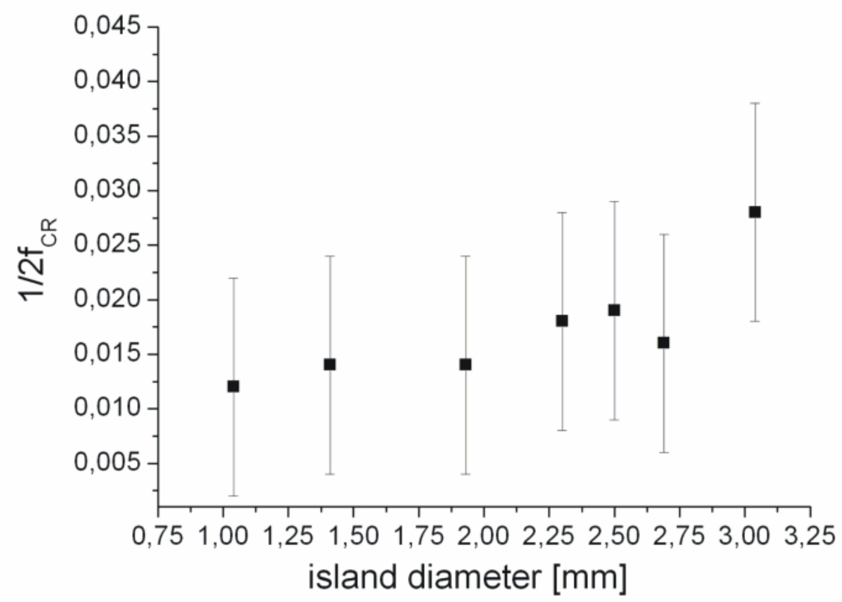


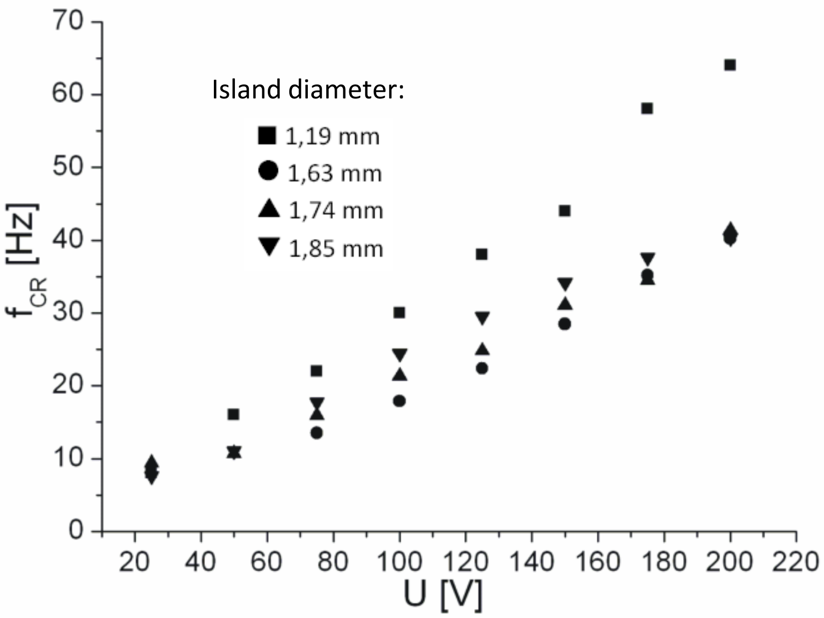
dynamic separation of charge in LC



dynamic separation of charge in LC

- critical frequency (f_{CR}) is linear in voltage
- dA/dt is linear in voltage
- f_{CR} does not depend on the diameter of the island





- f_{CR} does not depend on the thickness of the island

(repetitive experiments on new films yield very similar values of f_{CR})

dynamic separation of charge in LC

1. We estimate the EC mobility *via*

$$\mu = \frac{q}{6\pi R\eta}$$

literature gives ~**10^{-10} $m^2 V^{-1} s^{-1}$** for electrophoretic mobility of ions in LCs.

Electrophoretic mobility for different ion diameter and charge

q (e)	R (Å)	μ ($m^2 V^{-1} s^{-1}$)
1	1	$3{,}29\cdot10^{-10}$
2	5	$1{,}32\cdot10^{-10}$
3	10	$0{,}98\cdot10^{-10}$

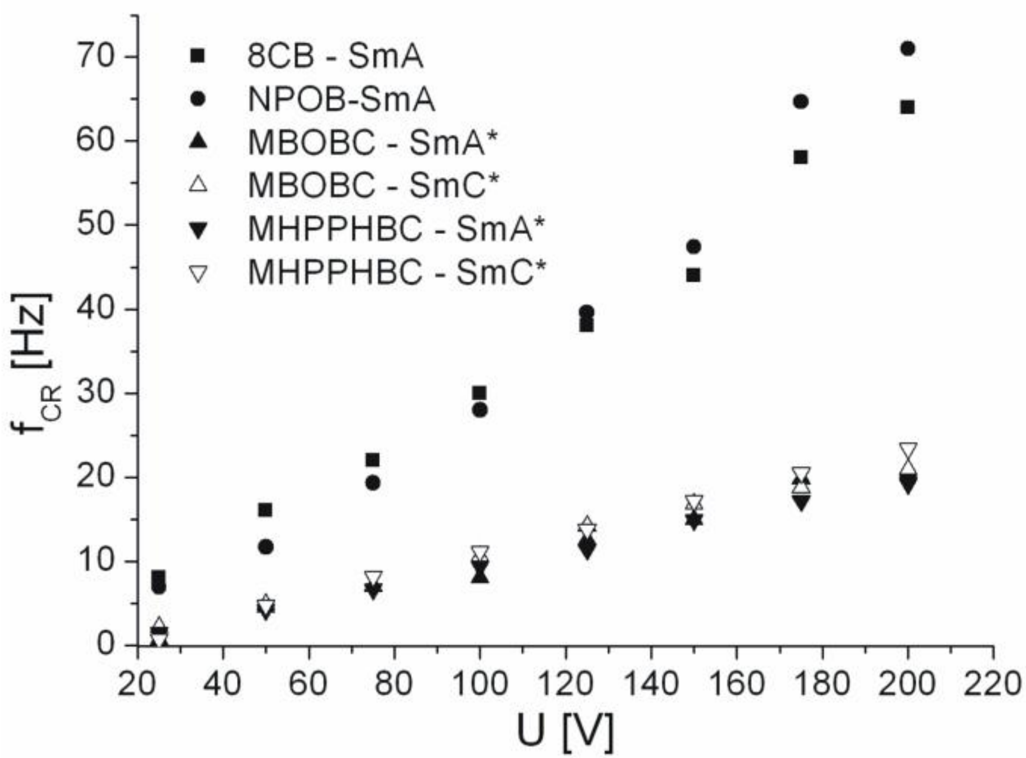
2. We estimate the distance d_{ions} traveled by the ions within $t = (2f_{CR})^{-1}$
d_{ions} compares well to the Debye screening length[1]:

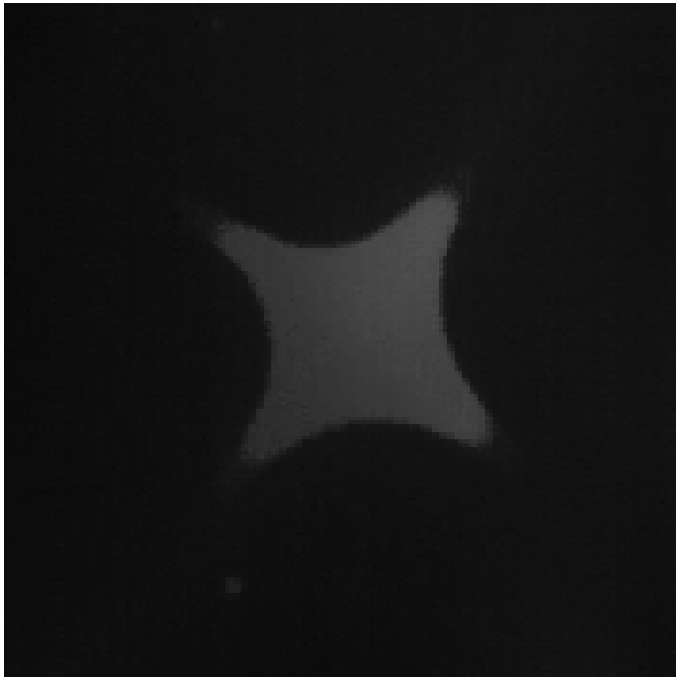
d_{ions} ranged from $d_{ions} = 50$ *nm* for NPOB in SmA phase
to $d_{ions} = 460$ *nm* for MHPPHBC in the SmC* phase.

These values are similar in magnitude to the reported value of the Debye screening length of 0,7 µm[1] in CS1015 SmC* phase.

[1] J.-B. Lee, R. A. Pelcovis and R. B. Meyer, *Phys. Rev. E, 2007,* ***75,*** 051701

dynamic separation of charge in LC





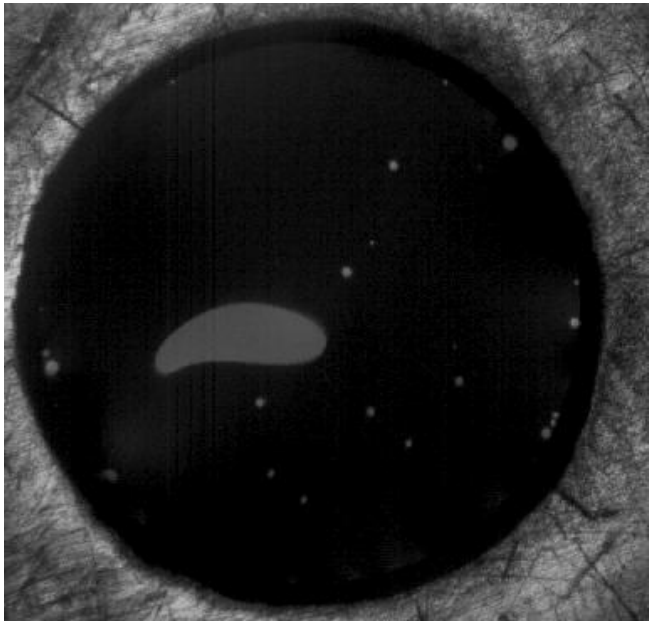
$$\mu(2f_{CR})^{-1}E_{||}$$ ~ *Debye Length*

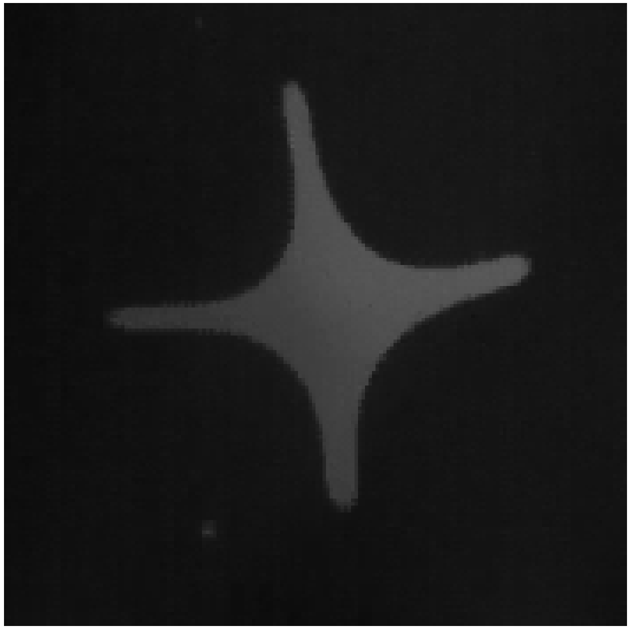
microscopic separation of charges

dynamic separation of charge in LC

- high frequencies – ions oscillate with amplitude < Debye length
- low frequencies – ions osicillate with amplitudes > Debye length
  → „microscopic" separation of charges

