Nanomaker

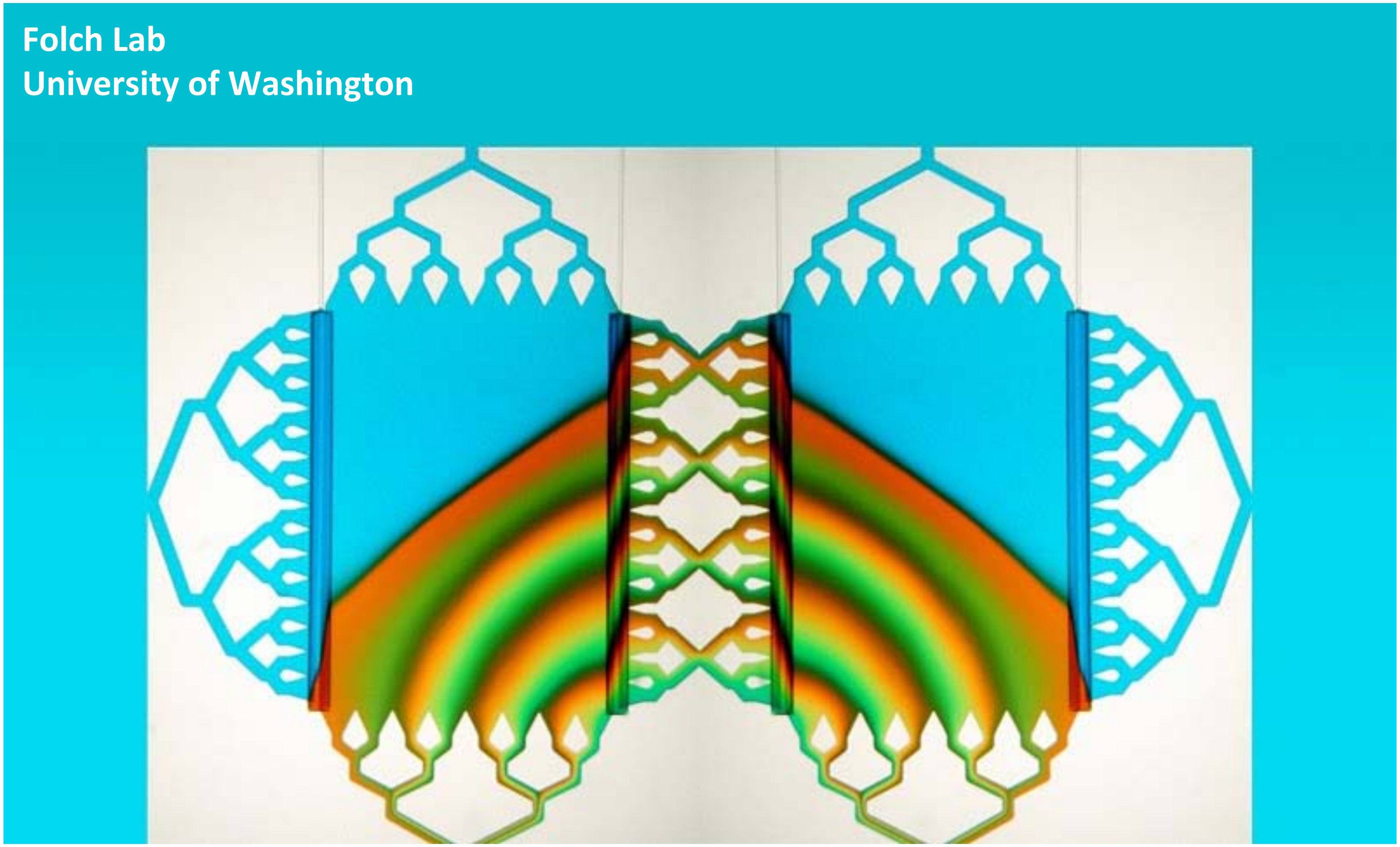
Lab #5: Paper Microfluidics

Microfluidics

Fabrication

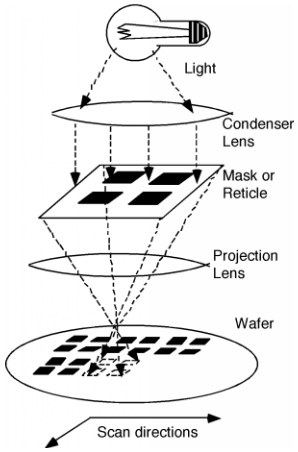
Applications

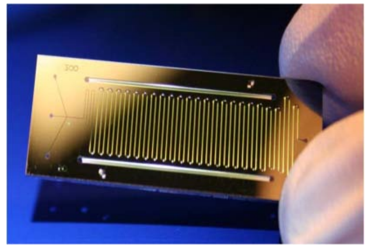
Microfluidics



What are microfluidics? What are they used for? Are they used in any commercial devices?

