Polymer-based Microfabrication

- PDMS
- SU-8
- PMMA
- Hydrogel

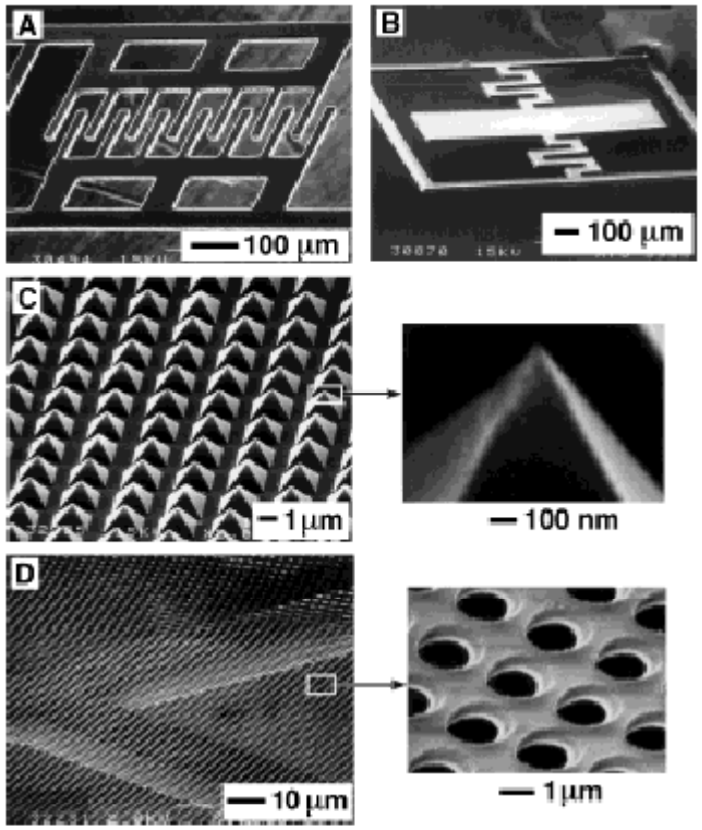
Soft Lithography

- Developed by Whitesides, et. al

  A set of techniques for microfabrication based on the use of lithography, soft substrate materials (PDMS) as a substrate , and molding of polymers

Simple and cheap fabrication

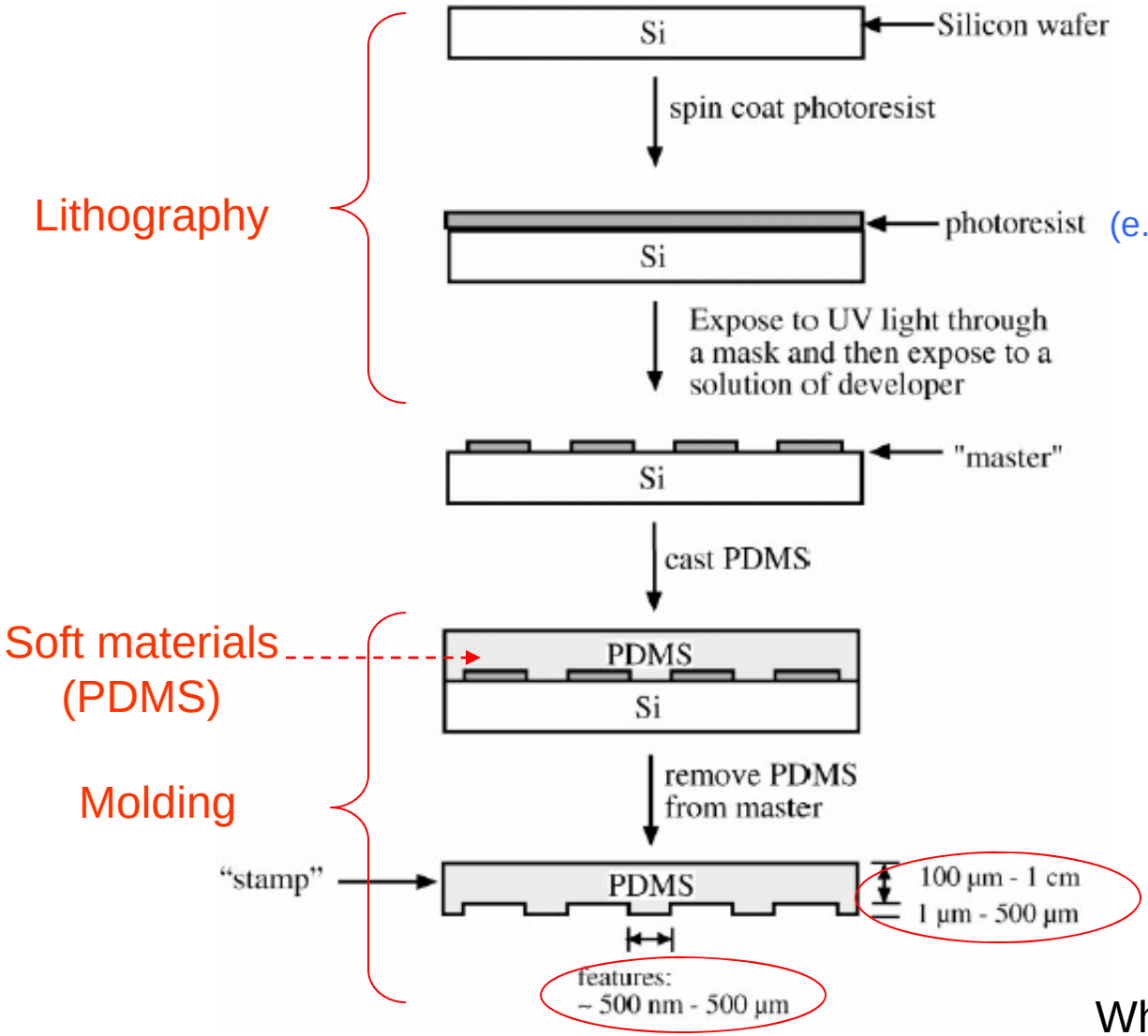
Rapid process for prototyping



- Micromolding
  - Microtransfer molding
  - Replica molding
- Microcontact Printing

