

Microfabrication: Soft Lithography

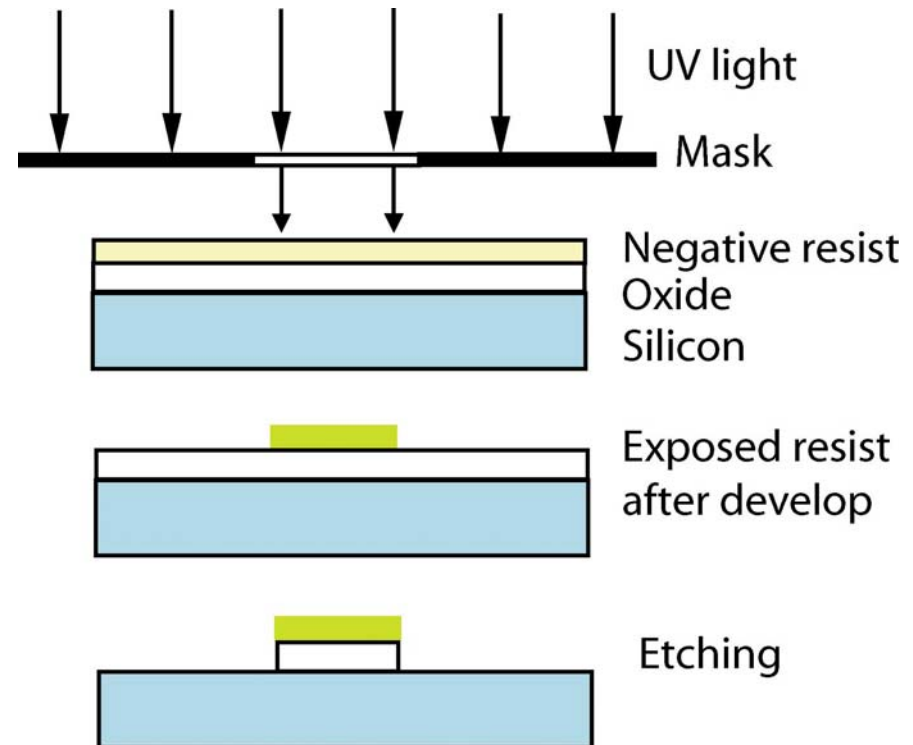
Recall: Lithography

- Lithography is the process by which the geometric patterns are transferred from a reticle to the substrate surface
- Photo lithography
- X-Ray lithography
- E-beam writing
- Focused ion beam writing

Microfabrication: Soft Lithography

Photo Lithography

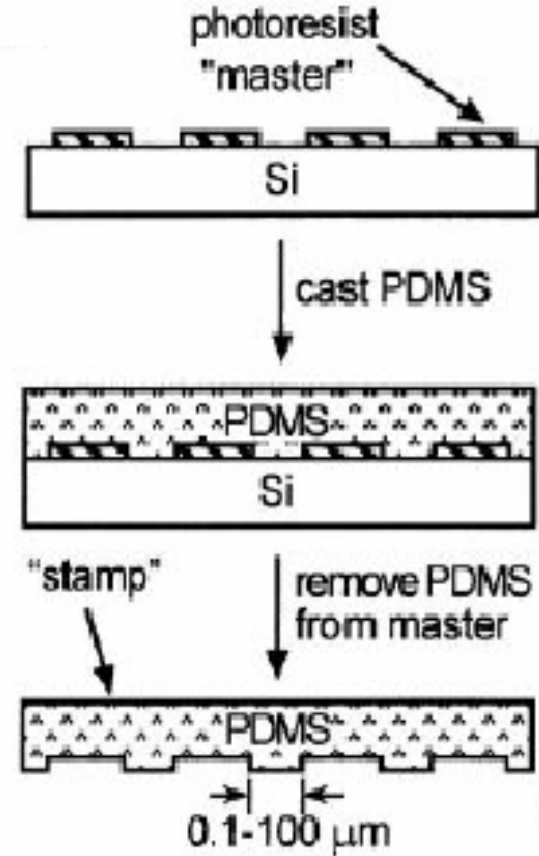
- Photolithography is an optical means for transferring patterns onto a substrate. It is essentially the same process that is used in lithographic printing
- Patterns are first transferred to an imagable photoresist layer