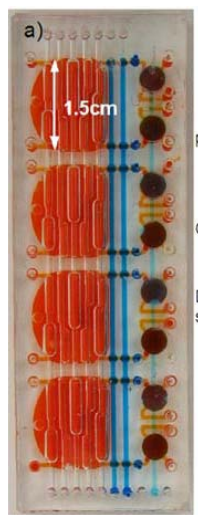
Varieties of Microfluidics



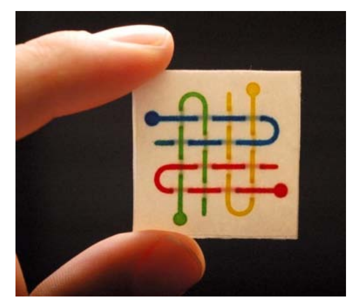


Glass or Silicon microfluidics, patterned using photolithography

Inkjet printed microfluidics in Shrinky Dinks (polystyrene) and Silicone rubber



Milled microfluidics in Polycarbonate



Printed wax microfluidics on filter paper

Microfluidics

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Fabrication Process

Design

Print wax microfluidic channels

Reflow wax on hotplate

Print chemical indicators

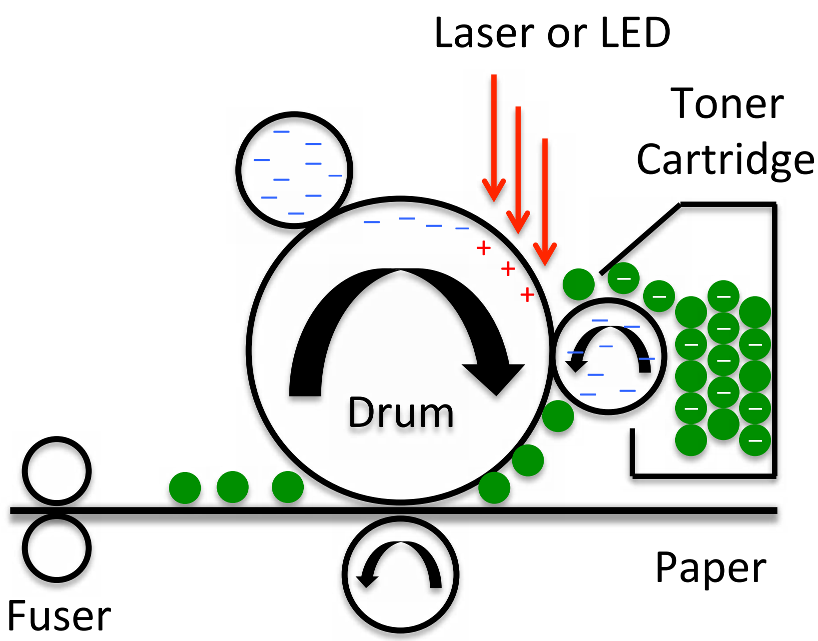
Before heating (wax on surface)

After heating (wax melts and wicks into paper)

Wax wicks into the paper through capillary action and creates a hydrophobic barrier