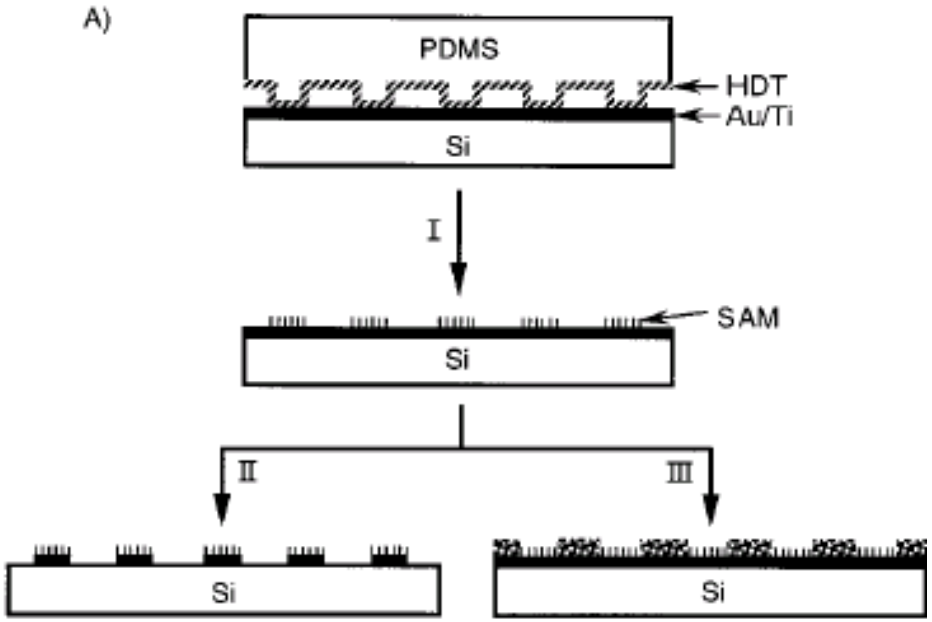
  Monolayer (protein, cells .etc)

Micromolding



Why micromolding ?

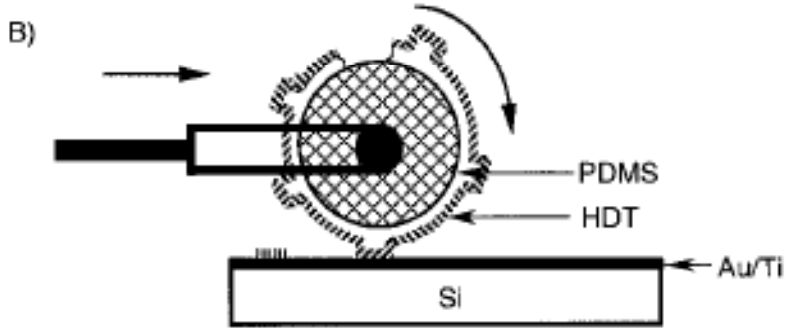
Microcontact Printing

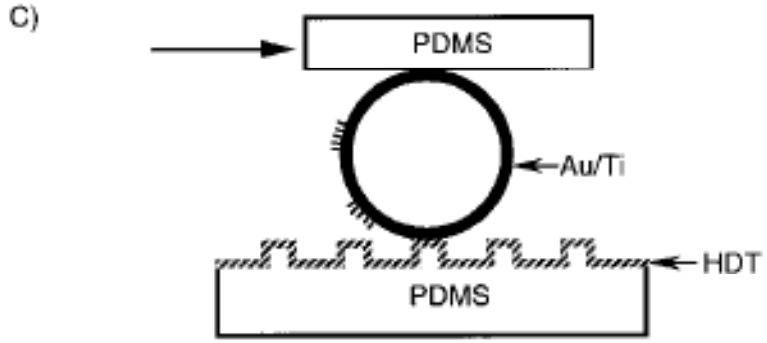


Printing on a planar substrate with a planar PDMS stamp

- Print and pattern a layer of molecules
- Print and pattern probes on microarray

Printing on a planar substrate with a rolling stamp





Printing on a curved substrate with a planar stamp

Microtransfer molding (μTM)