- the boundary of the meniscus becomes charged and undergoes an electrohydrodynamic instability
  → **macroscopic** separation of charges





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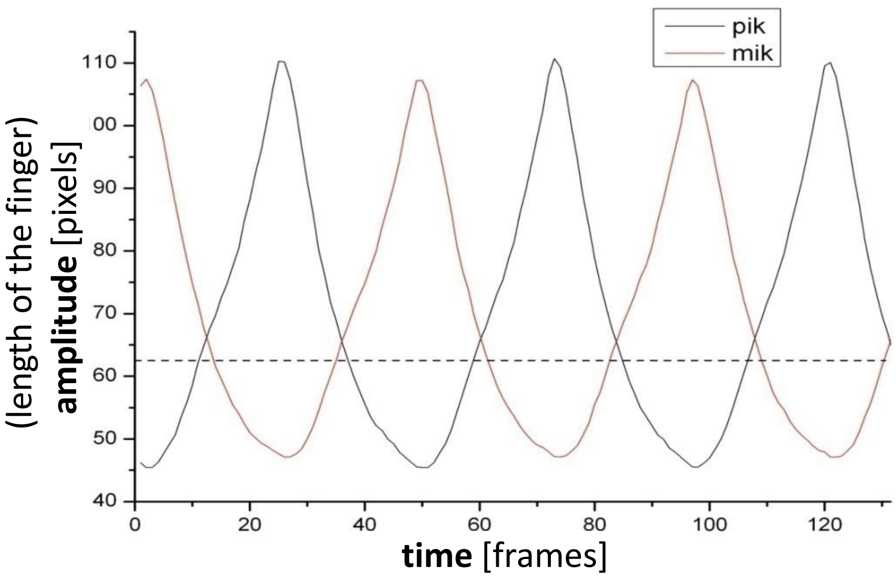
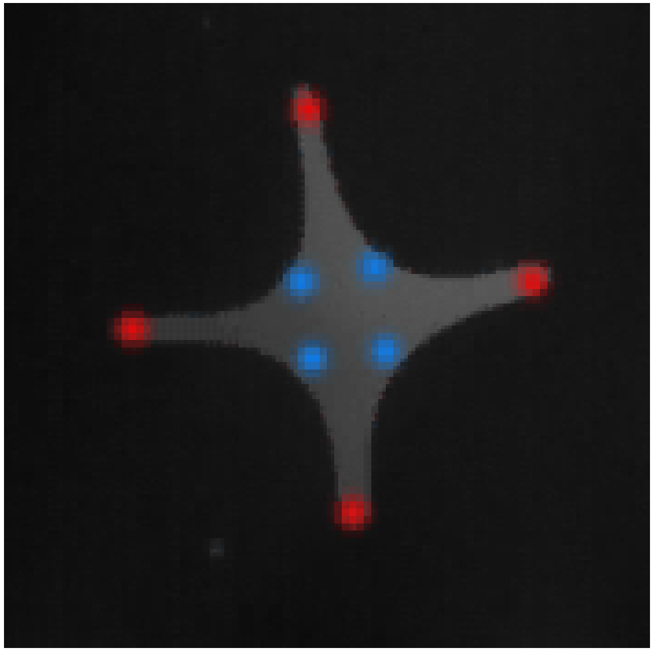
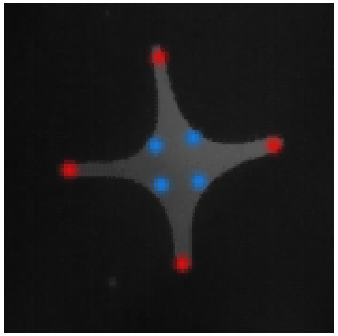




dynamic separation of charge in LC



- we can visualize (indirectly) the motion of ions

- instability only ensues when ions are separated over distances larger than the Debye length

- macroscopic separation of charges, slow relaxation → dynamically controlled

- dynamic **separation of charge in LC**

  can we see the motion of ions with an optical microscope?

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  ionic contribution to polarization of droplets

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  1000 fold increase of the rate of phase separation

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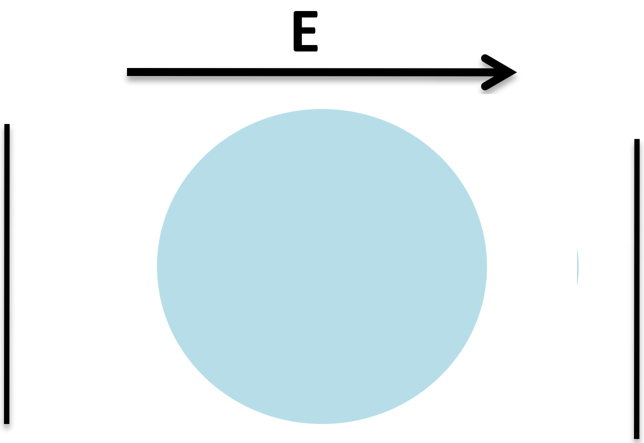
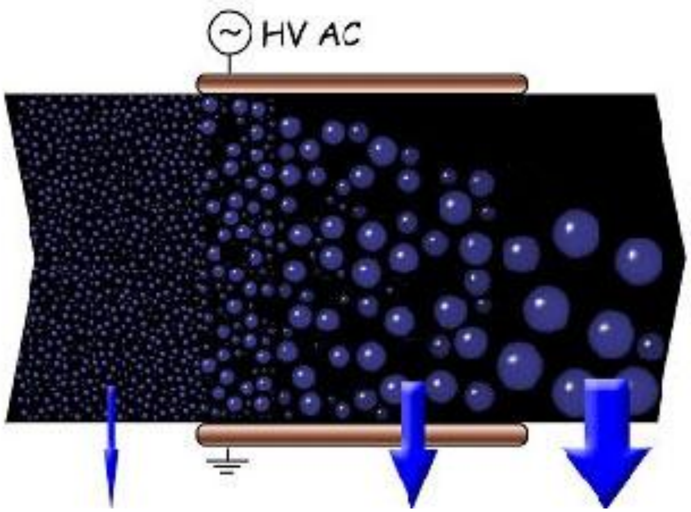
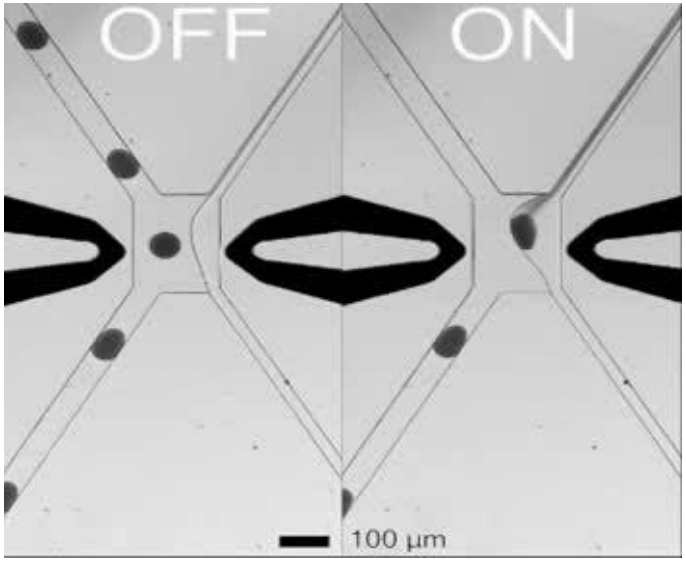
electrocoalescence