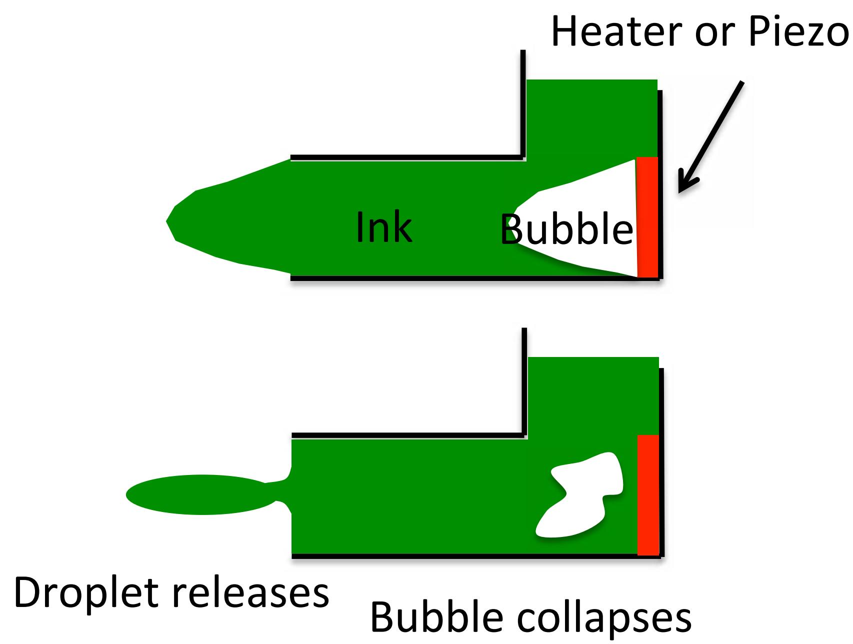
Printer

Laser printer



An electrically charged rotating drum coated with photoconductors, removes charge from the areas exposed to light.

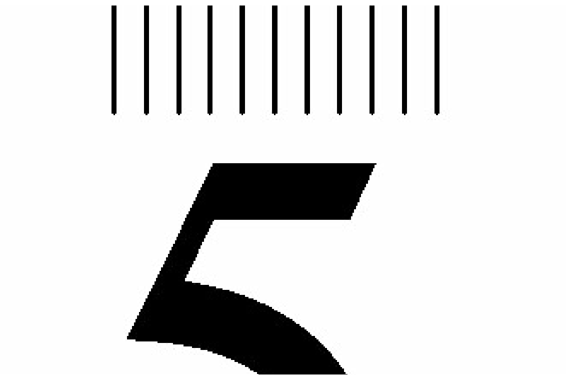
Inkjet printer



A microscopic nozzle creates a continuous stream of ink droplets via creating a bubble by a heater or an acoustic wave by a piezoelectric crystal.

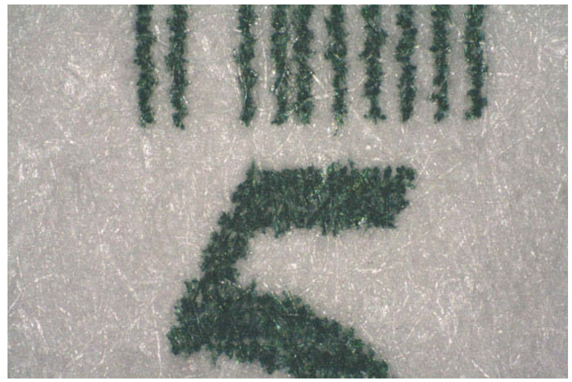
Printer Resolution

Original Image
(Photoshop, 2400dpi)



Linewidth = **30μm**

Inkjet Printout
(Epson Stylus NX110)



Actual Linewidth ~ **100μm**

Wax Printout
(Xerox Phaser 8560)