Microfabrication: Soft Lithography

Soft Lithography

Recent advances in micrometer-scale patterning and molding of “soft” materials, typically polymers, have allowed the efficient and inexpensive production of intricate microstructures



G.M. Whitesides, et. al, "Soft lithography in biology and biochemistry,"
Annual Review of Biomedical Engineering, Vol.3, pp. 335-373, 2001.

Soft Lithography: Materials

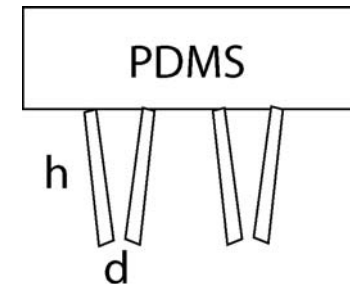
The Key Element of Soft Lithography

- An elastomeric block with patterned relief structures on its surface is the key to soft lithography. This elasticity is why these techniques are called "soft"
- PDMS (PolyDiMethylSioxance) elastomers is widely used
 - silicon rubber
 - PDMS are fluid at room temperature
 - Solidify when mixing with cross-link agent

Soft Lithography: Materials

The Key Element of Soft Lithography

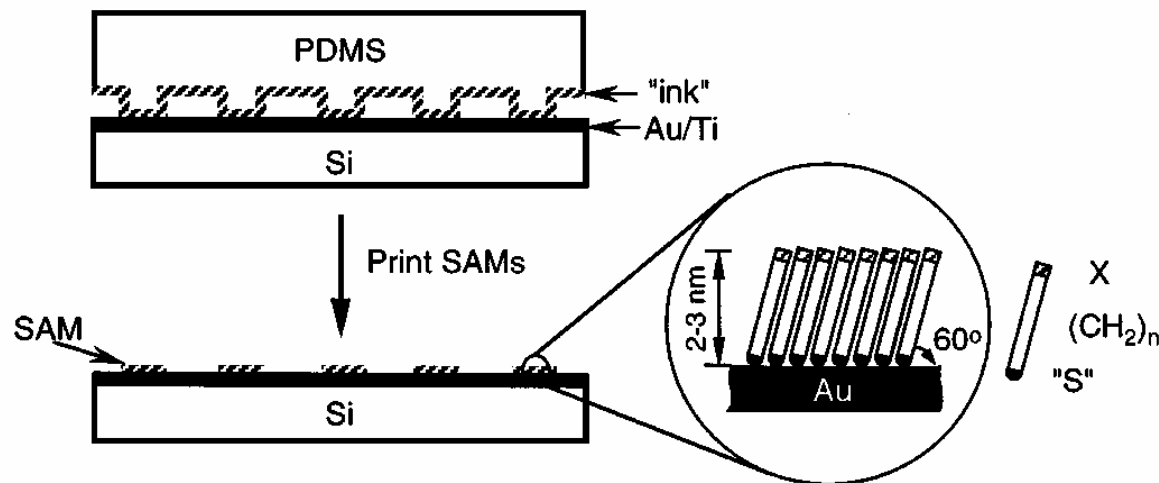
- PDMS properties:
 - Soft, make conformal contact with surface
 - Chemical stability
 - Thermal stability, up to 186 °C in air
 - Not swell due to humidity
 - Optically transparent
 - Isotropic and homogeneous
- Technical problems
 - Thermal expansion after curing
 - Small aspect ratio



Soft Lithography: μ Contact Printing

How To Use Patterned PDMS for Lithography?