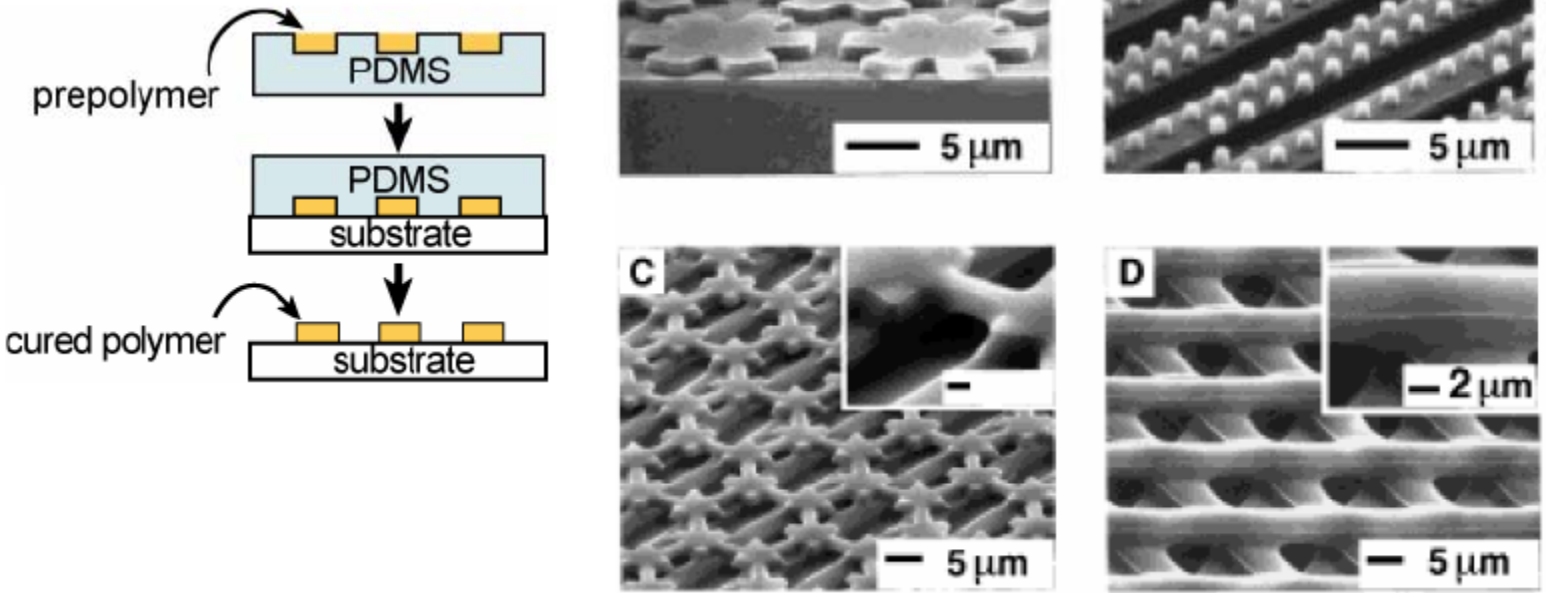


Figure 24. SEM images of polymeric microstructures fabricated by μTM:[36] A) patterned, isolated microstructures of PU on silver (one layer); B) isolated microcylinders of epoxy on 5-μm lines of epoxy supported on a glass slide (two layers); C) a continuous web of epoxy over a layer of 5-μm lines of epoxy supported on a glass slide (two layers); D) a three-layer structures on a glass slide made from a thermally curable epoxy.

Micromolding in Capillaries (MIMIC)

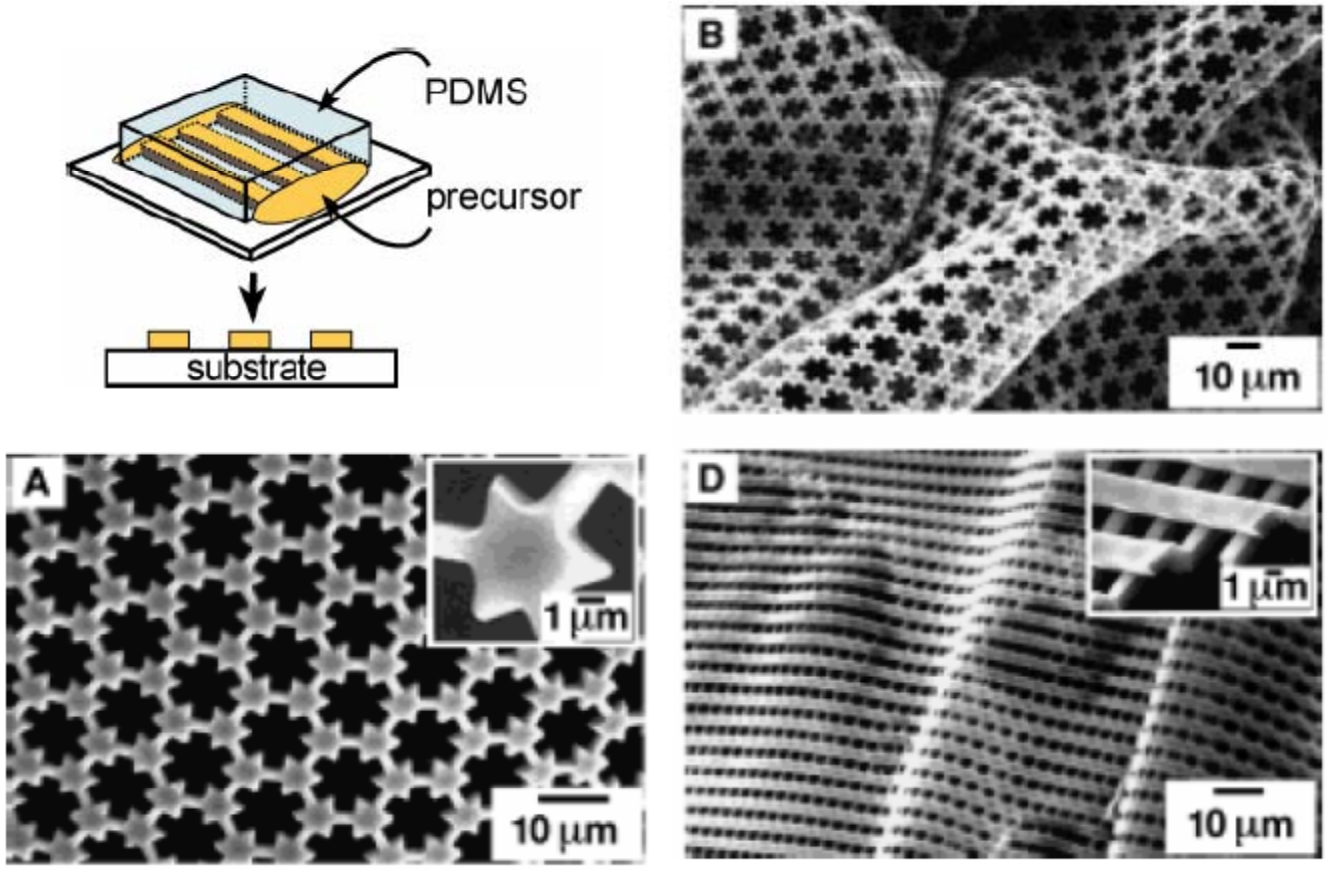
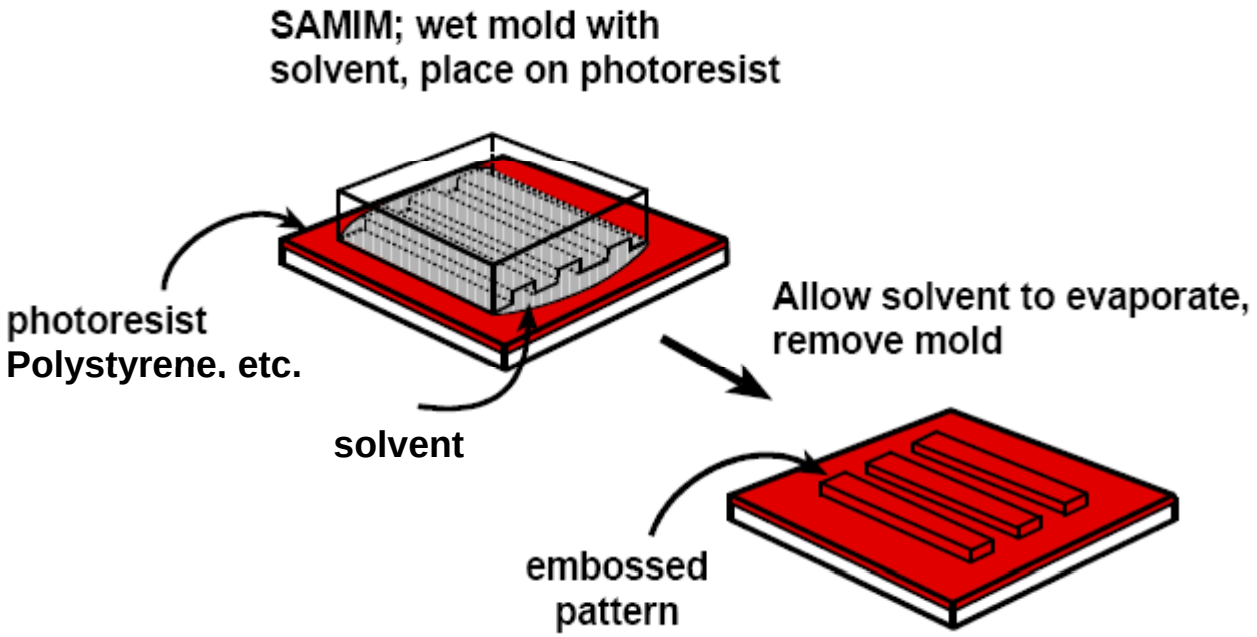