Actual Linewidth ~ **120μm**

Linewidths Made using Powerpoint

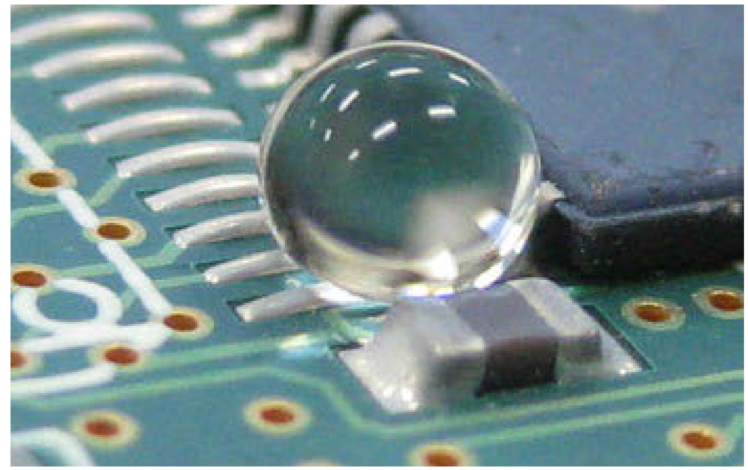
0pt = 100-150μm

0.25pt = 200μm

0.5pt = 300μm

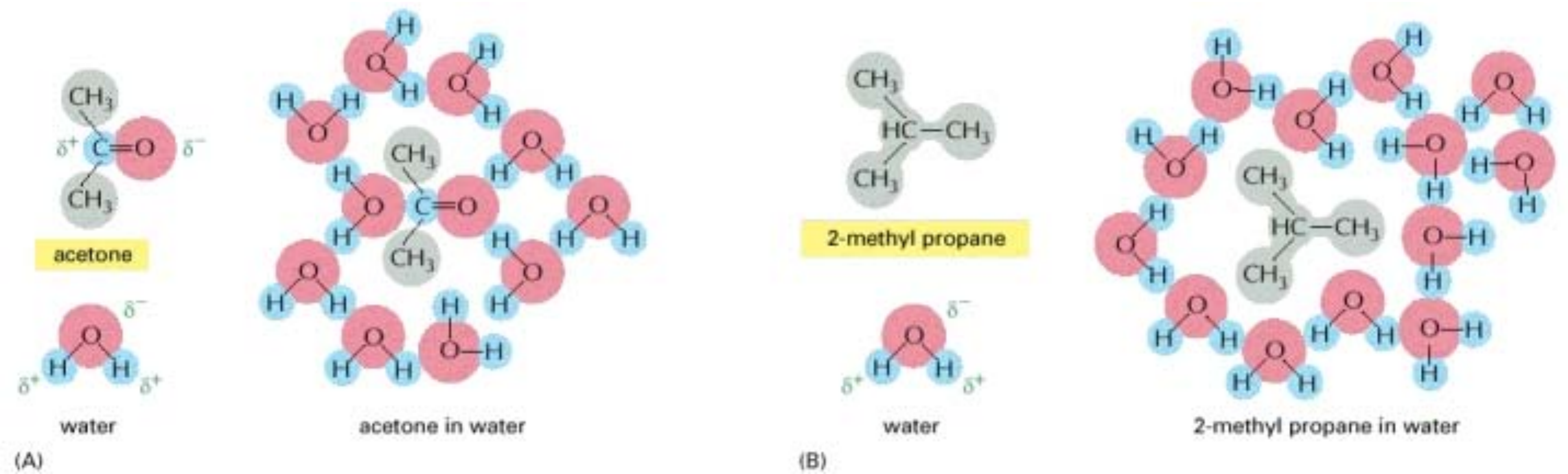
0.75pt = 400μm

Hydrophobicity



Hydrophilic: Hydrogen bonds can form between water molecules and other polar molecules

Hydrophobic: Hydrogen bonds do not form between water molecules and nonpolar molecules



Hydrophilic or Hydrophobic?

Lotus leaf | Glass | Soap

Can you change hydrophobicity?

Diagram of Wenzel and Cassie-Baxter states removed due to copyright restrictions. Refer to image on Wikimedia Commons.

If the solid surface is rough, and the liquid is in intimate contact with the solid asperities, the droplet is in the Wenzel state. If the liquid rests on the tops of the asperities, it is in the Cassie–Baxter state.

