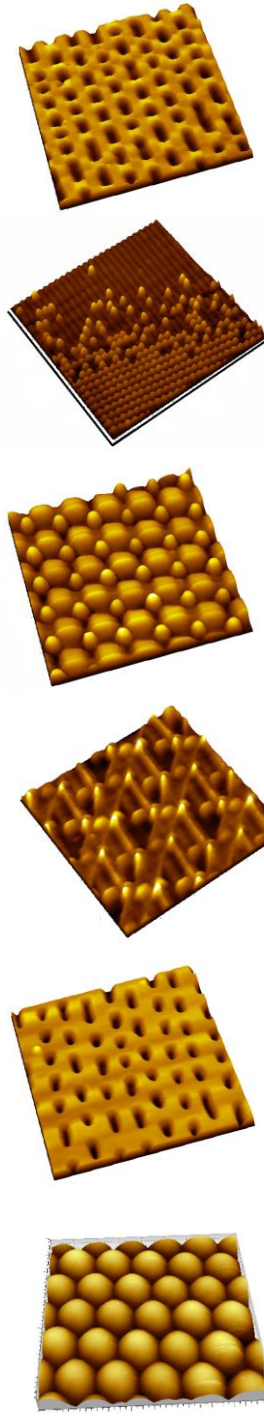

Introduction to Soft Lithography

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Soft Lithography Methods

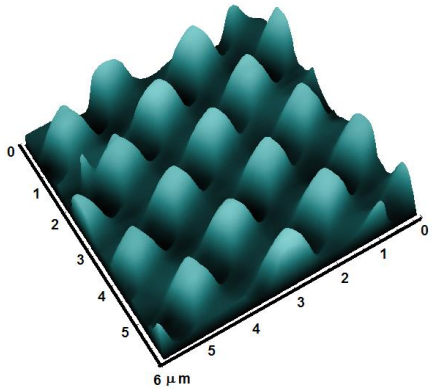
- These are rather specific towards soft surfaces (polymers and gels) as well as for applications which do not require extremely stringent quality control or defect free patterns like micro electronics.
- There are several application areas, where large area meso and nano scale structures are necessary, but even if there are some defects here and there, it is fine.
- Sensors, Bilogical applications, structural color, textured hydrophobicity: progress in all these areas depend on availability of robust, simple, easy to execute and CHEAP patterning techniques that can create large area (~ cm^2) patterns with good reproducibility
- The ability to create defect free structures should be reasonable.

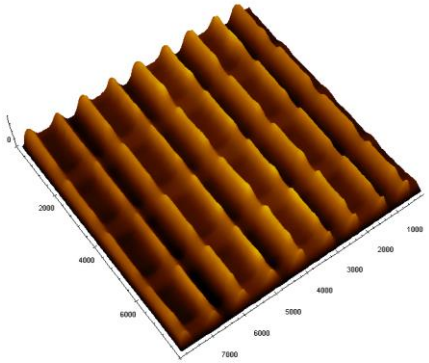
Most cases, the concept works on getting a Perfect Negative Replica of the Original Stamp!

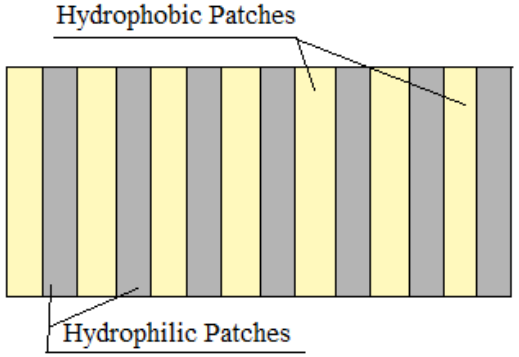
Soft Lithography Techniques: Classifications

Based on the Nature of Patterns:

- Chemical Patterns
- Topographic Patterns





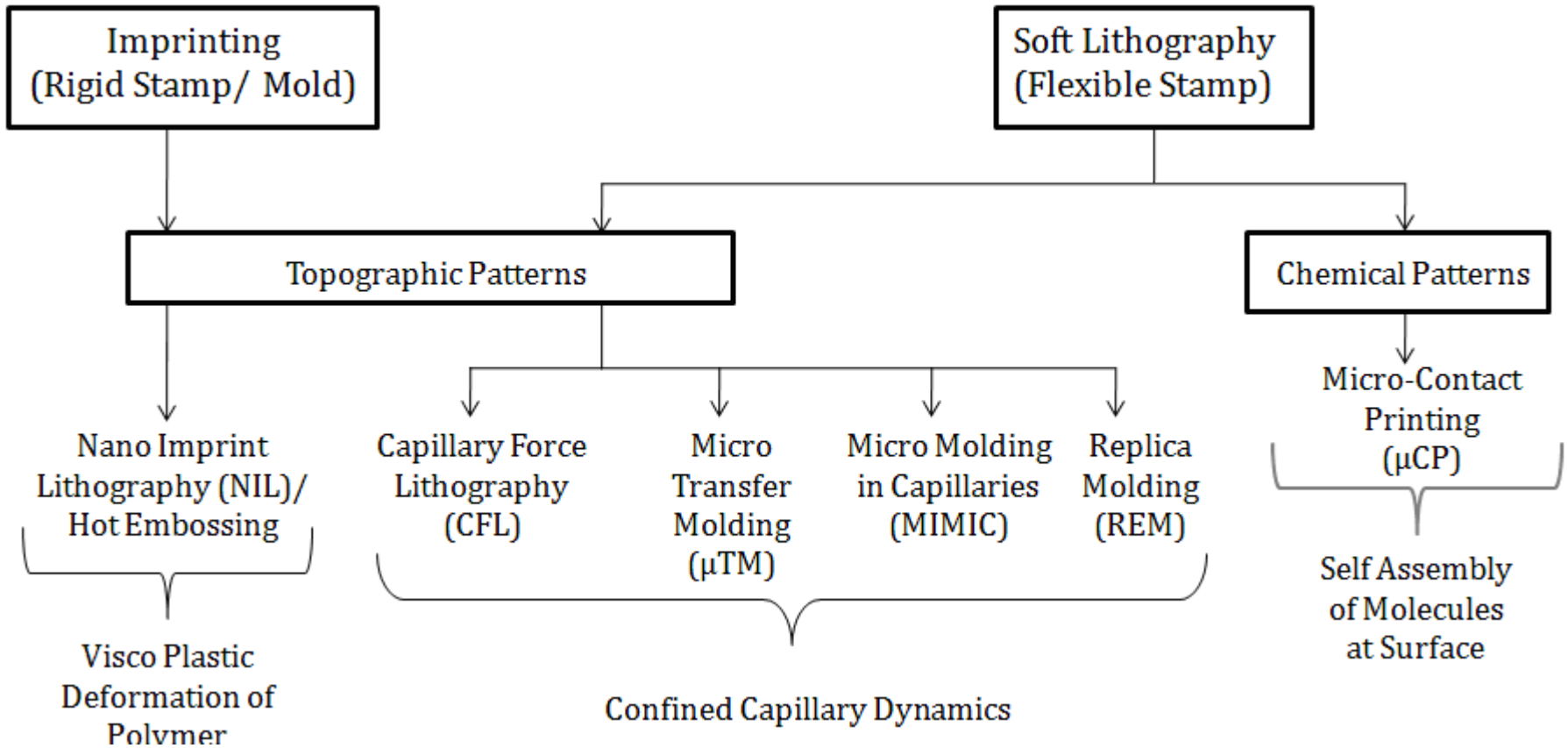


Topography is Rather Smooth

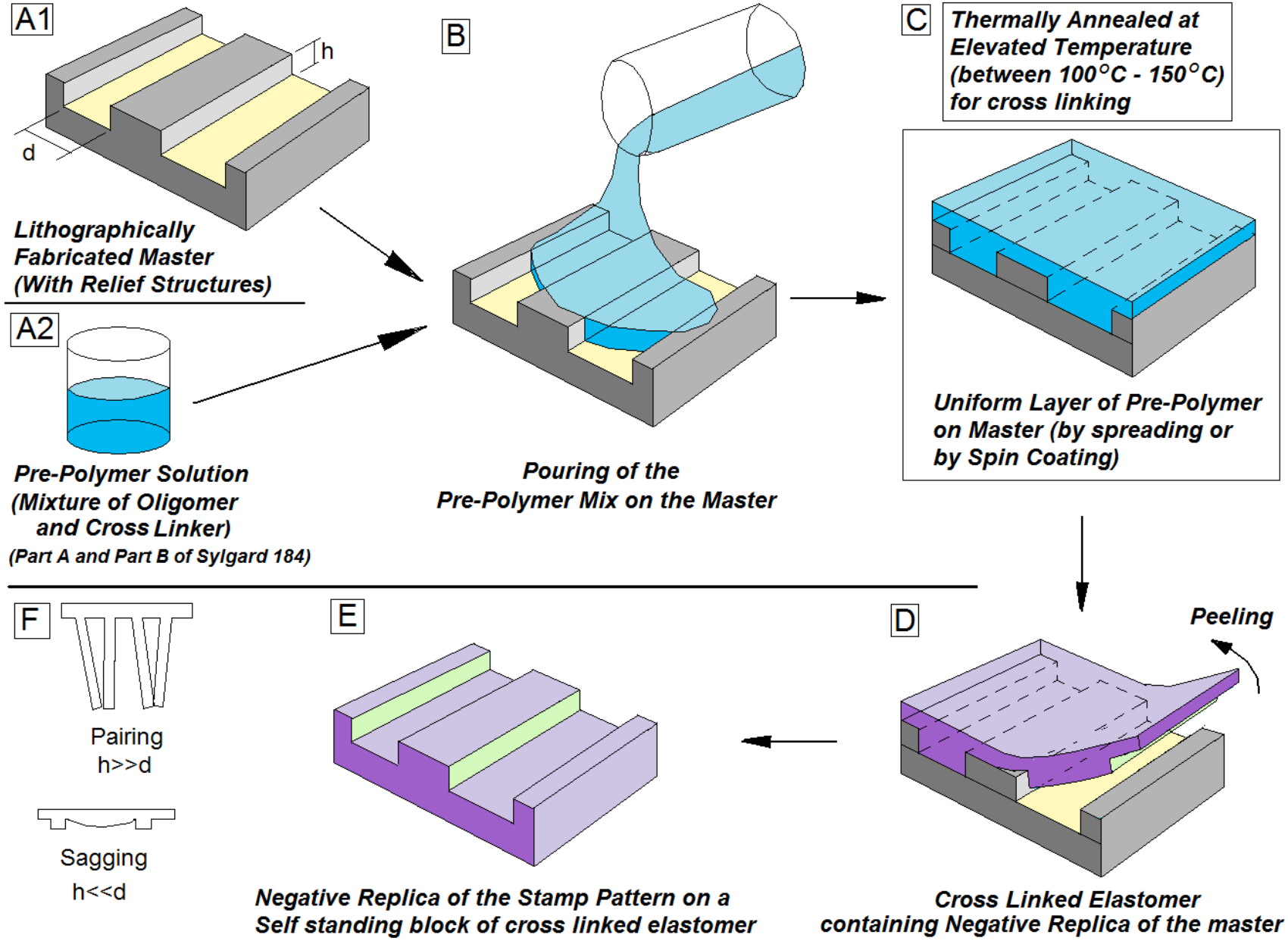
Based on the Nature of Mold or Stamp Used:

- Rigid Stamp
- Flexible Stamp
- Dissolvable Stamp

Soft Lithography Techniques: Classifications

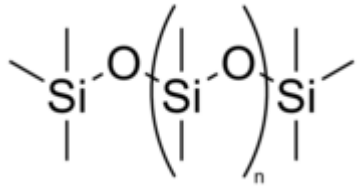