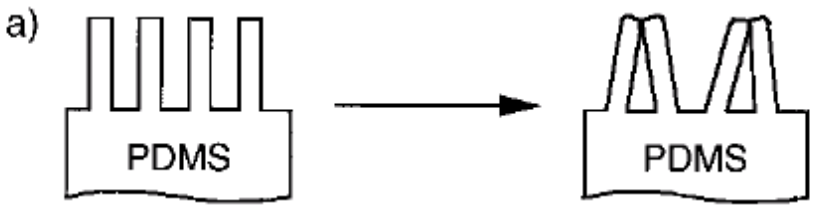
Figure 27. SEM images of polymeric microstructures fabricated by MIMIC from prepolymer of polyacrylate (A, C) and polyurethane (B, D) without solvents.[37, 179] The structures in B and D are freestanding; the buckling occurred during sample preparation and demonstrated their strength.

Solvent Assisted Micromolding (SAMIM)

- PDMS mold is wetted a solvent that can swell the polymer
- Solvent swells/dissolves a thin layer of polymer
- The resulting fluid (gellike Polymer/solvent) conforms the mold pattern
- Solvent evaporates and pattern solidifies



Technical Problems in Soft Lithography

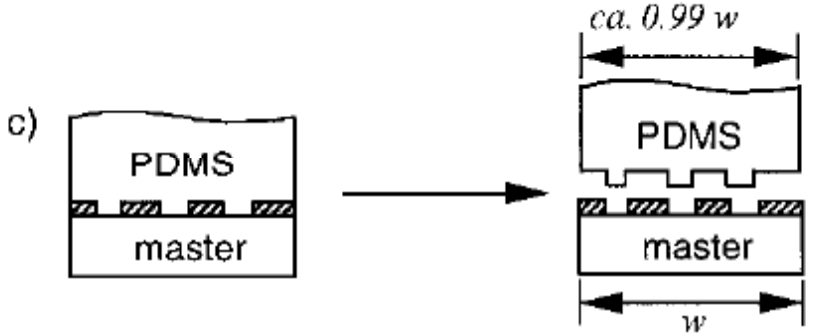


Pairing

- Occurs at high aspect ratio
- Caused by weight and surface tension

Sagging

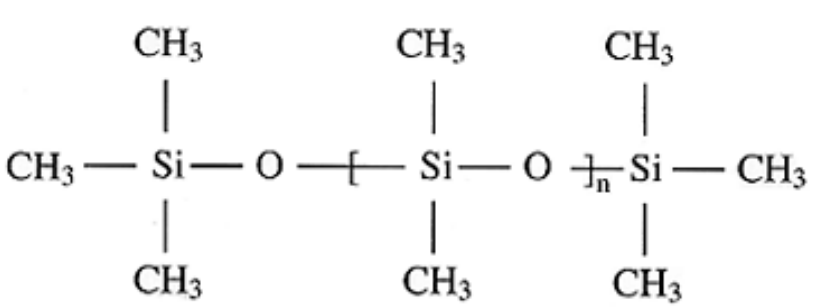
- Occurs at low aspect ratio
- Caused by compression force while inking