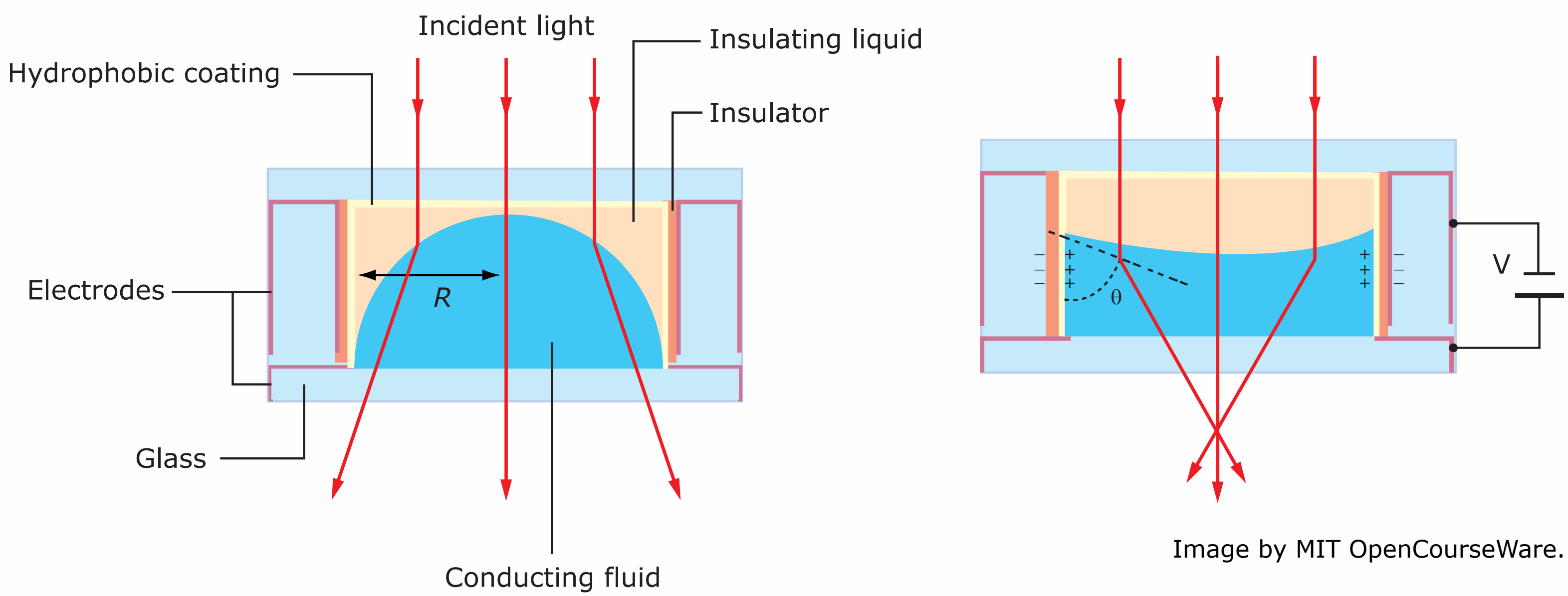


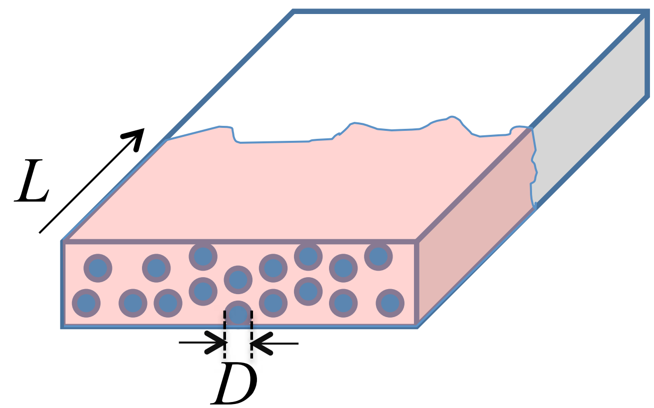
Image by MIT OpenCourseWare.

In an electrowetting-based optofluidic lens (left), the application of a voltage alters the solid-liquid interfacial tension, and with that the contact angle (right)

Capillary Action

Both Water and Wax on the Filter Paper are Driven by Capillary Action

$$L = \left(\frac{\gamma D t}{4\eta}\right)^{\frac{1}{2}}$$



Low viscosity (η) liquids with large surface tension (γ) will wick quickly in porous materials over time (*t*). Heating the wax lowers its viscosity.

Photograph of oil lamps removed due to copyright restrictions.

Oil lamps made from old incandescent light bulbs. Capillary action allows oil to flow up the wick.