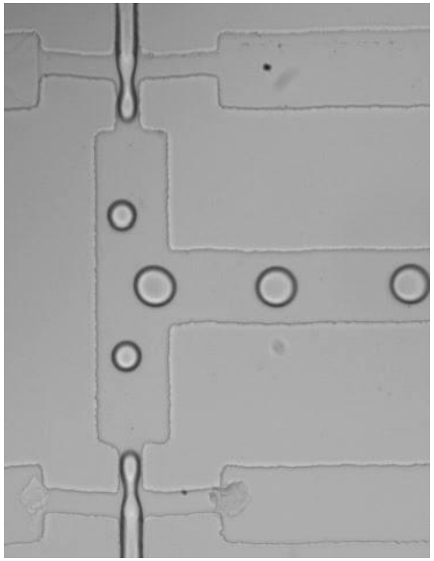




U = 2.3 kV DC



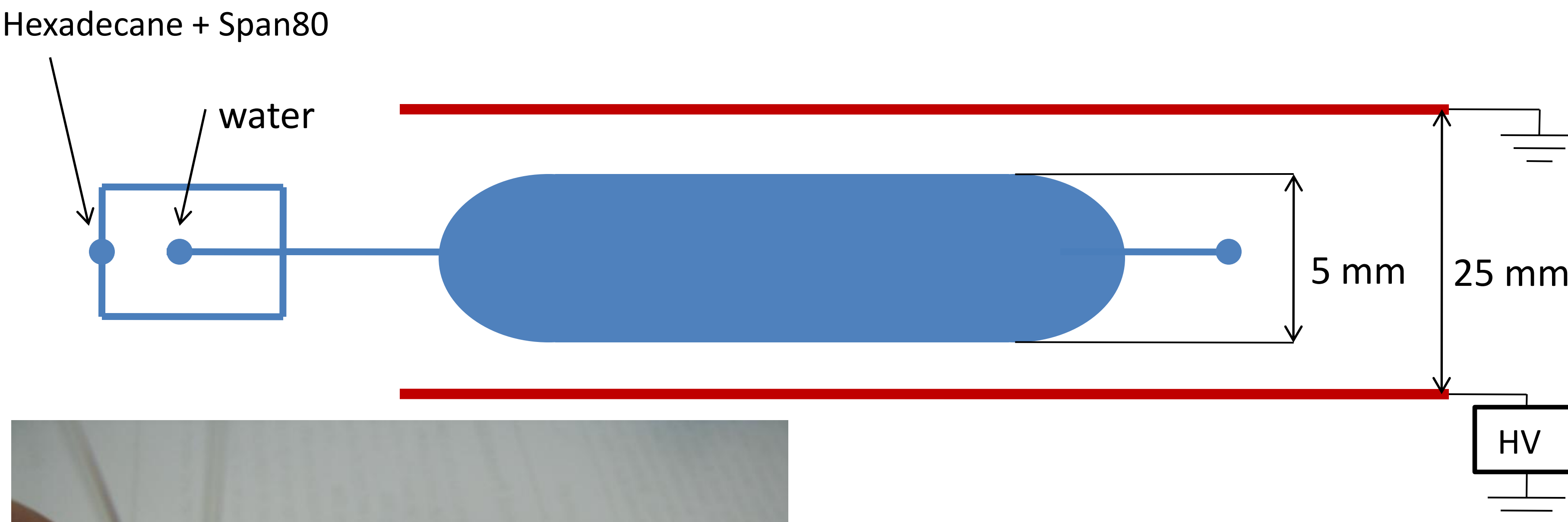
U = 400 V

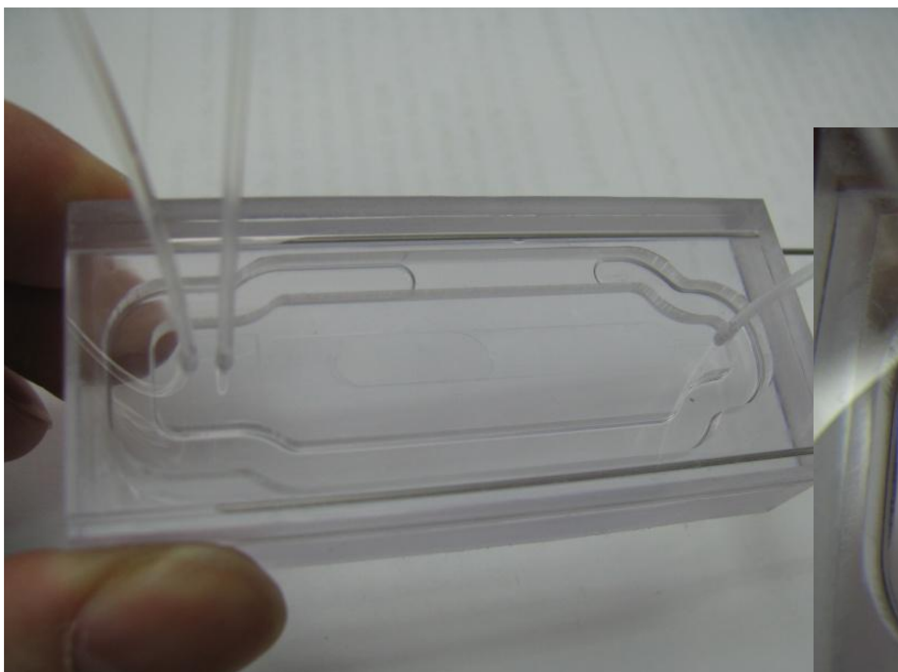


L. Fidalgo *et al*.
Angew. Chem. Int. Ed.
2008, 47

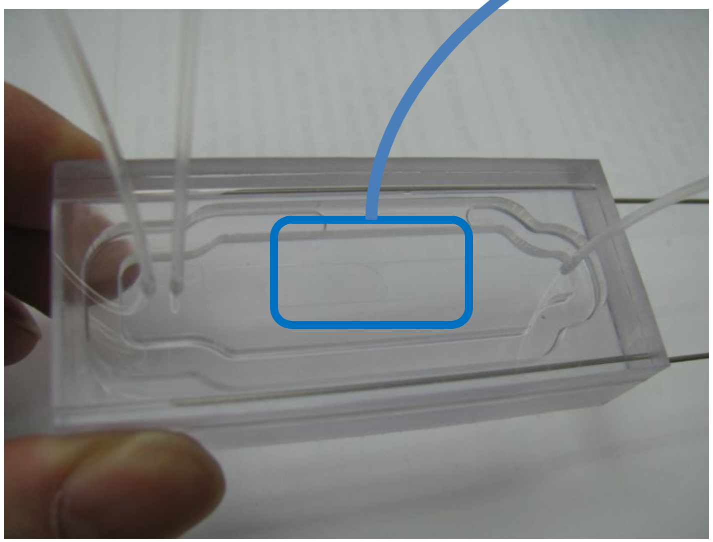
R. Link *et al*.
Angew. Chem. Int. Ed.
2006, 45

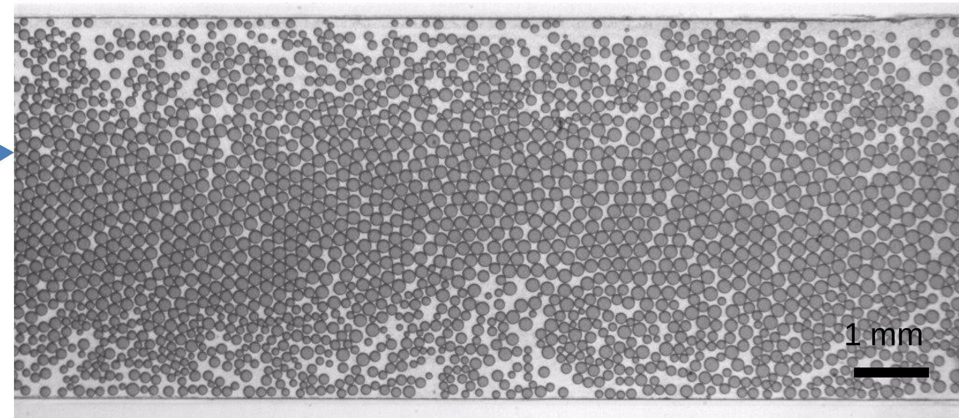
electrocoalescence



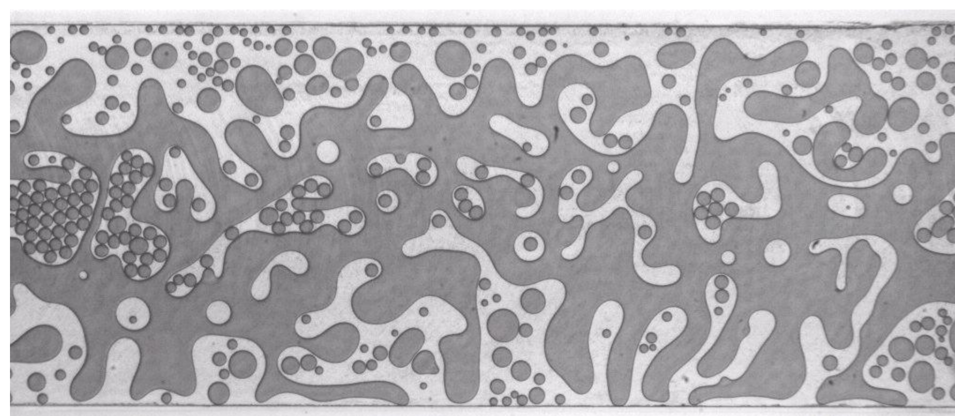


electrocoalescence

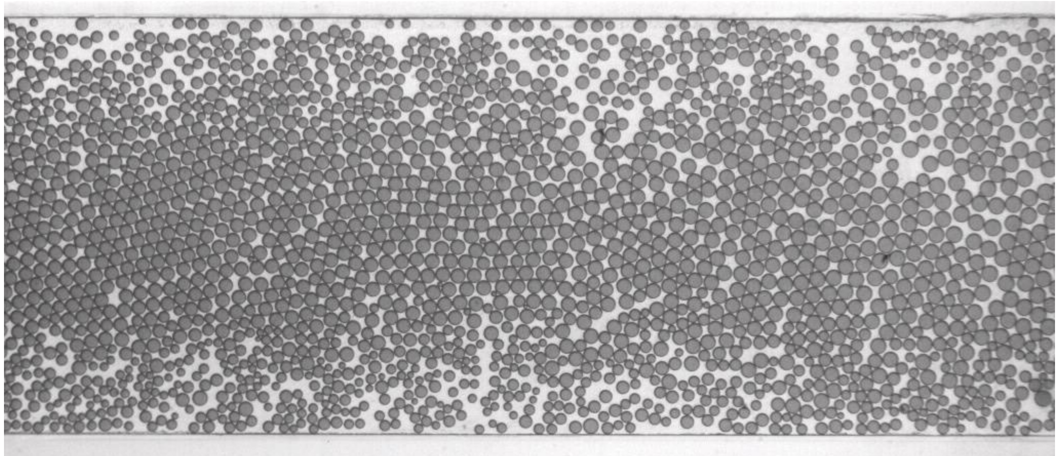




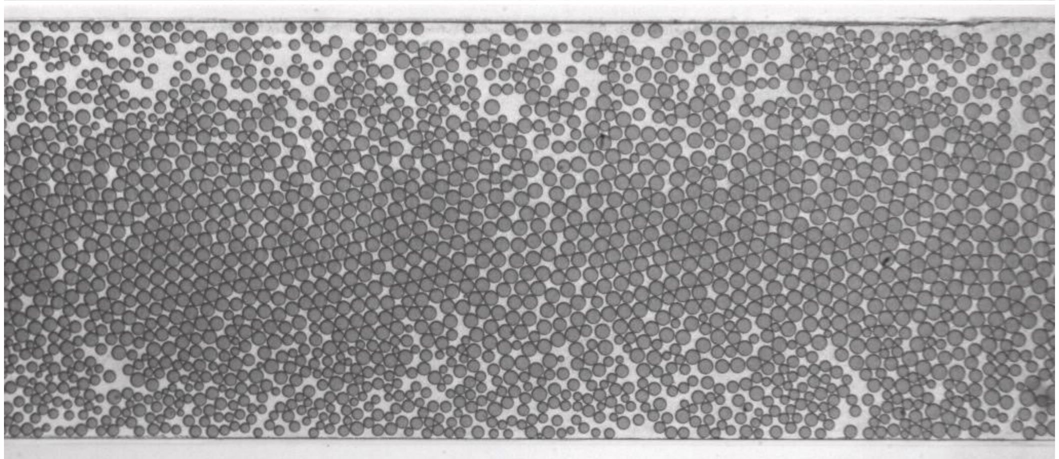
AC EF



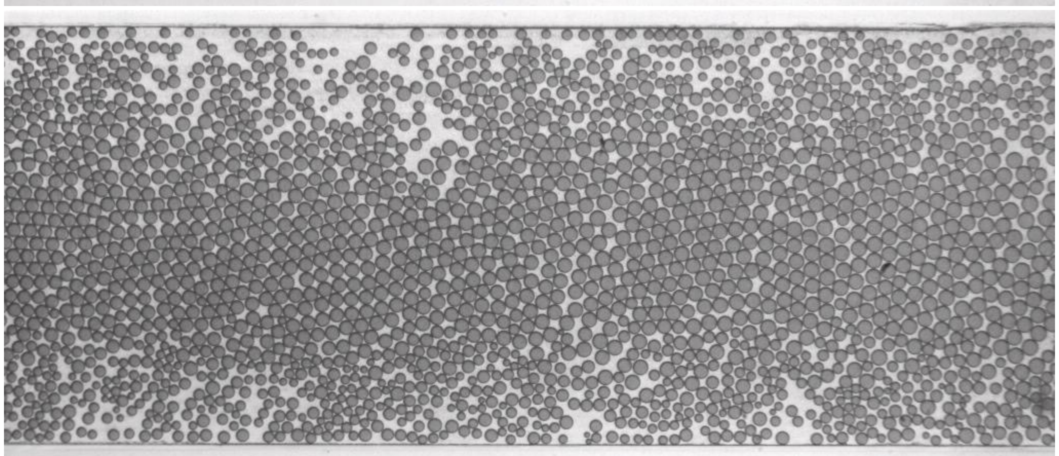
Oil phase: hexadecane + 2% SPAN 80
Droplets: water + dye