- Microcontact Printing: Use the PDMS as a stamp to form patterns of monolayers on the substrate
 - Ink: Bio-chemical molecules, for example, single-stranded DNA



Y. Xia and G.M. Whitesides, "Soft lithography"
Annual Review of Material Science, Vol.28, pp. 153-184, 1998

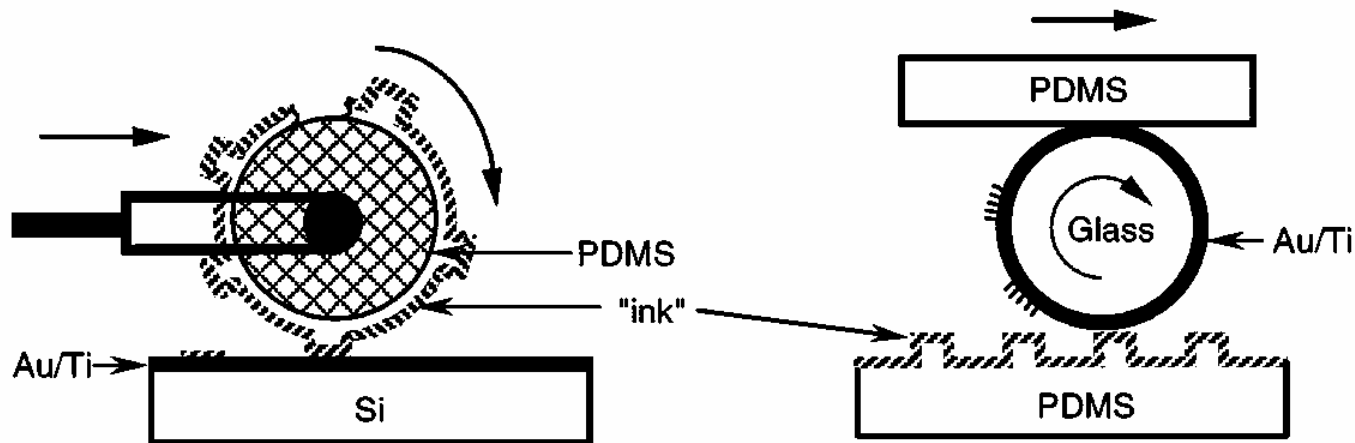
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Soft Lithography: μ Contact Printing

Comparing to Photolithography?

- Low Cost: non-expensive PDMS, many PDMS can be molded from the same master
- Flexibility: able to print on non-planar surface

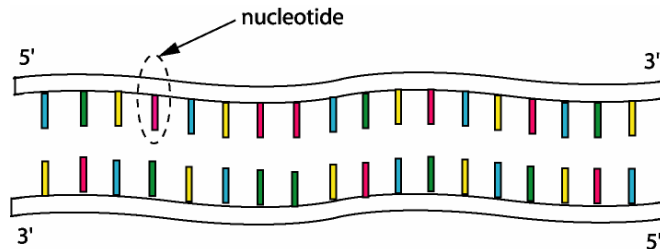


Y. Xia and G.M. Whitesides, "Soft lithography"
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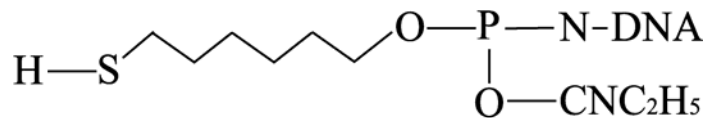
Soft Lithography: μ Contact Printing