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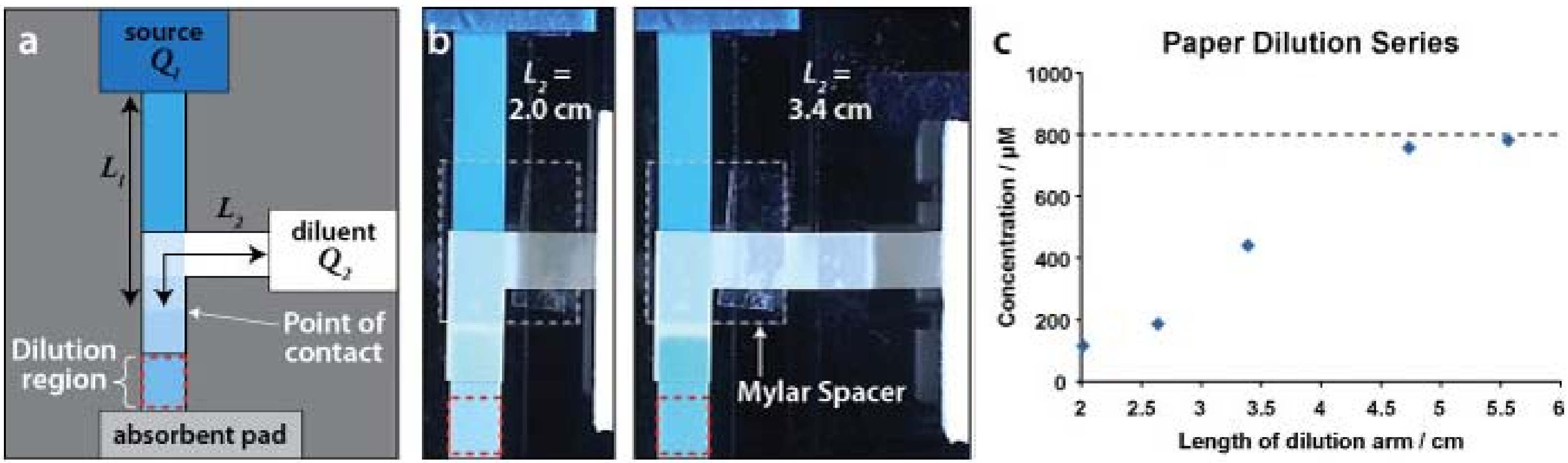
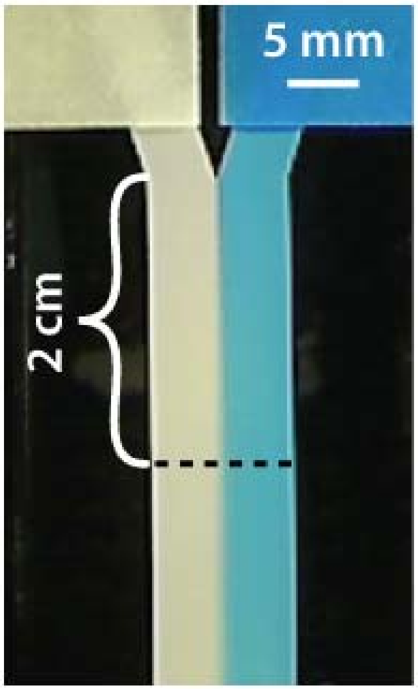
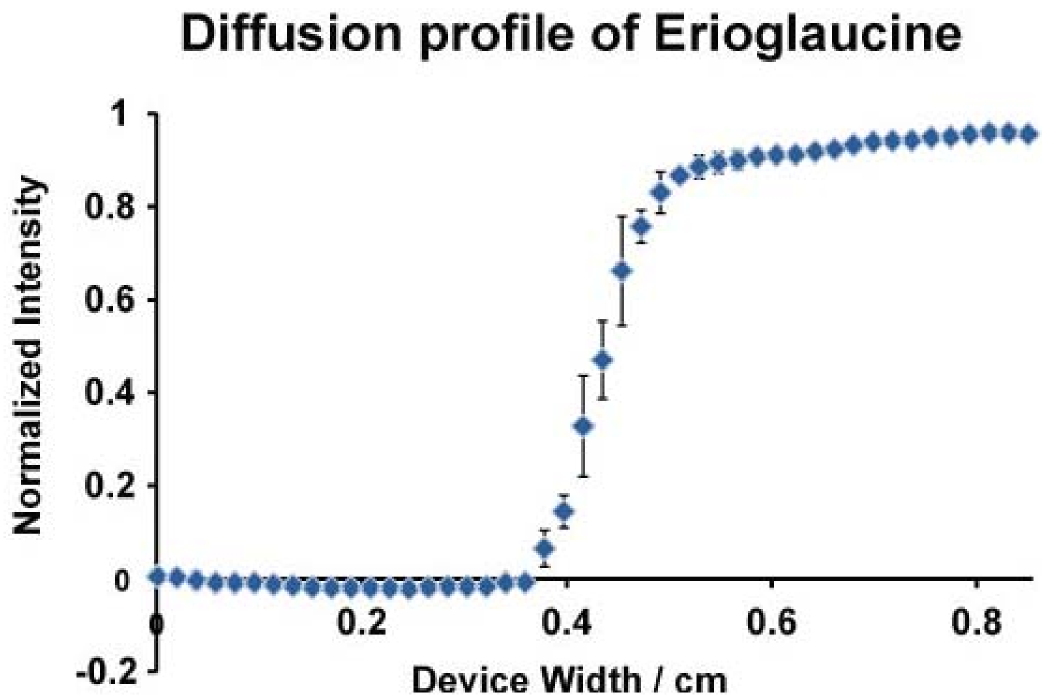
Dilutions



A sample can be diluted accurately by controlling the relative addition of sample and diluent. By modifying the relative resistance of two inlet channels (in this case, by the length of each channel arm) their relative contribution can be controlled, allowing the creation of a dilution circuit.