1 kHz, 100 V

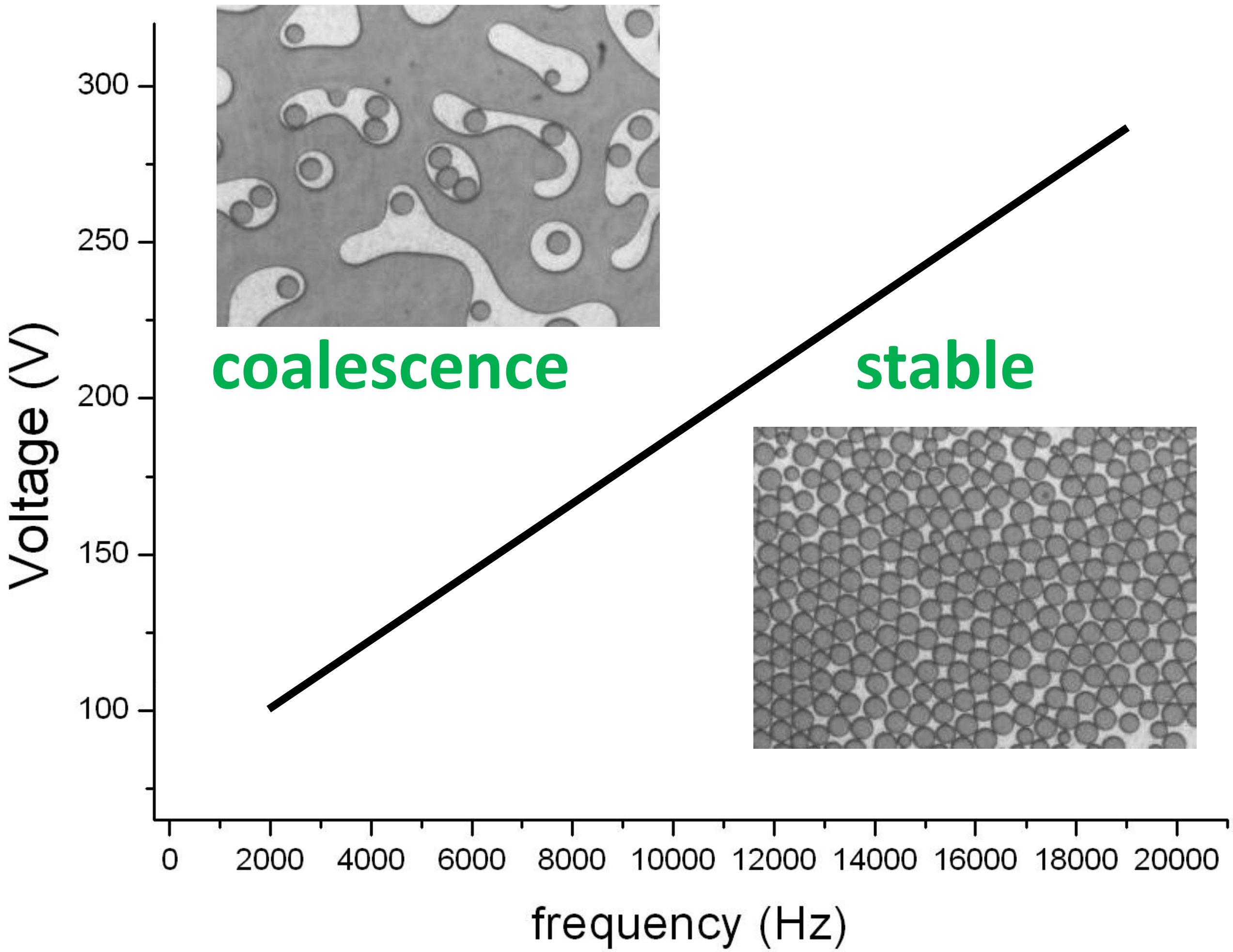


1 kHz, 500 V



1 kHz, 5000 V

electrocoalescence



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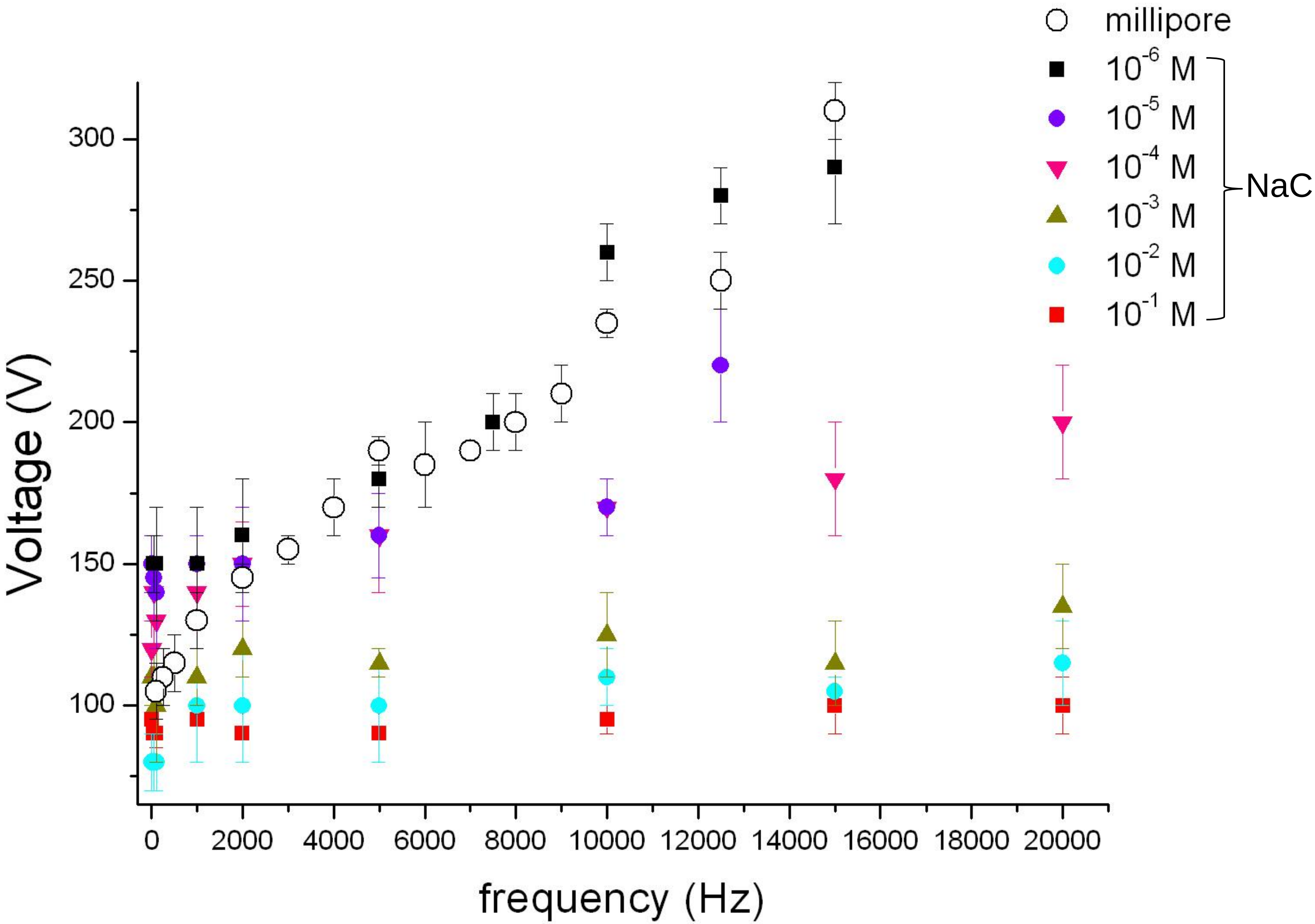
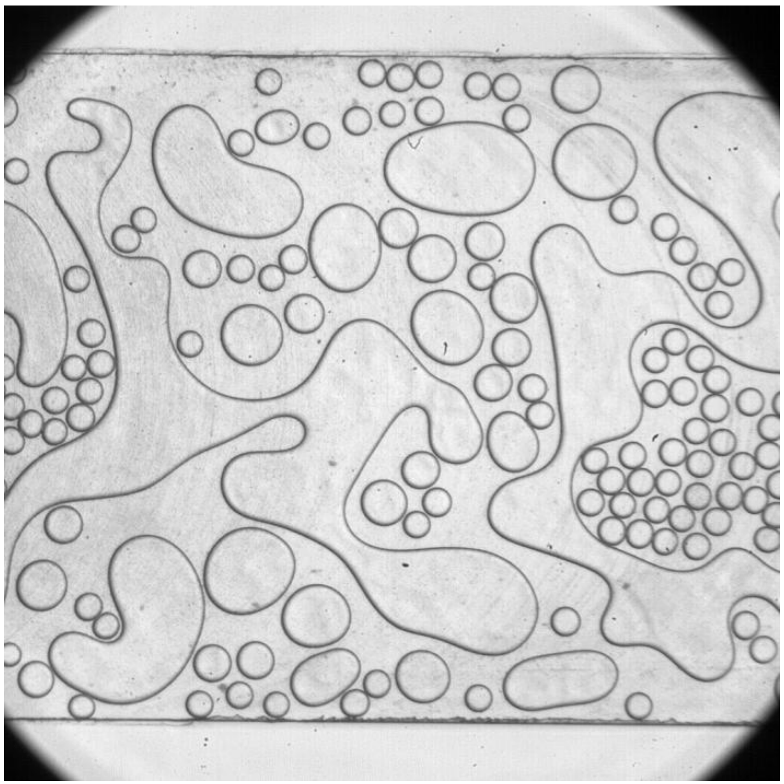