Replica Molding



Material for Replica Molding

- The material used for REM is Cross linkable Poly-dimethyl siloxane (PDMS), which falls into a general category of materials called elastomers.



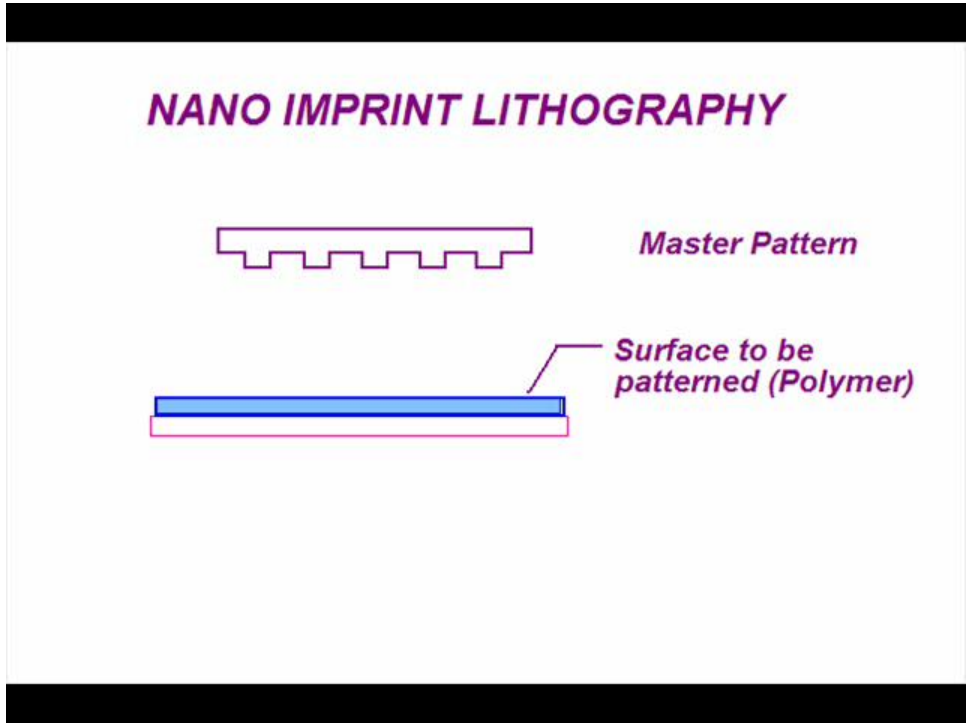
- Elastomers are crosslinked amorphous polymers that are used at temperatures above their glass transition temperature, *Tg*.