Applications: Biosensors

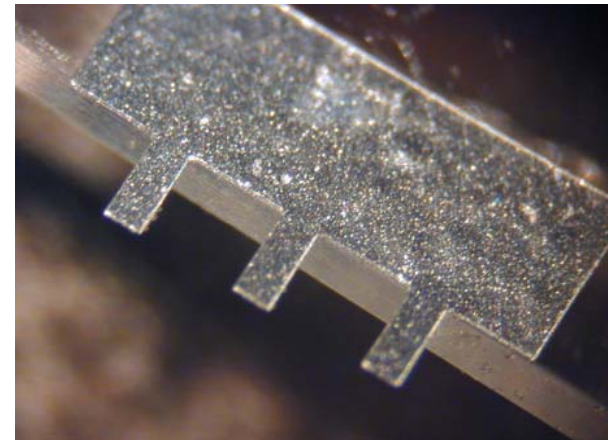
- DNA hybridization detection



Double-stranded DNA



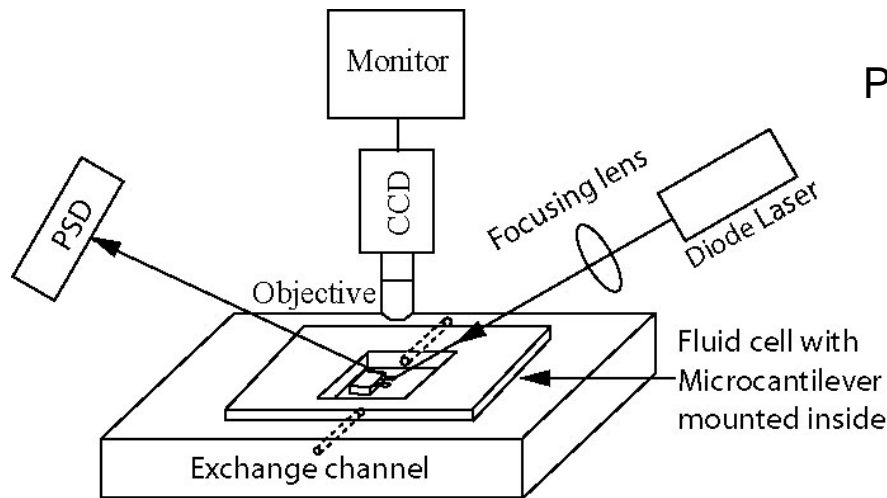
Thiol-modified single-stranded DNA
to be used as probe DNA