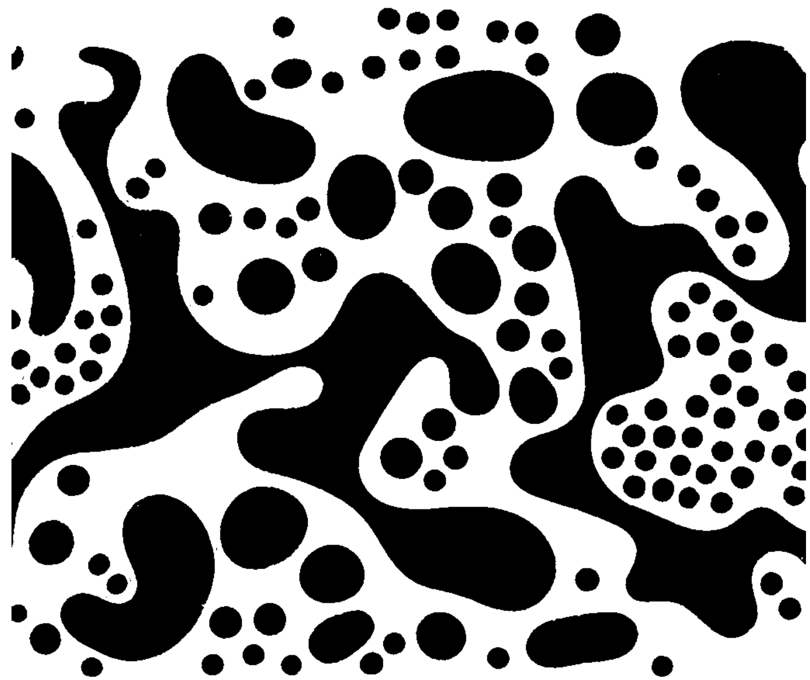
electrocoalescence

Image analysis

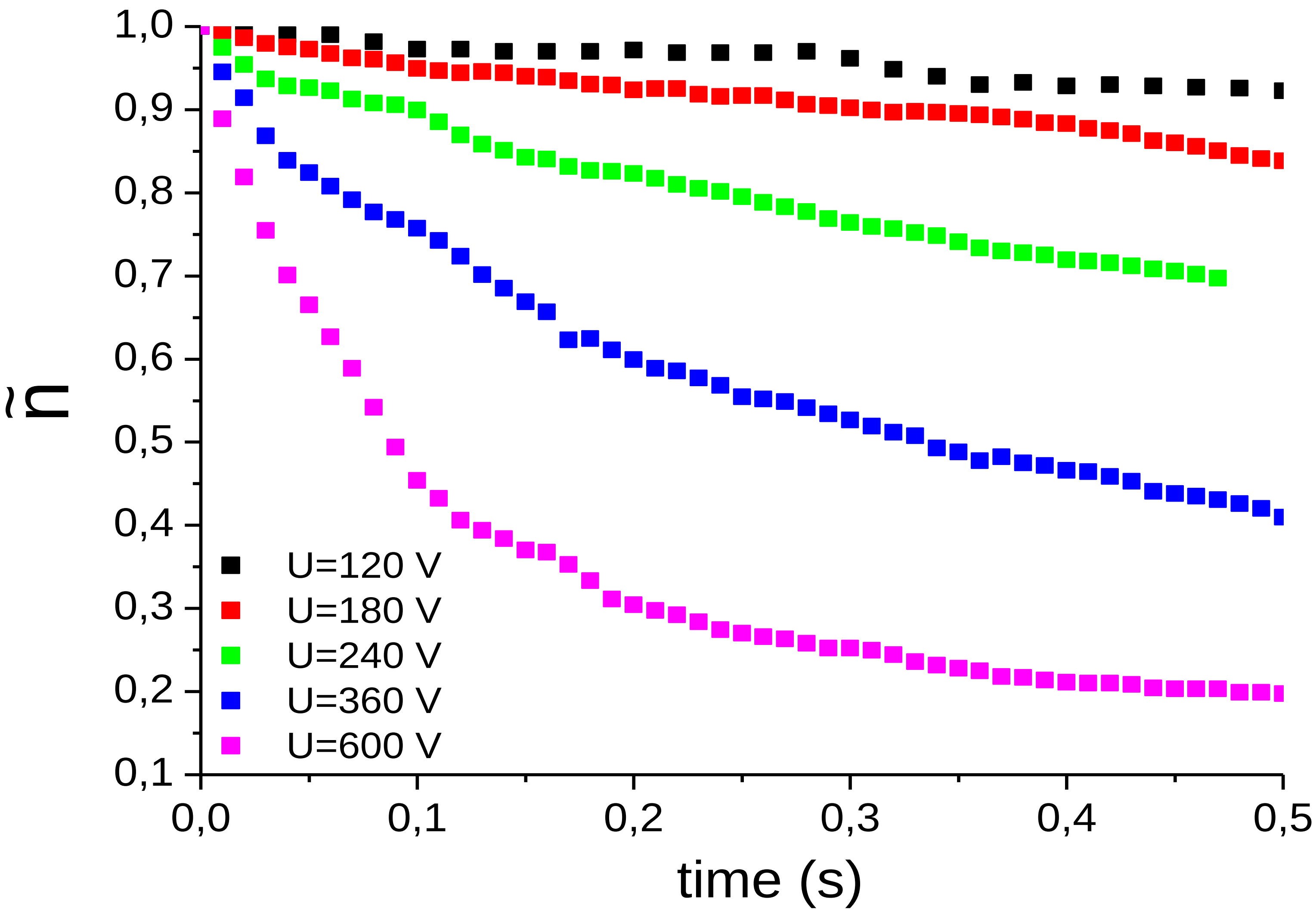
number of droplets

total contour





electrocoalescence – influence of voltage



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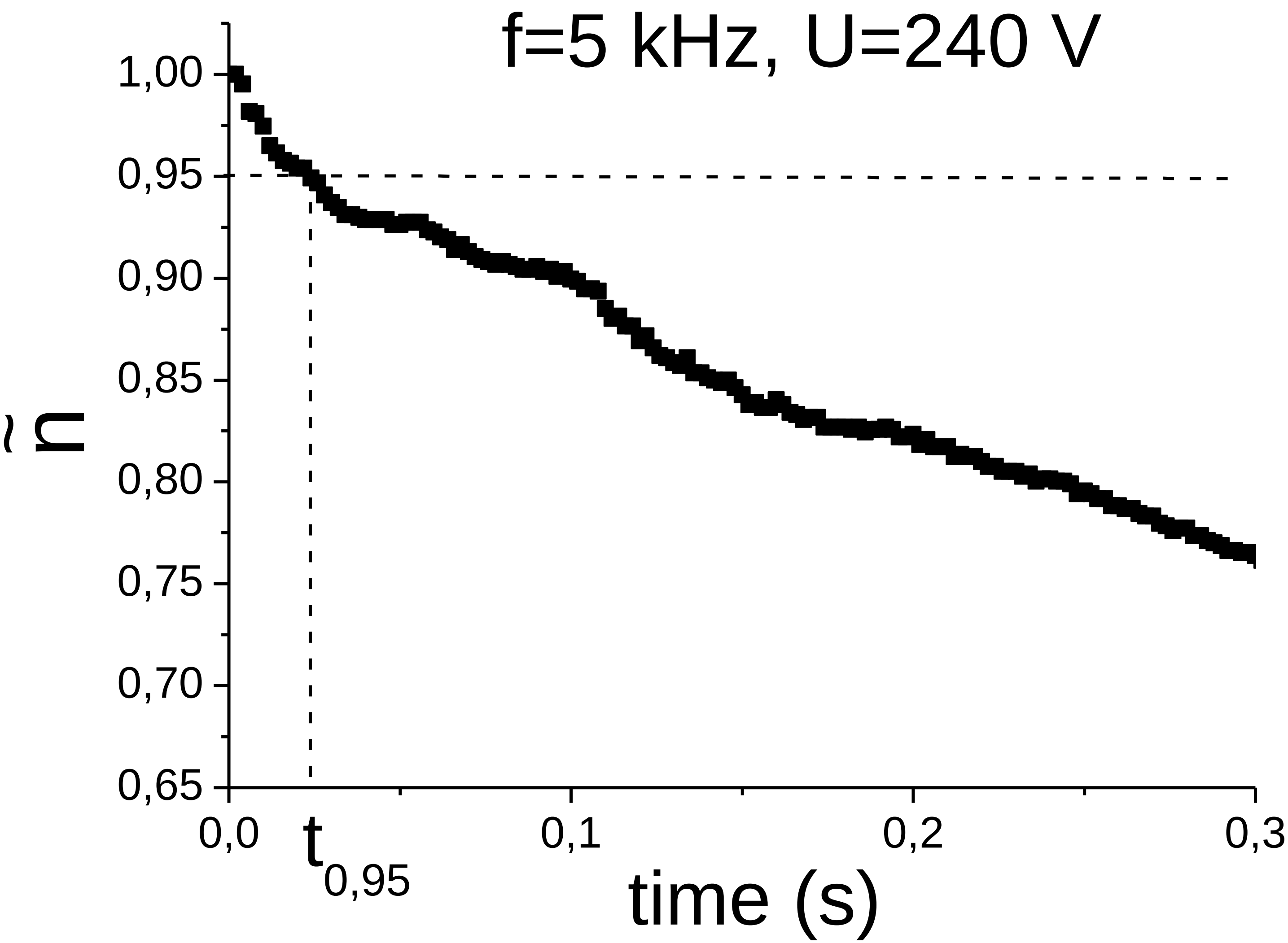
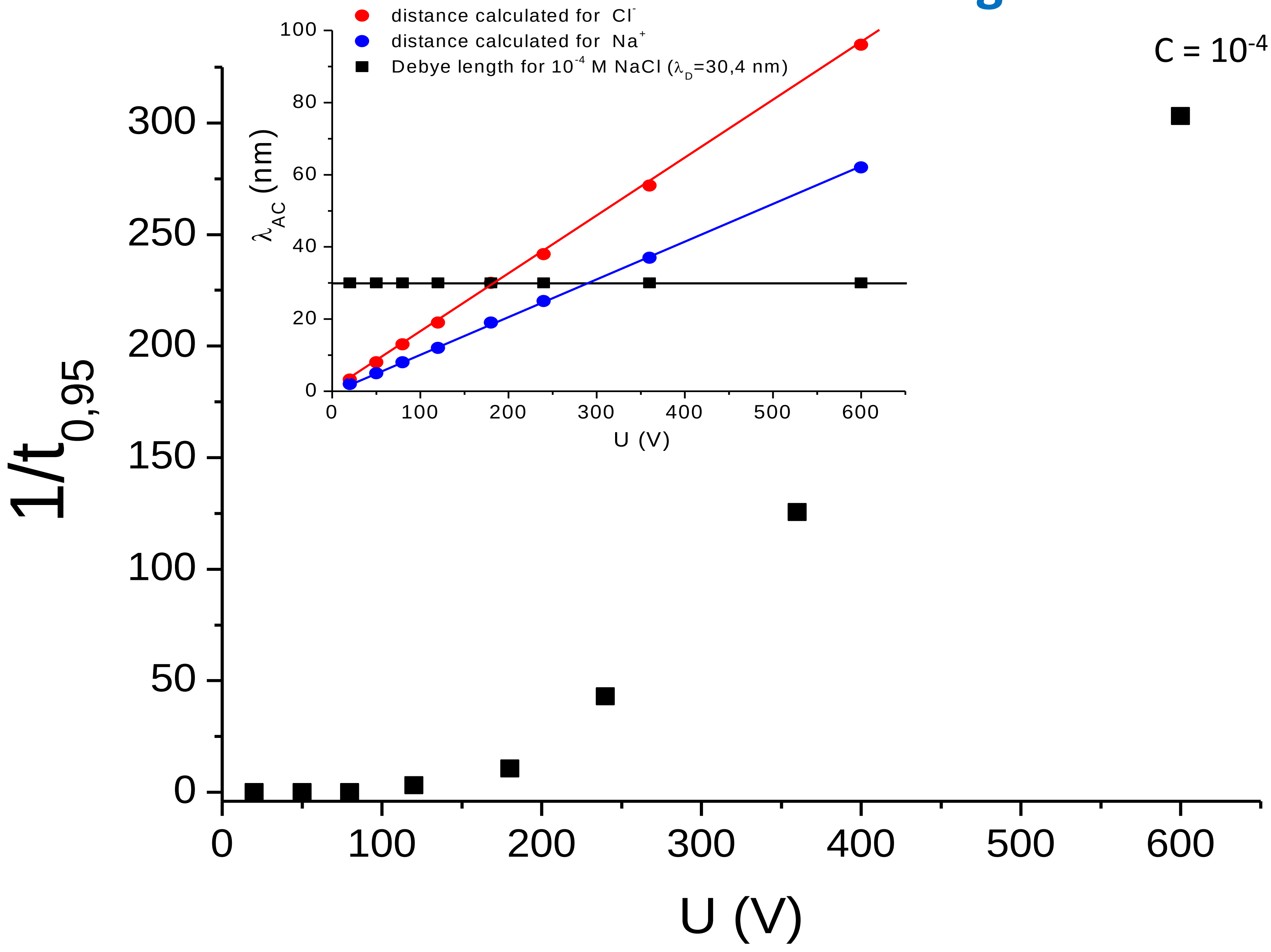
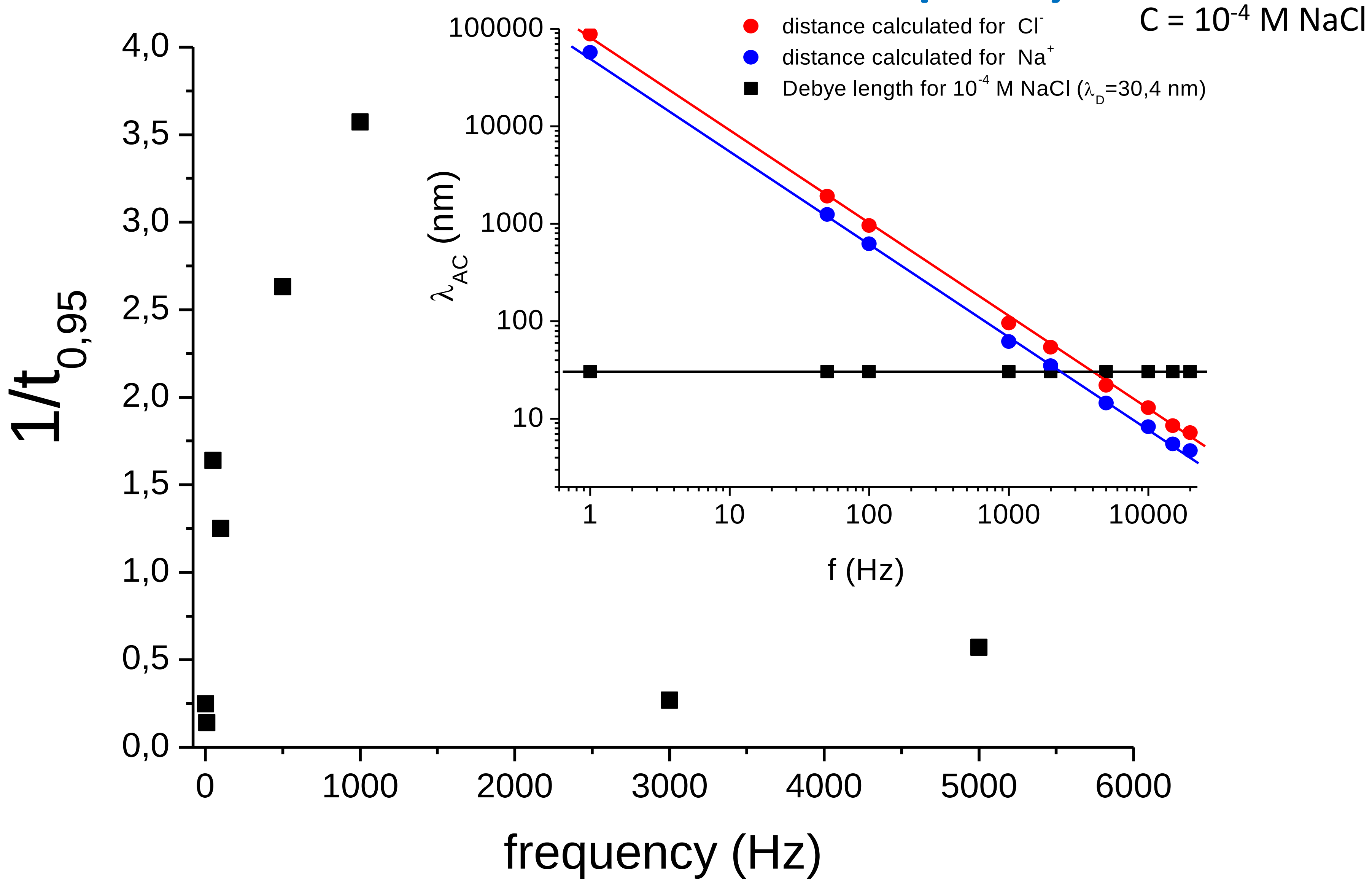