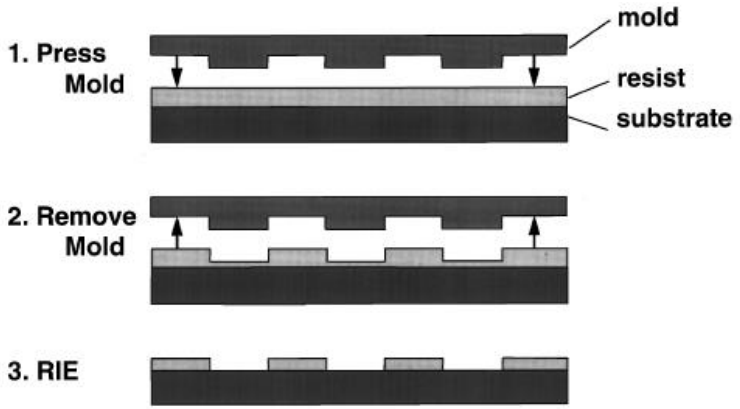
- *Above the glass transition temperature, molecules gain thermal* energy that enables them to move in a coordinated manner, making the elastomers rubbery, soft and flexible.

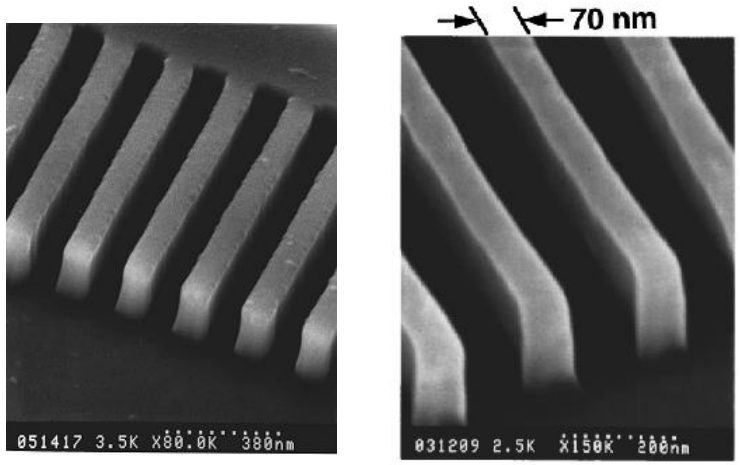
Sylgard Group of Products from Dow – Croning USA

Nano Imprint Lithography (NIL)

J. Vac. Sci. Technol. B, 14, 4129, 1996







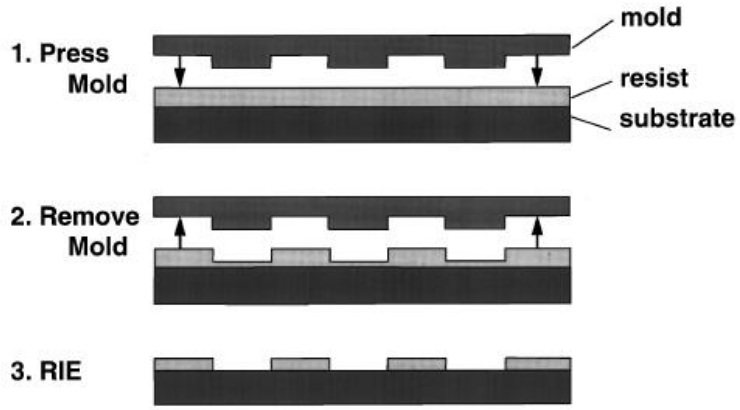
For the original Work

Mold is Rigid:

Patterned Silicon Wafer, Silica or even other materials can be used

Nano Imprint Lithography (NIL)

J. Vac. Sci. Technol. B, 14, 4129, 1996



Advantage:

- Large area patterning capability
- Applicable for many different polymers.
- Resolution achieved ~ 10 nm.
- Possible to achieve patterns over fairly large area.