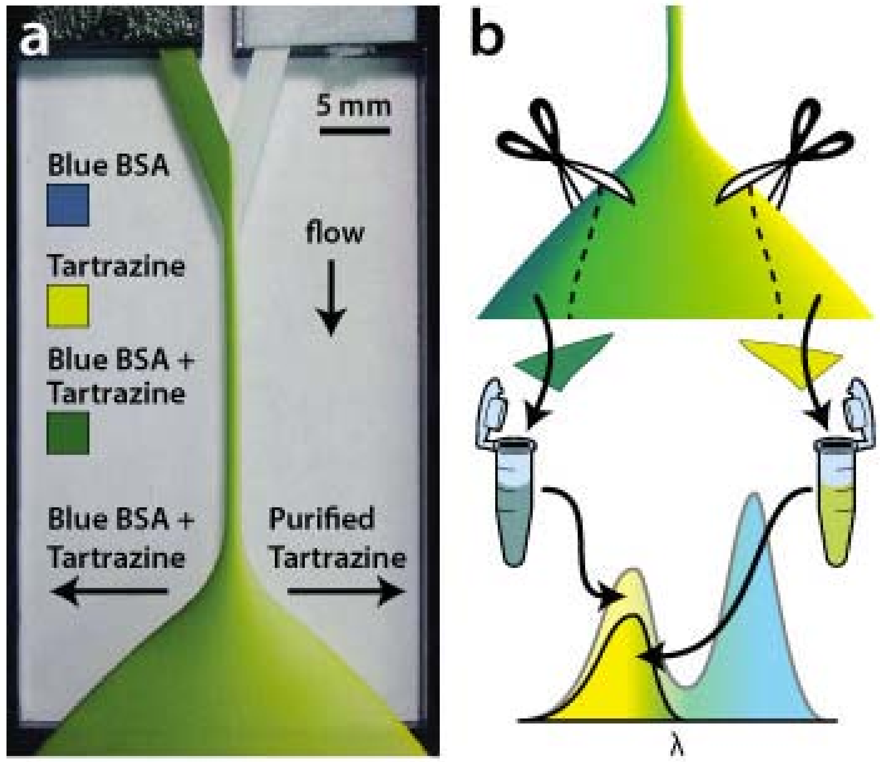
Diffusion-Based T Sensor





As two flow streams run parallel to one another, molecules from each stream diffuse across the fluid interface. The extent of the spreading depends on a variety of factors, allowing molecules of interest to be identified by the concentration profile of visible solution components across the flow streams.

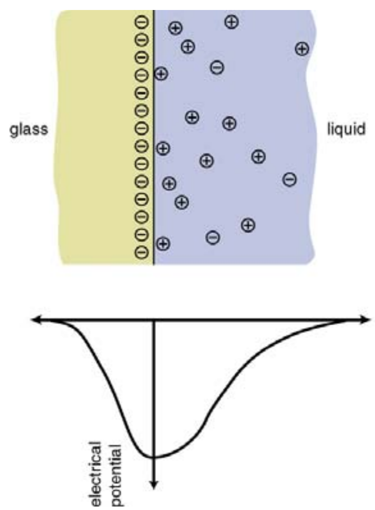
H-Filter



The paper H-filter was used it to separate a small molecule (yellow dye) from a large molecule (blue protein). The yellow extract was recovered by simply cutting out the yellow part of the 2DPN outlet. Paper H-filters could be used to extract analytes from complex samples for downstream analysis.

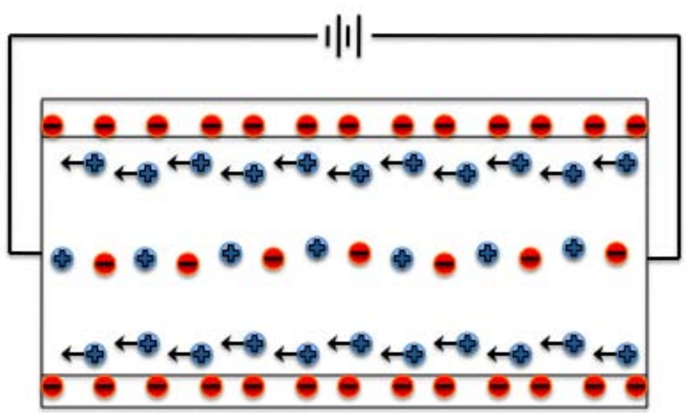
Electroosmotic

The glass/water interface



- SiOH molecules at surface of glass react with $(OH)^-$ ions in water, negatively charging the surface of the glass
- Free H^+ ions in the water are attracted to the negatively charged glass surface .
- The tail of the layer of H^+ ions is free to move under the influence of an applied E-field