electrocoalescence – influence of voltage

C = 10^{-4} M NaCl



electrocoalescence – influence of frequency



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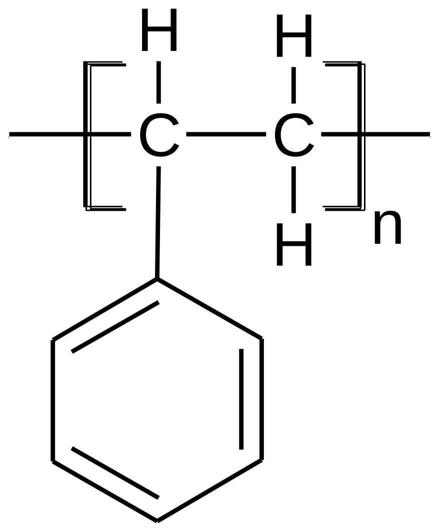
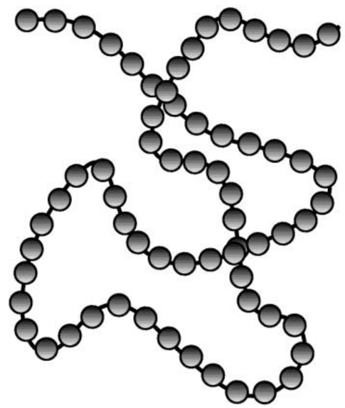
  1000 fold increase of the rate of phase separation

- **summary**

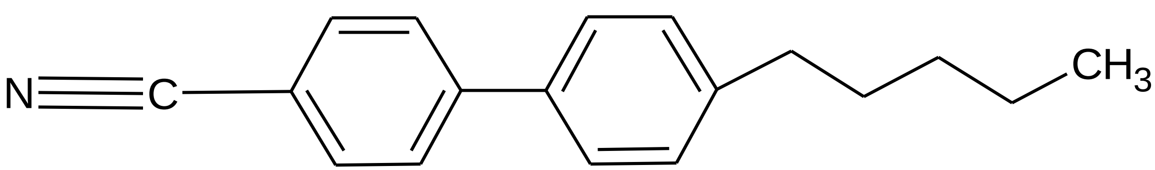
phase separation in polymer & liquid crystal blend

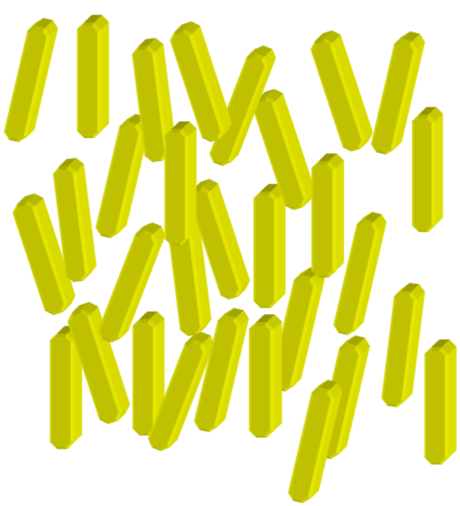
Polymer-polystyrene





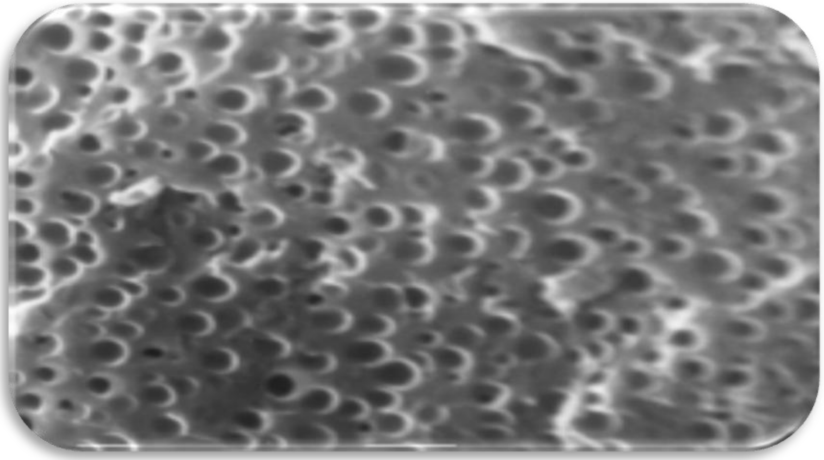
Liquid crystal-5CB



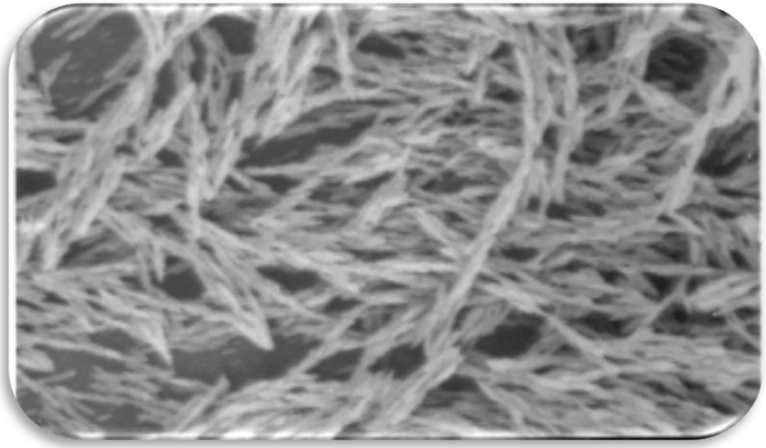


phase separation in polymer & liquid crystal blend

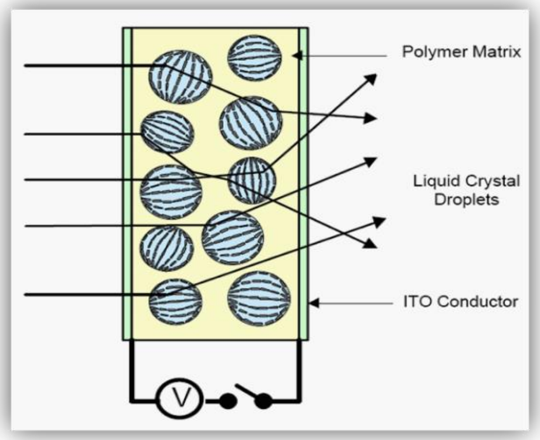
polymer-dispersed liquid crystals (PDLCs)

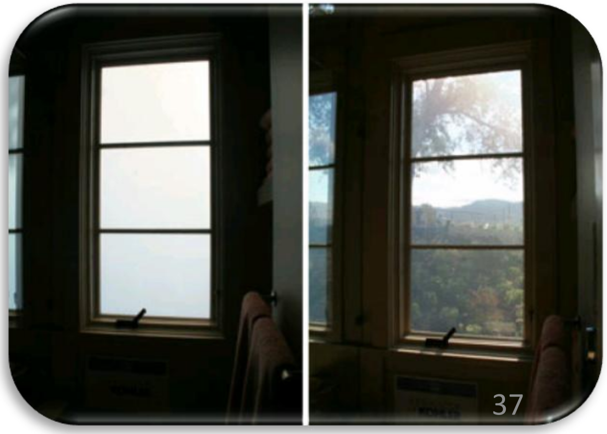


polymer-stabilized liquid crystals (PSLCs)