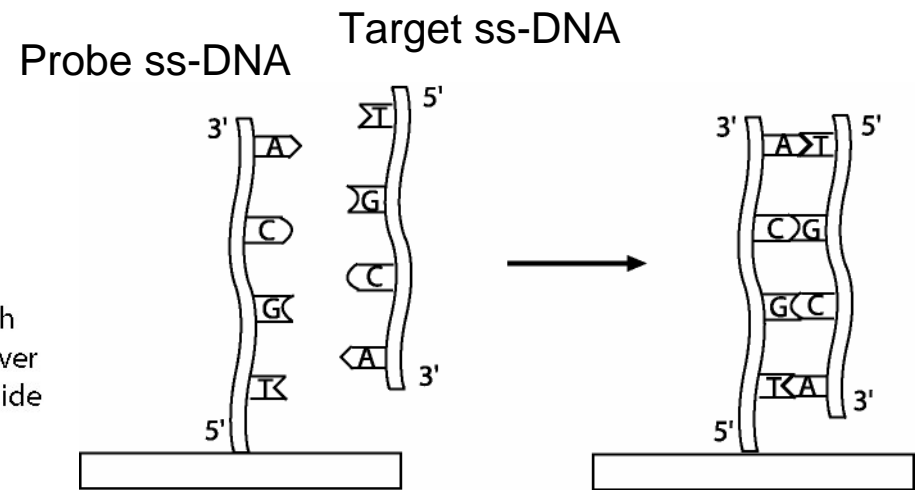
Soft Lithography: μ Contact Printing

Applications: Biosensors

- DNA hybridization detection



Drawing of the assembled biosensor



DNA hybridization

R. X. Zhang and X. Xu, Applied Physics Letters, Vol. 85, pp2423-2426, 2004

Soft Lithography: Microfluidic Channels

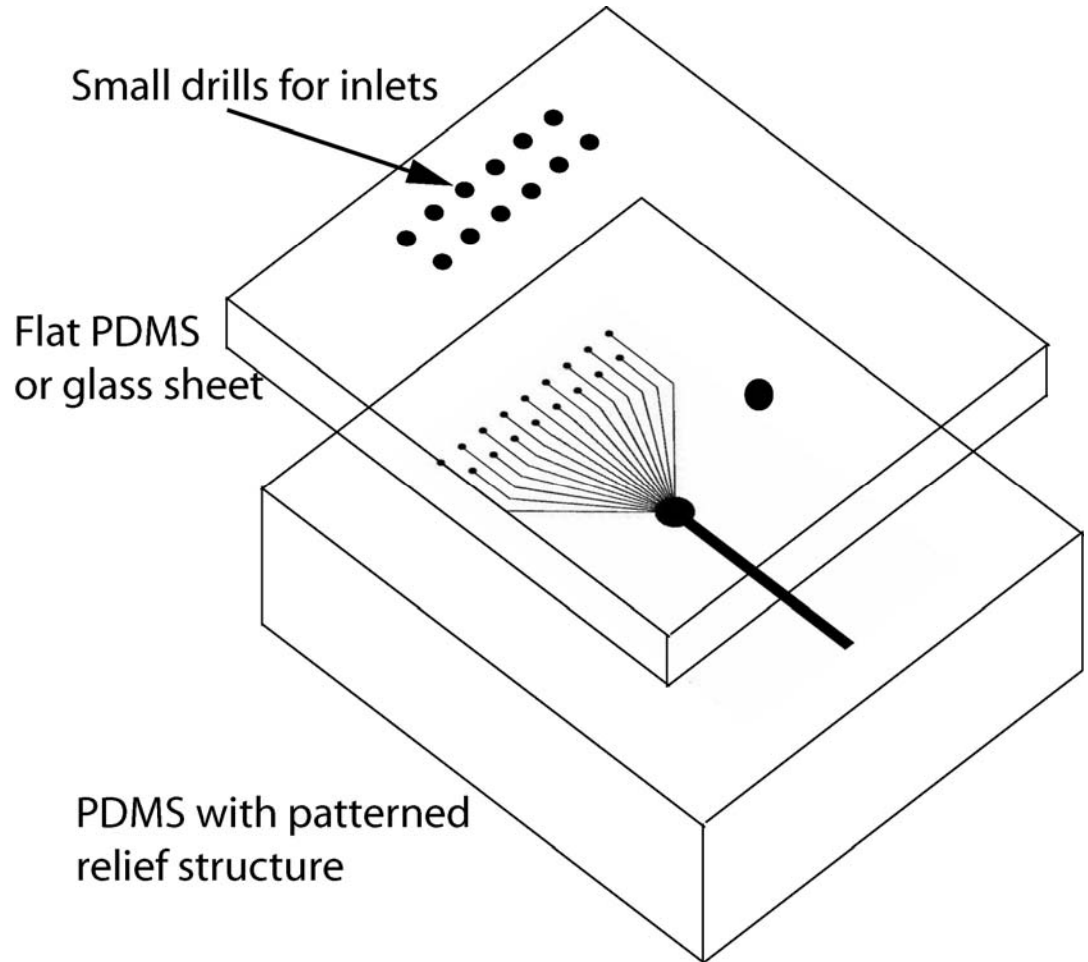
How To Use Patterned PDMS for Lithography?

- Soft lithography is well suited for generating microfluidic channels in PDMS
- Microfluidic channel finds applications in
 - CPU cooling
 - Advanced Chemical instruments
 - Bio-sensors
- PDMS provide an alternative to the materials first used for microfluidic systems, namely, silicon and glass