Some Critical Issues and Limitations

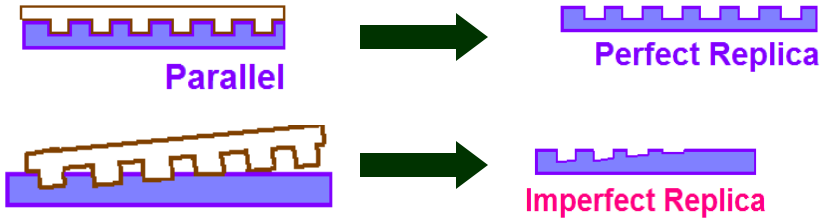
High Temperature

High Pressure

Adhesion of Mold with Resist (Polymer): Severe Chances of Mold Damage

Critical Parallelism between mold and film has to be ensured!

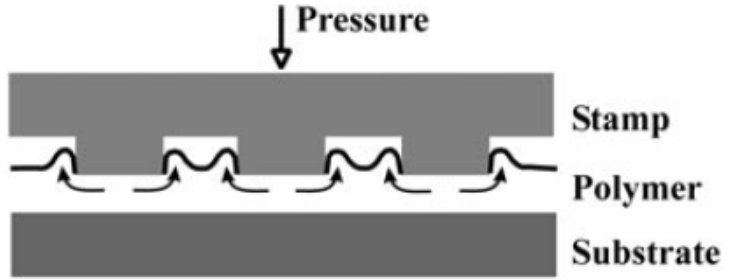
Non Planar Surfaces cannot be patterned

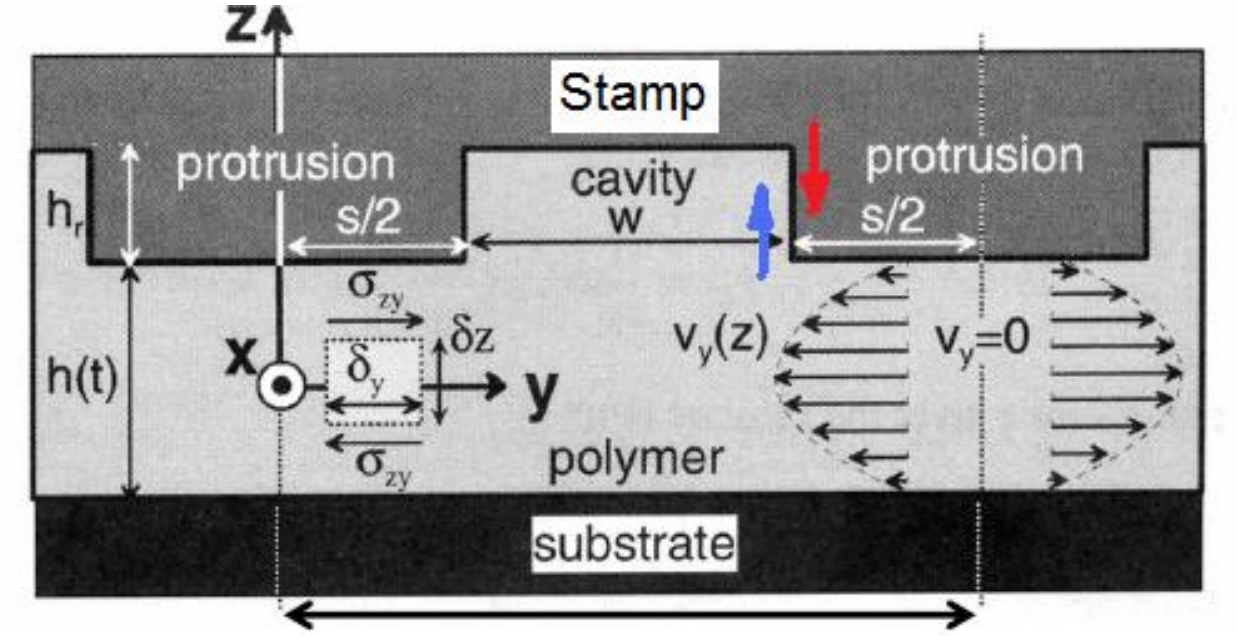


Mold Release agents

Nano Imprint Lithography (NIL)