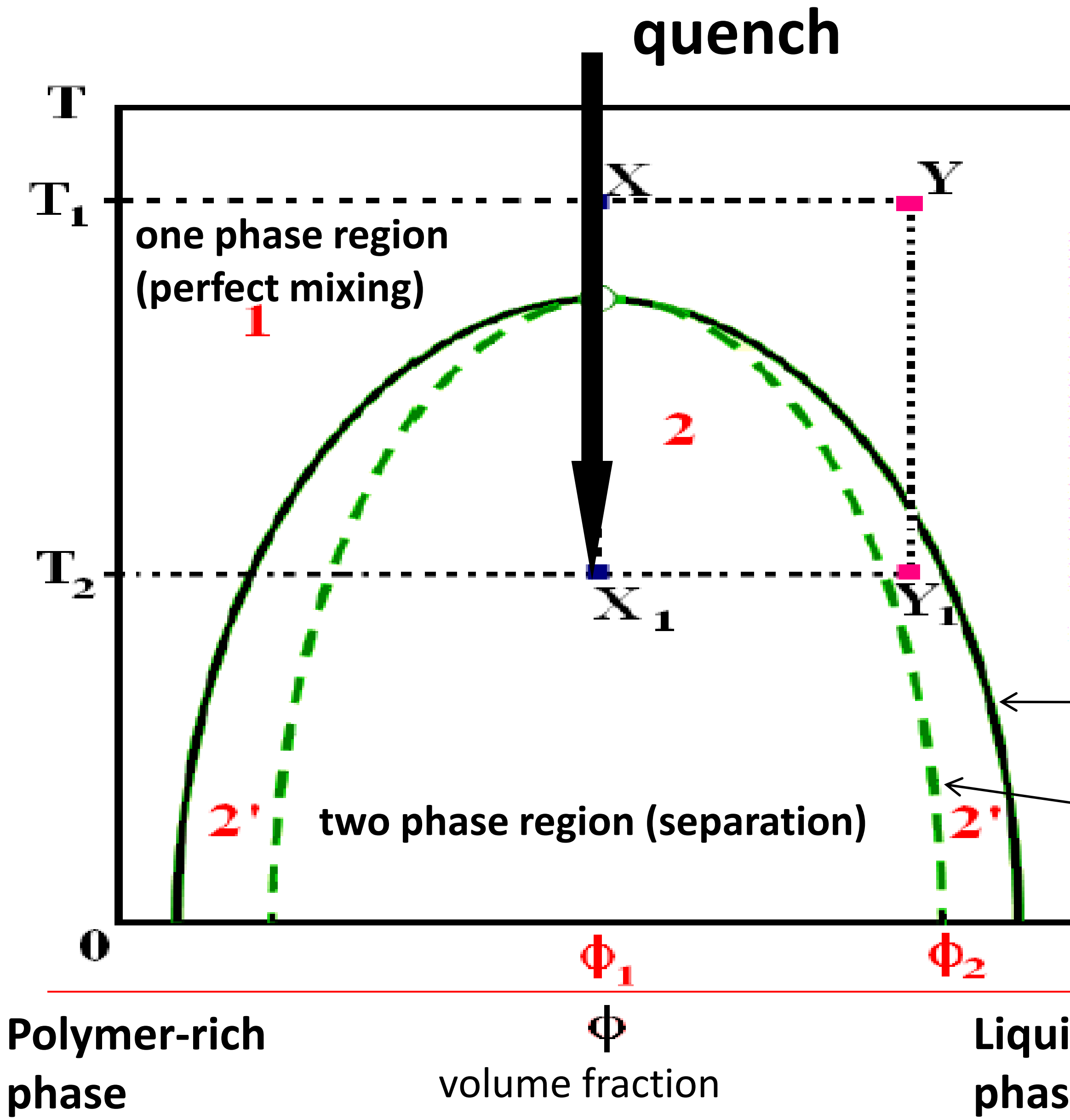


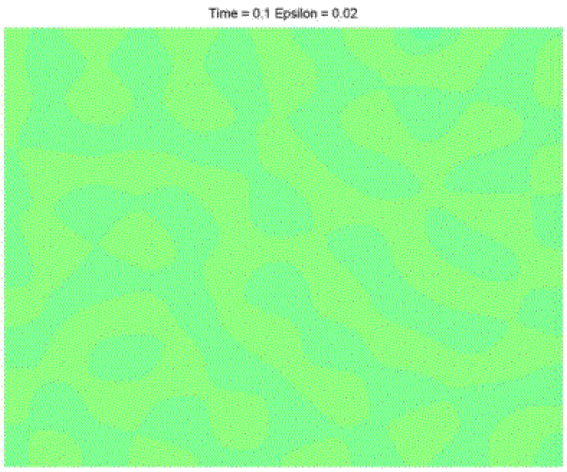
PDLCs were invented at Kent State University in 1983.



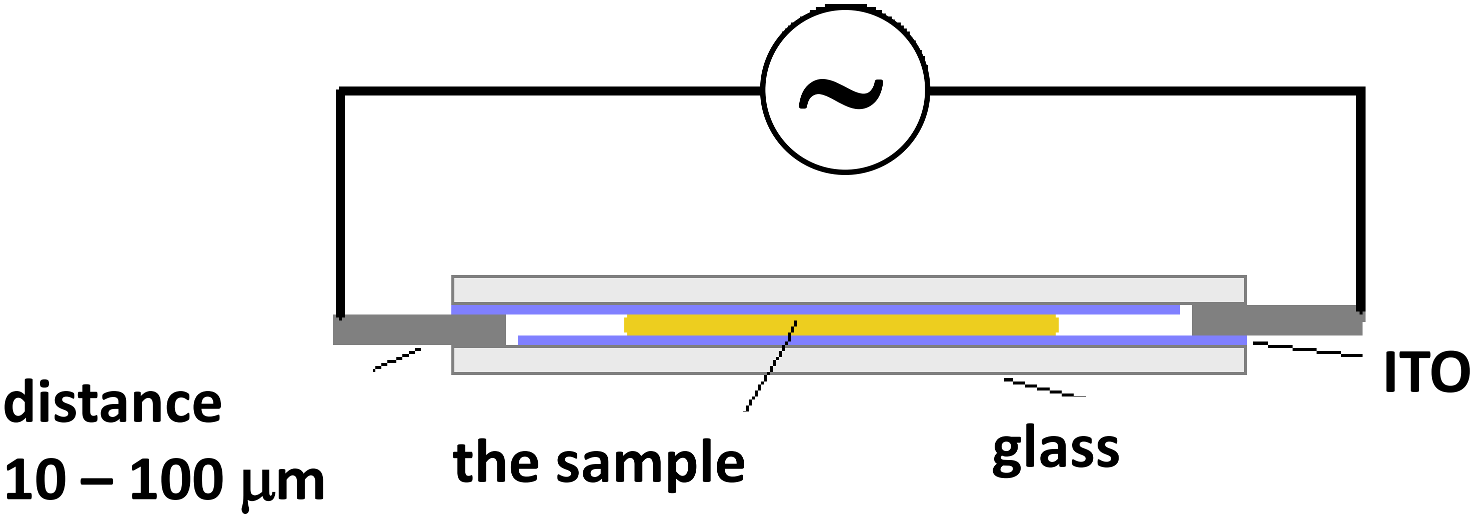


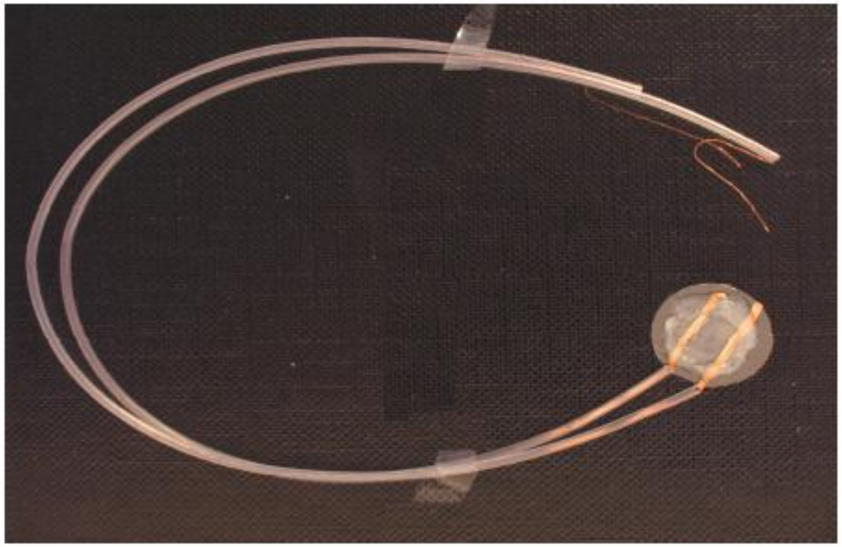
phase separation in polymer & liquid crystal blend



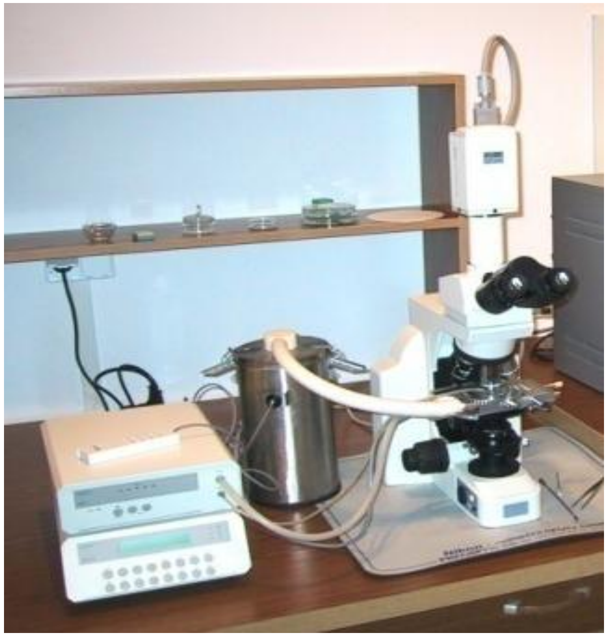


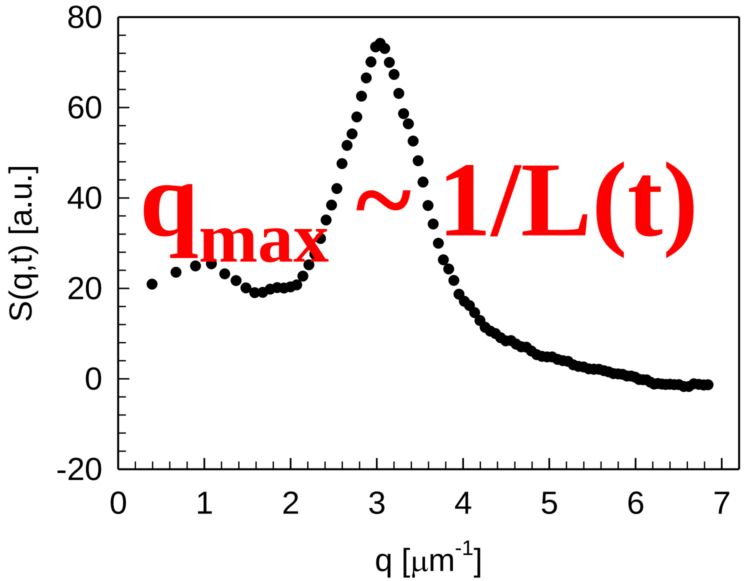
phase separation in polymer & liquid crystal blend