Soft Lithography: Microfluidic Channels

How to make a microfluidic channel

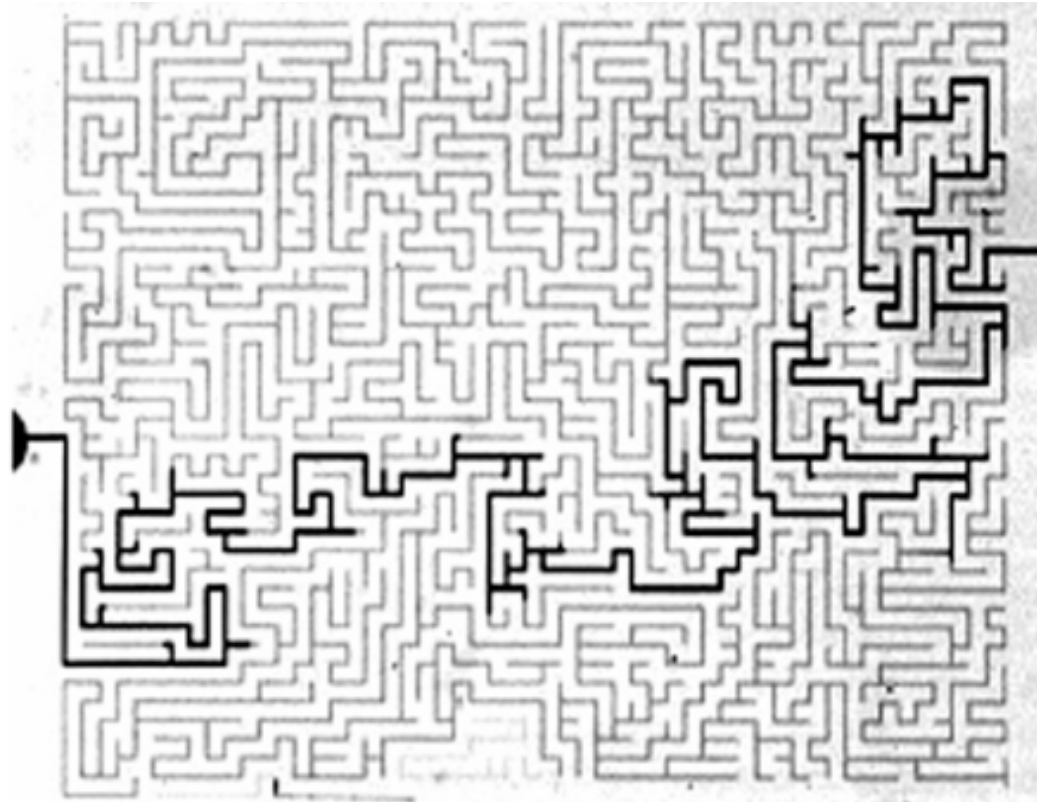
- Example of a micro-mixer
- The PDMS piece is released from the master
- Bond a standard glass slide on top of it