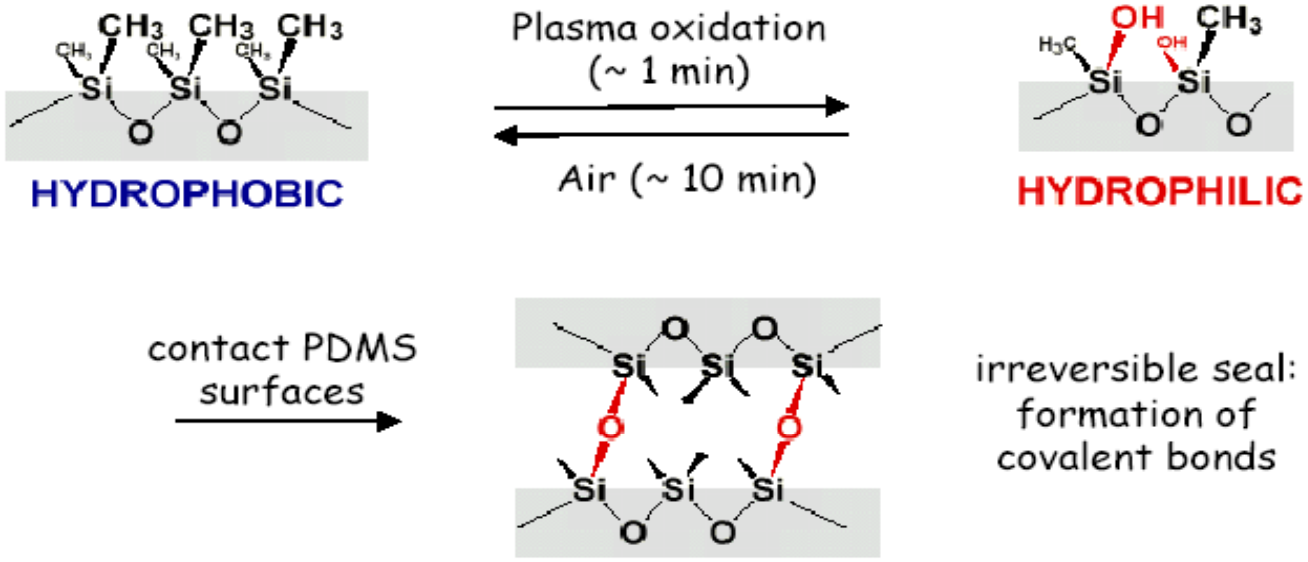
Shrinking / swelling

- Shrinking during curing
- Swelling by nonpolar solvents

PDMS (Polydimethylsiloxane)

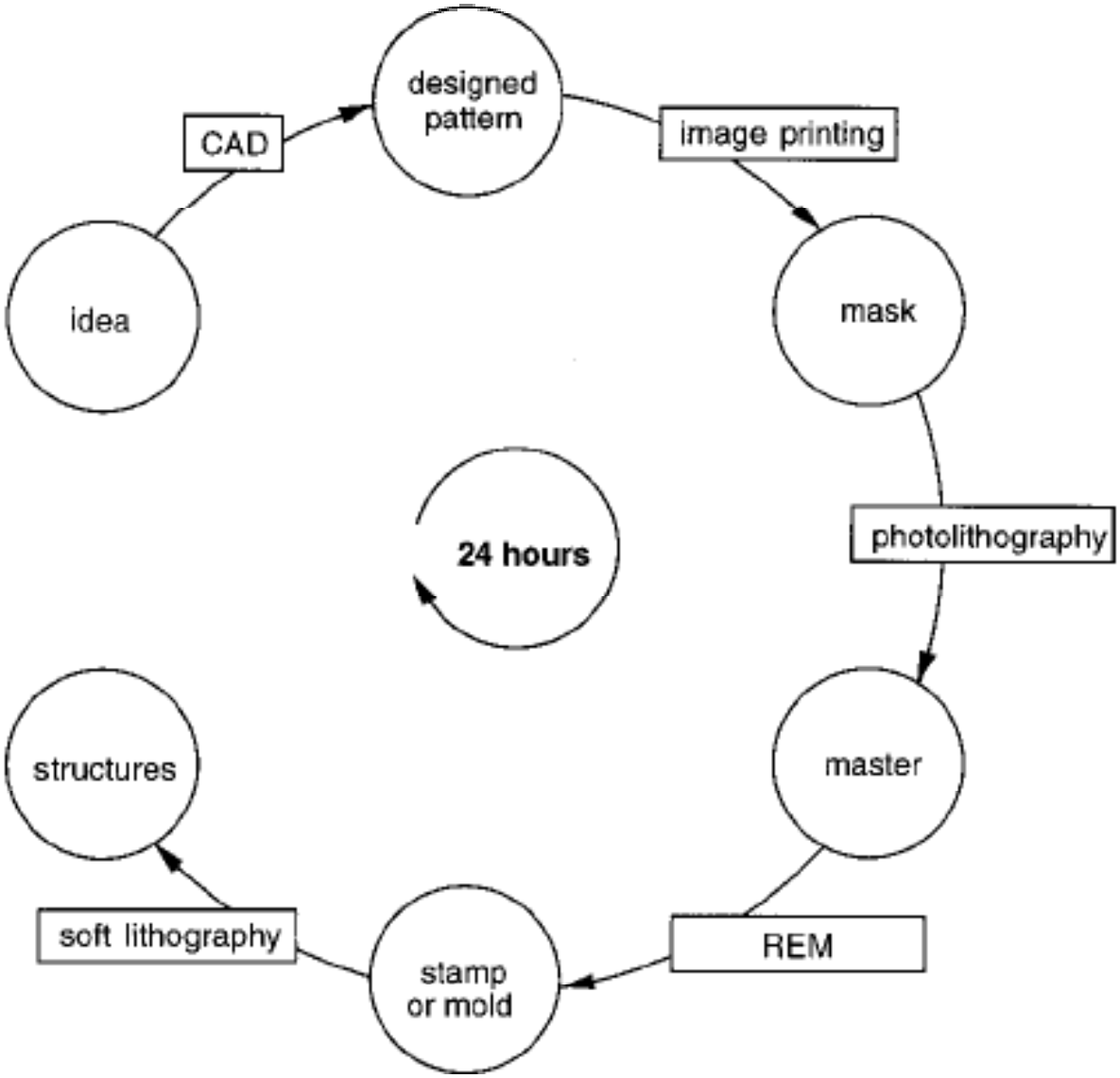


- Deforms reversibly
- Can be molded with high fidelity
- Optically transparent down to ~300nm
- Durable and chemically inert
- Non-toxic
- Inexpensive



- Upon treatment in oxygen plasma, PDMS seals to itself, glass, silicon, silicon nitride, and some plastic materials

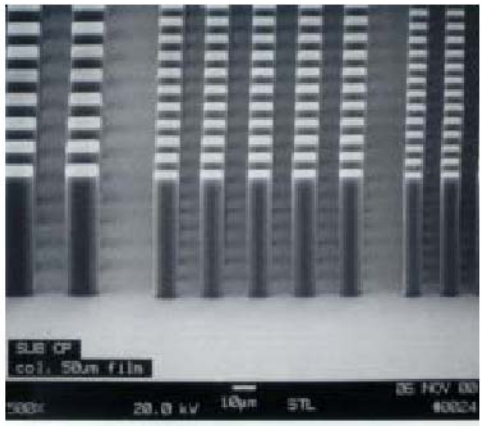
Rapid Prototyping Procedure for Soft-lithography



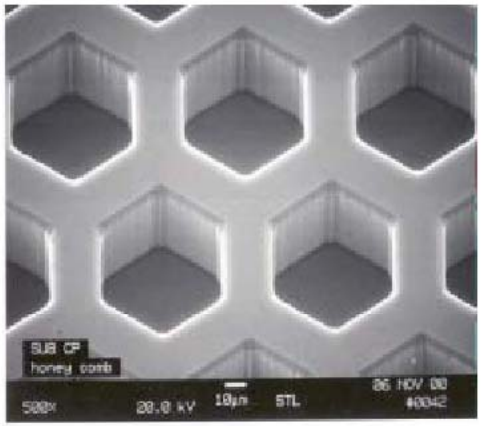
Thick Resist (e.g. Su-8) Lithography

SU-8 is a negative photoresist based on EPON SU-8 epoxy resin for the near-UV wavelengths from 365 nm to 436 nm. At these wavelengths the photoresist has very low optical absorption, which makes photolithography of thick films with high aspect ratios possible.