Example: Electroosmotic pump in glass capillary



- Applying a voltage across a glass capillary will cause the H^+ ions at the interface to move to a lower potential
- The ions will drag the water in the center of the channel with them

Medical Devices

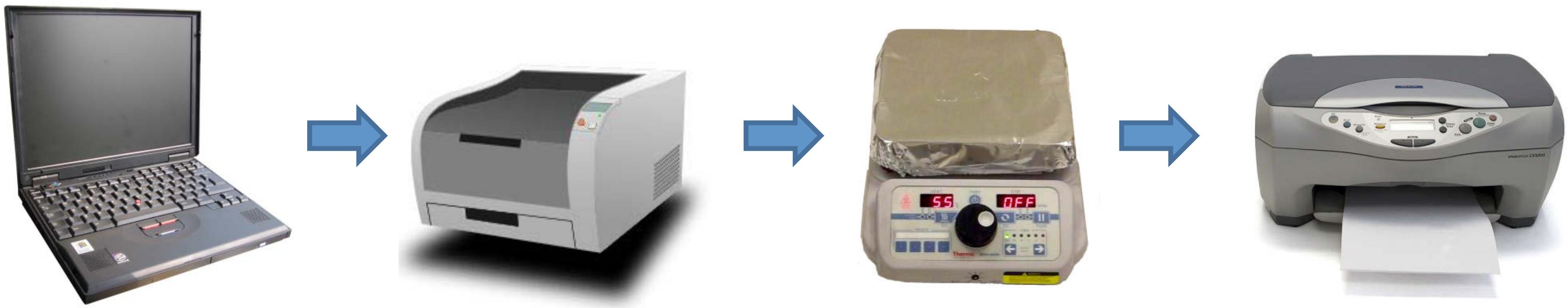
Photographs of μPADs removed due to copyright restrictions.

Refer to: Fig. 1C, 3C, and 3D from Martinez, A. W., S. T. Phillips, et al. "Diagnostics for the Developing World: Microfluidic Paper-Based Analytical Devices." *Analytical Chemistry* 82 (2010): 3-10.

Conclusions

Hydrophobicity

Capillary Action



Images of laptop and printers are in the public domain.

Surface Heterogeneity

Diagram of Wenzel and Cassie-Baxter states removed due to copyright restrictions. Refer to image on Wikimedia Commons.

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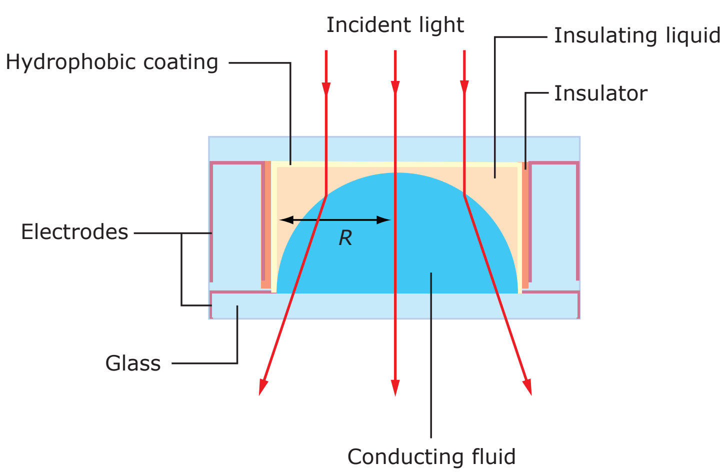
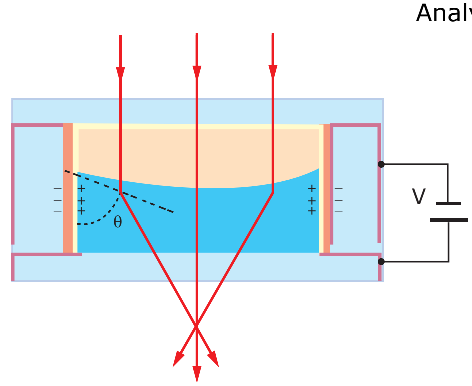
Refer to: Fig. 1C, 3C, and 3D from Martinez, A. W., S. T. Phillips, et al. "Diagnostics for the Developing World: Microfluidic Paper-Based Analytical Devices." *Analytical Chemistry* 82 (2010): 3-10.

Electrowetting





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