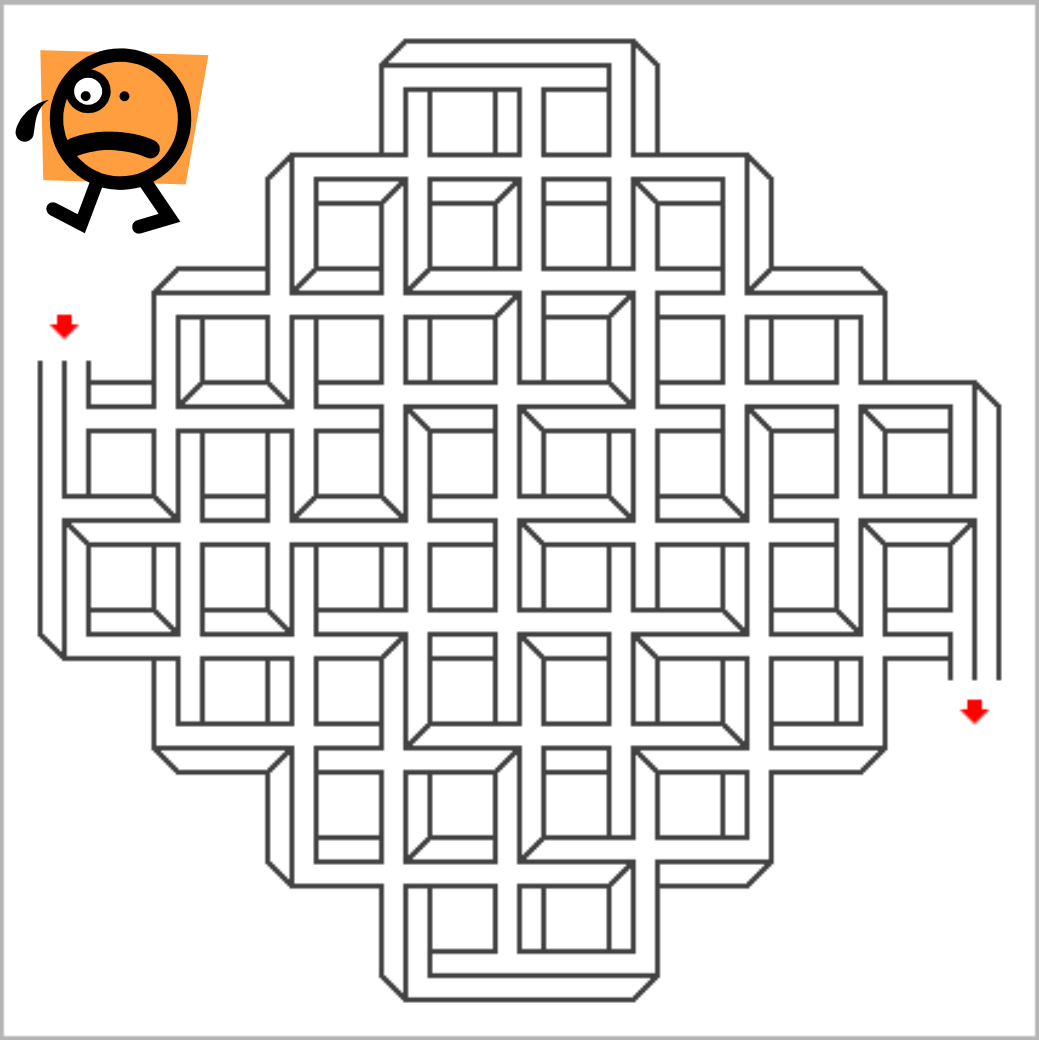
Soft Lithography: Solving Mazes

Michael J. Fuerstman, et al., Solving Mazes Using Microfluidic Networks, *Langmuir* 2003, 19, 4714-4722.

Department of Chemistry and Chemical Biology, Harvard University



Soft Lithography: Solving Mazes

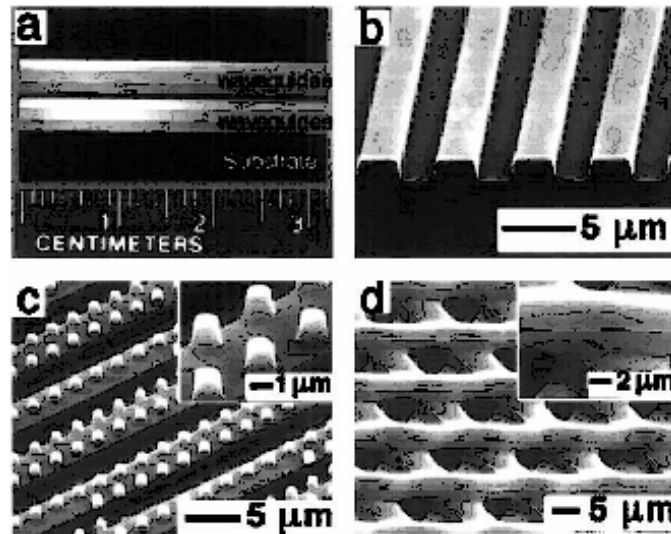


Soft Lithography: Microfluidic Channels

- Typical width of the microchannel: tens of micrometers
- The thickness of the channel is controlled by the the thickness of the photoresist
- The PDMS channels have advantages over silicon or glass microfluidic channels
 - Inexpensive
 - Flexible and durable
 - Simple to prototype
- They have the disadvantage that they are not stable in contact with some organic solvents and at high temperatures.

Soft Lithography: Other Applications

- Replica Molding (REM)
- Microtransfer Molding (μ TM)
- Fabrication of Functional Microelectronic Devices
- Fabrication of Complex Optically Functional Surfaces



Polymeric microstructures fabricated using μ TM