Product Name	Viscosity (cSt)	Thickness (µms)	Spin Speed (rpm)
		1.5	3000
SU-8 2	45	2	2000
		5	1000
		5	3000
SU-8 5	290	7	2000
		15	1000
		10	3000
SU-8 10	1050	15	2000
		30	1000
		15	3000
SU-8 25	2500	25	2000
		40	1000
		40	3000
SU-8 50	12250	50	2000
		100	1000
		100	3000
SU-8 100	51500	150	2000
		250	1000



5µm, 10µm and 20µm post arrays in a 50µm thick film.



Honeycomb structure in thick SU-8 resist

1 St(Stroke)= 1 cm^2s^{-1}

- **Steps**

65-95 C

365-436 nm

65-95 C

150-200 C

Spin speed:

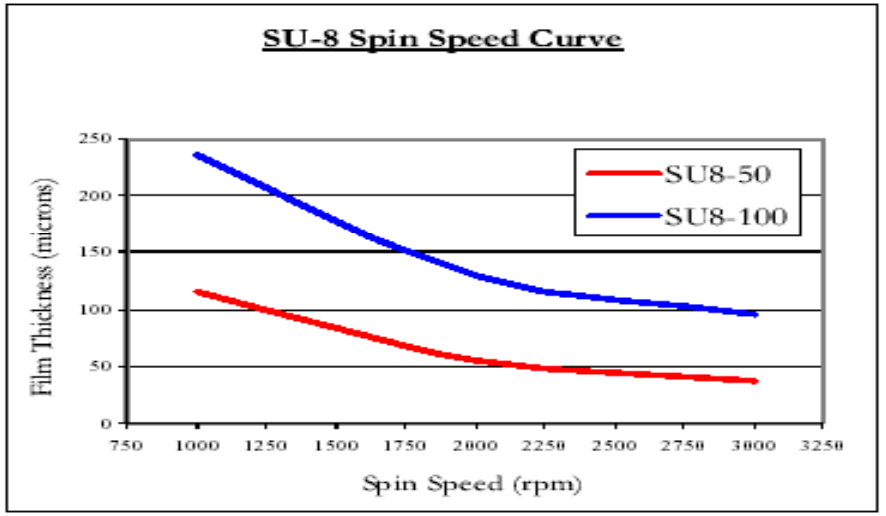


Figure 1. Spin speed vs. thickness curves for selected SU-8 resists.

Baking times (min) :

Product Name	Thickness (µms)	Pre-bake @65°C	Softbake @95°C
	40	5	15
SU-8 50	50	6	20
	100	10	30
	100	10	30
SU-8 100	150	20	50
	250	30	90

(Microchem, Inc.)

PMMA (Poly methyl methacrylate)

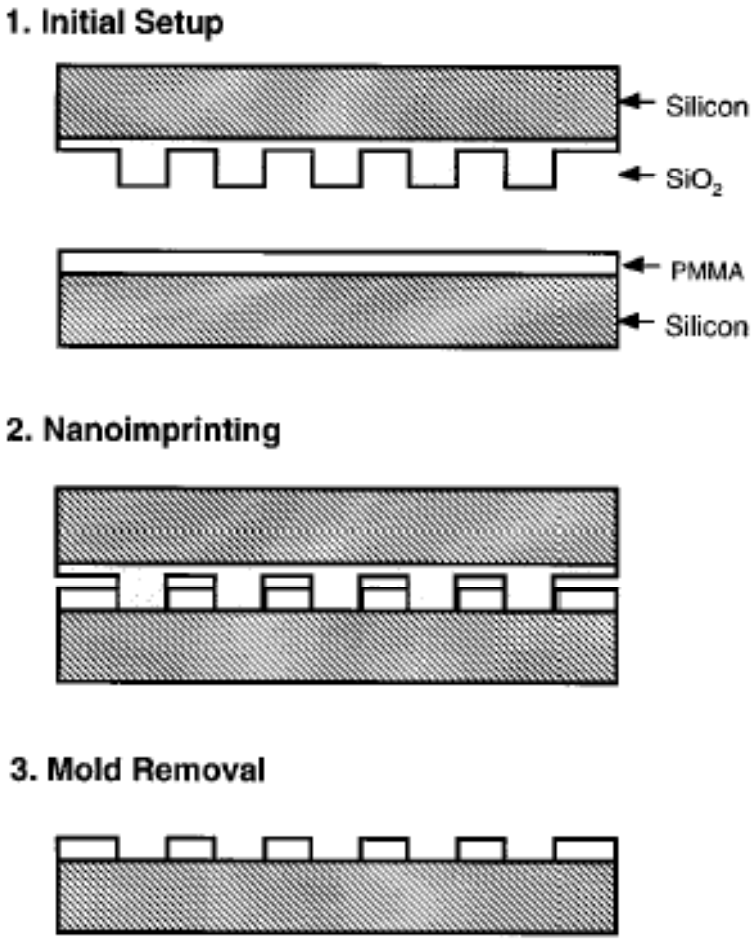
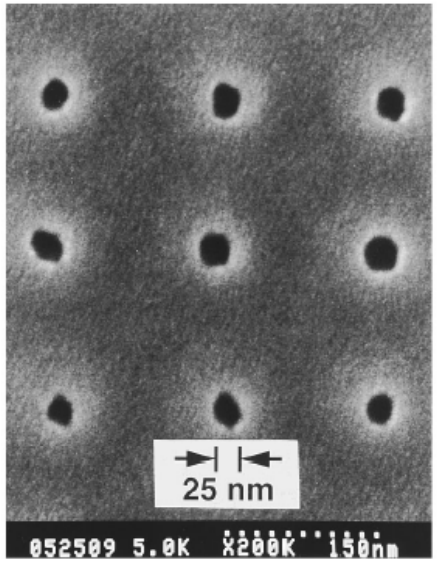
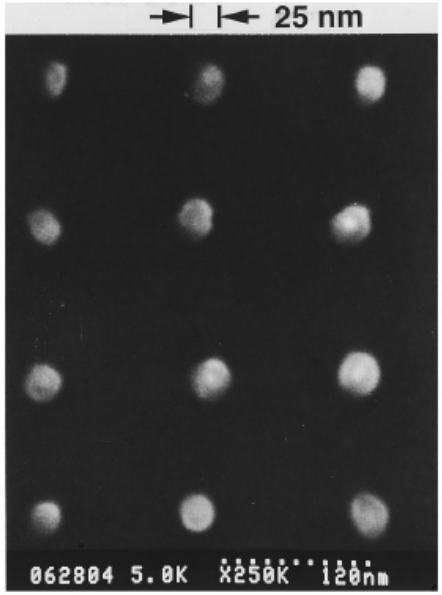