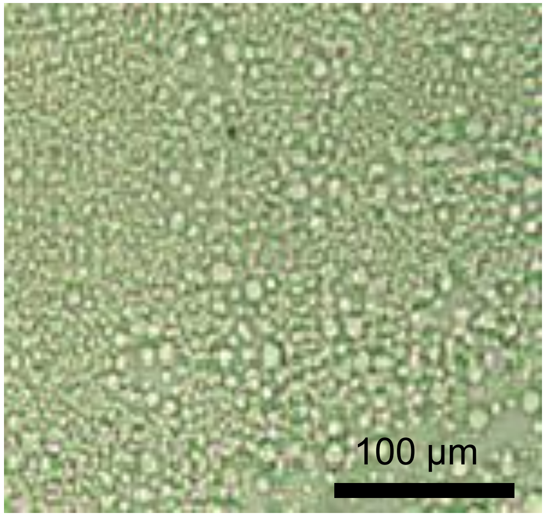




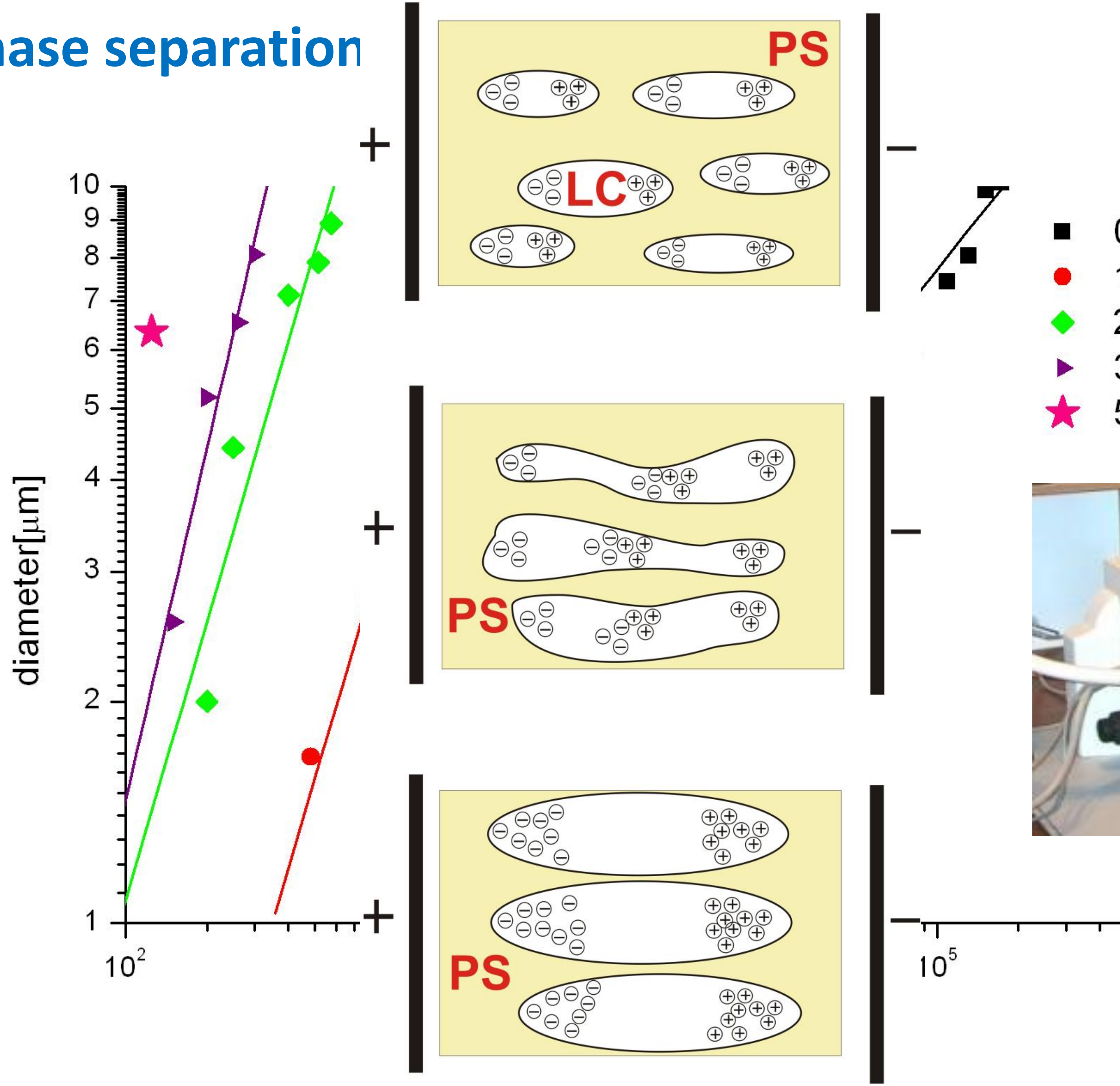
phase separation in polymer & liquid crystal blend



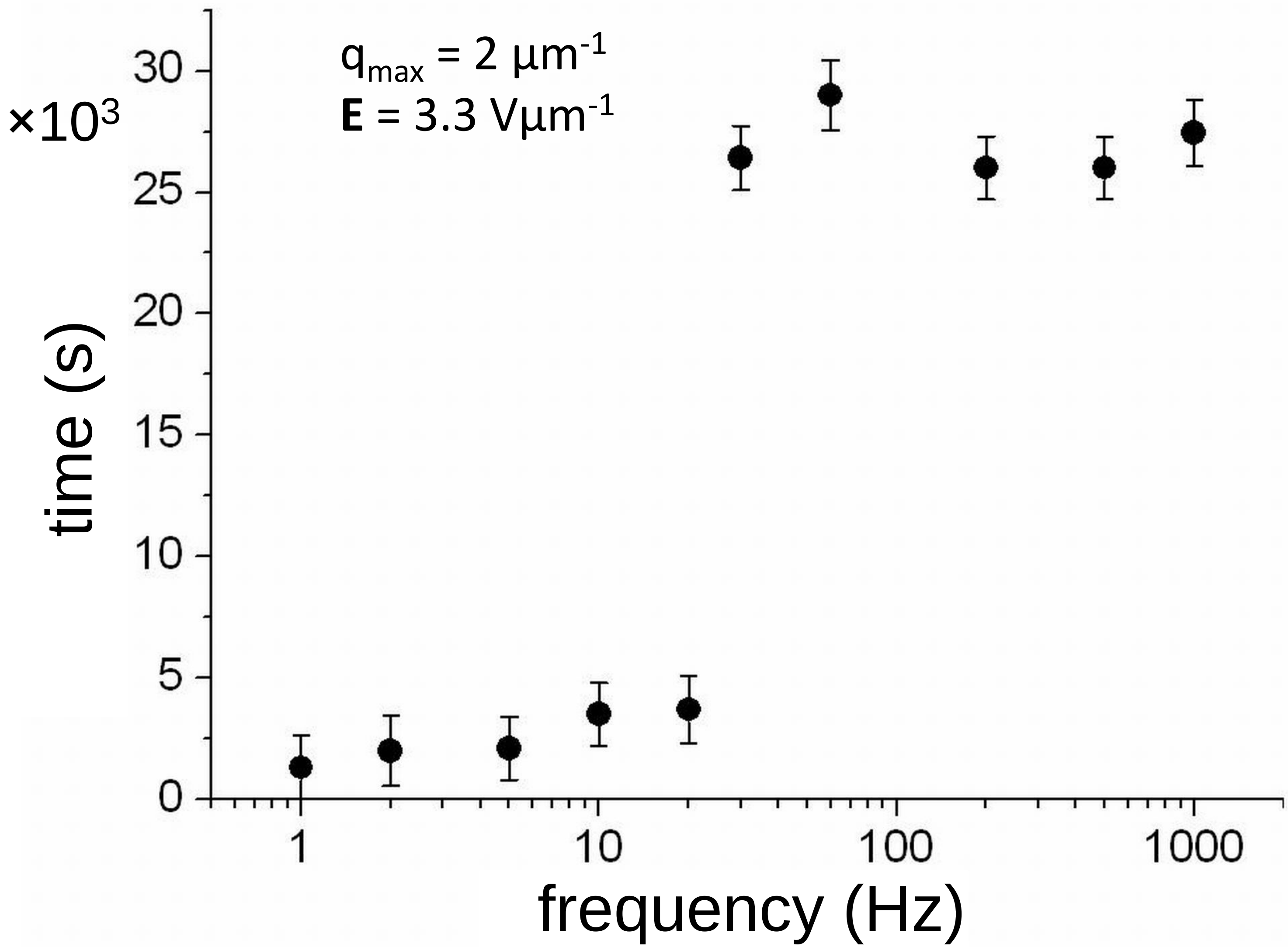




phase separation



phase separation – influence of frequency



- dynamic **separation of charge in LC**

  can we see the motion of ions with an optical microscope?

- **phase separation in a blend of LC and PS**

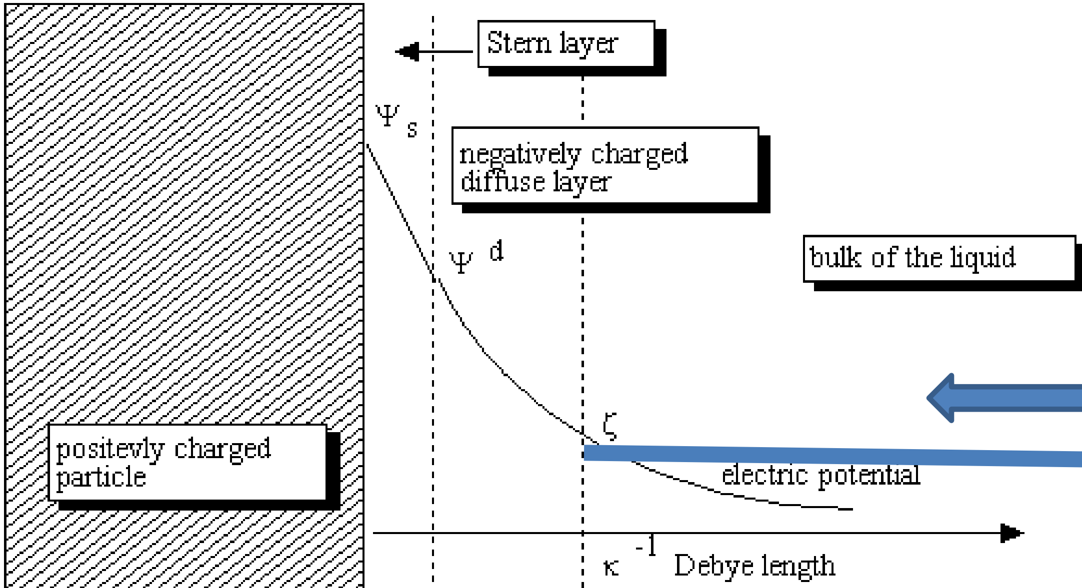
  1000 fold increase of the rate of phase separation

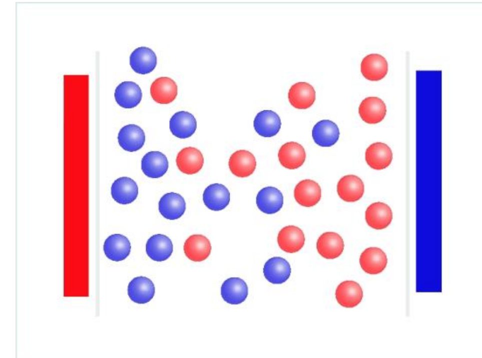
- **electrocoalescence**

  ionic contribution to polarization of droplets

- **summary**

summary





- dynamic **control of the efficiency of screening**
- **separation of charges** at the microscale
- possibility of macroscopic separation *via* other mechanisms
- **uses/applications:**
    - electrocoalescence
    - phase separations
    - electrokinetic transport ?
    - ordering of colloids ?

Thank you!