FIG. 1. Schematic of nanoimprint lithography process.

(Renstrom)



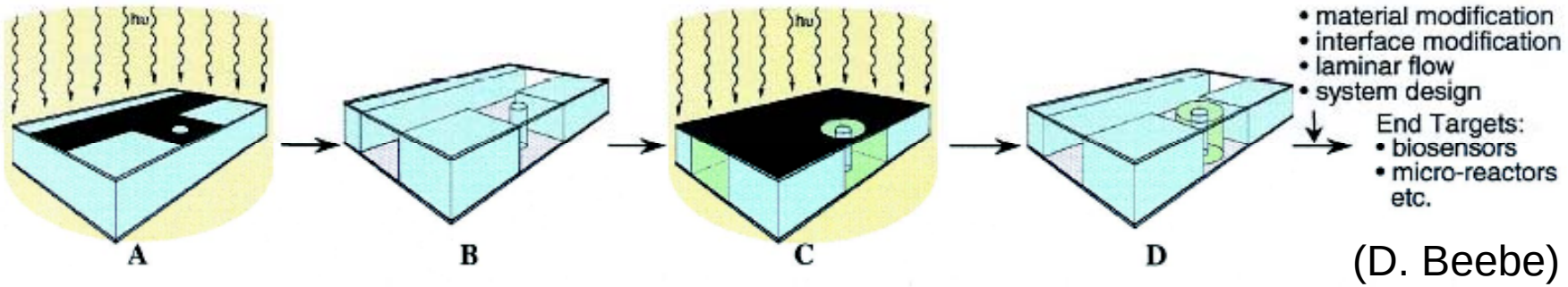
Dot pattern imprinted into PMMA (poly-methymethacrylate). The dots have a 25 nm diameter and 120 nm period



Ti/Au dot pattern on a silicon substrate fabricated using nano-imprinting and a lift-off process. The dots have a 25 nm diameter and 120 nm period

Hydrogel Based Microfabrication

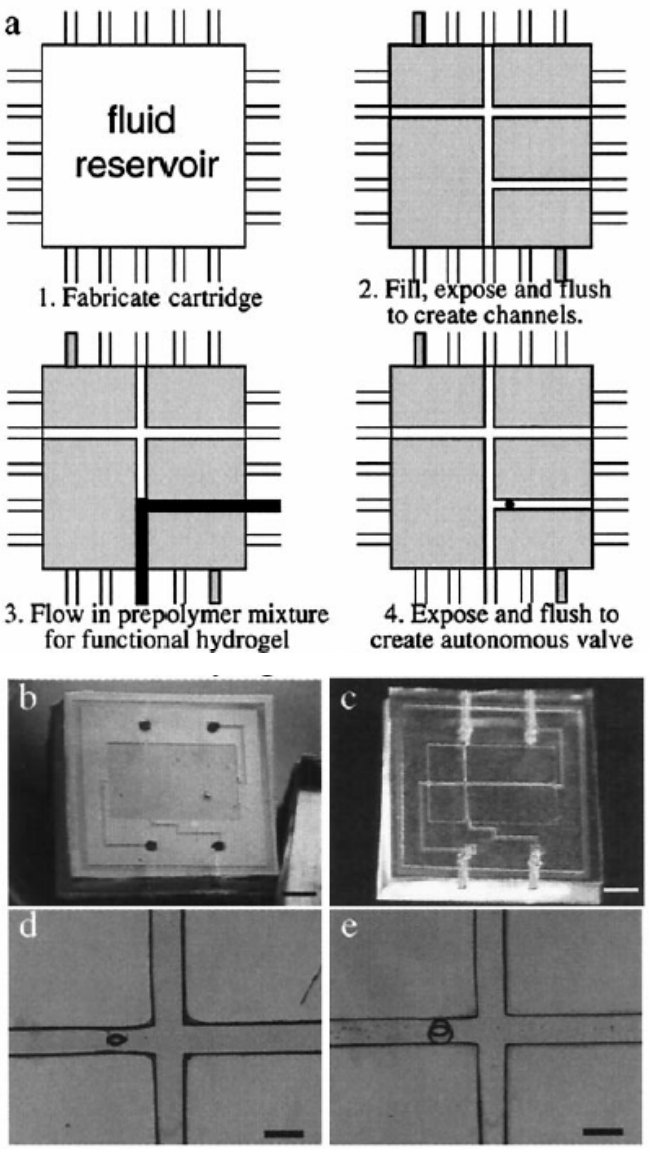
- Hydrogel Fabrication
  - Photosensitive (polarity like negative PR)
  - Liquid-phase photo-polymerization
  - Laminar flow-aided patterning
  - Functional (stimuli-responsive) and non-functional materials
  - Fabrication of fluidic channels, actuators, valves, pumps
  - Typical polymerization time: 5-40 sec (UV light)
  - Minimal Total fabrication time of a system (<10 min)



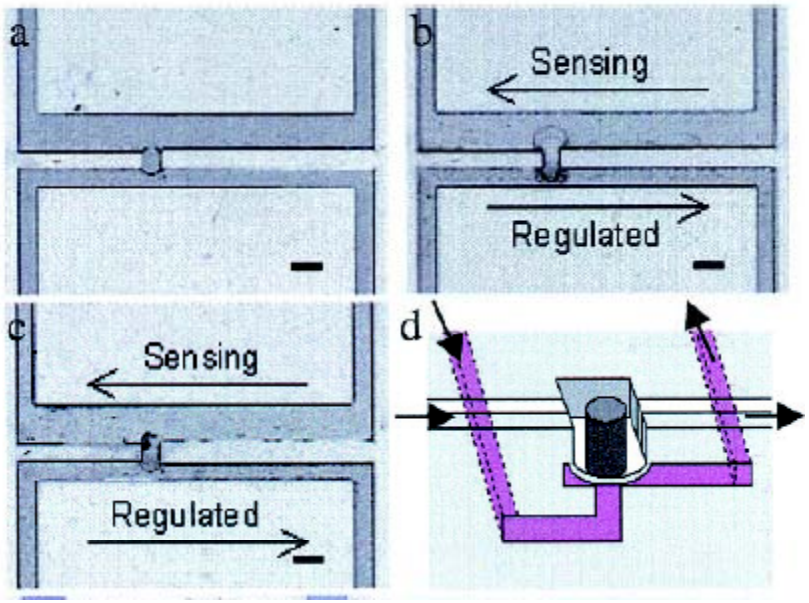
(D. Beebe)

A hydrogel jacket valve in a T channel

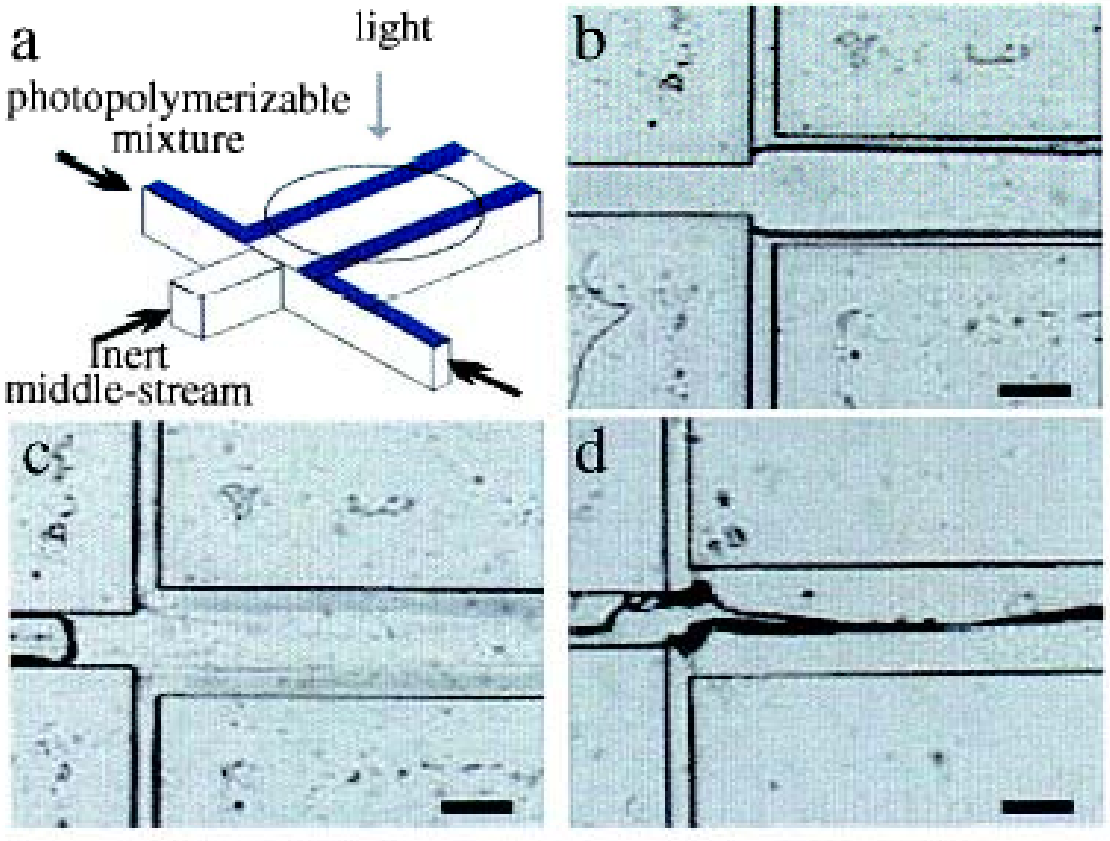
Fabrication of a valve in a Hydrogel Microchannel



2-D and 3-D micro fluidic network



Geometry Control during Fabrication by Using Laminar Flows



Rigid Materials vs. Soft (Elastomeric) Materials

Rigid materials

Crystalline silicon, amorphous silicon, glass, quartz, metals

Advantages:

- Fabrication process is mature and well developed
- Bulk-etching for forming two- and three-dimensional shapes
- Batch process – compatible with IC process
- Silicon dioxide: good quality, stable chemically and thermally

Disadvantages:

- Expensive
- Brittle
- Opaque (for silicon) in the UV/Vis regions
- Low dielectric strength (Si)
- Surface chemistry is difficult to manipulate

Packaging/Bonding:

- Anodic bonding
- Fusion bonding
- Polymer bonding

Good and Bad !!

Rigid Materials vs. Soft (Elastomeric) Materials

Soft materials

PDMS, PMMA, Polyimide, Hydrogel, etc..

Advantages:

- Quick
- Inexpensive
- Flexible (for actuation such as valuing)
- Transparent to visible/UV
- Durable and chemical insert
- Surface property easily modified
- Improved biocompatibility and bioactivity

Disadvantages:

- Limited to simple structure
- Low thermal stability
- Low thermal and electrical conductivity
- Techniques for microfabrication not as well developed

Packaging/Bonding:

- Through surface modification – easy but not robust