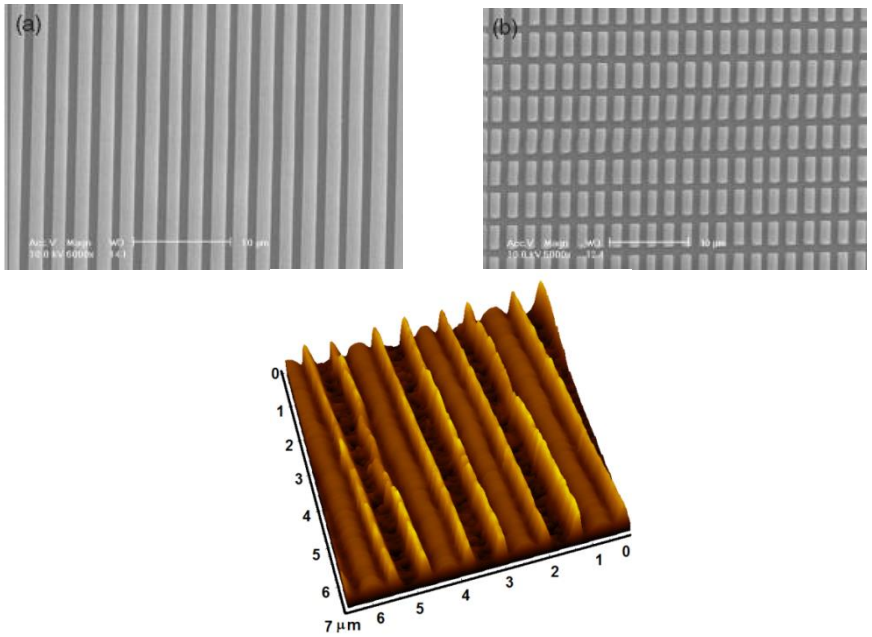
Hydrodynamics and Stresses

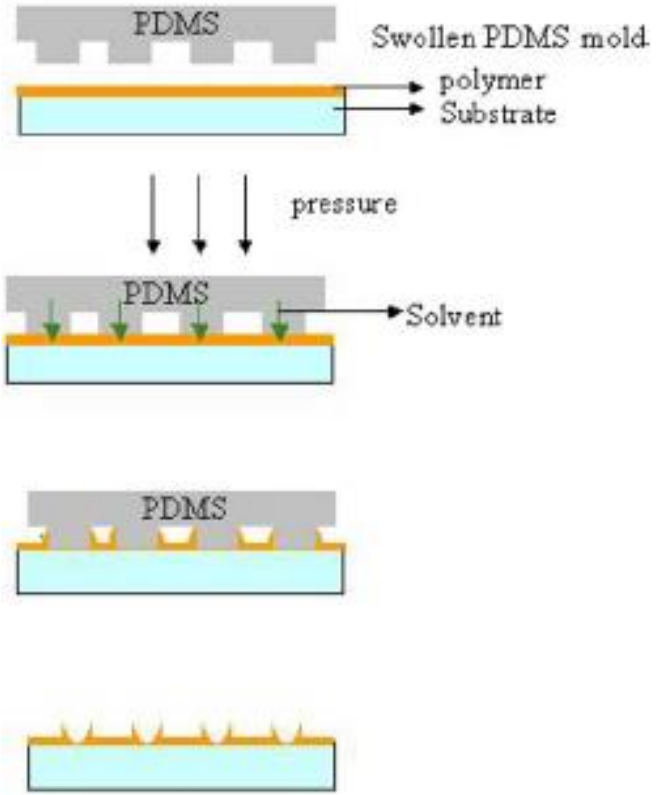




Capillary force Lithography

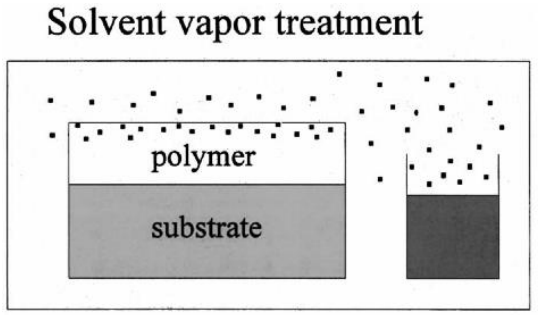
- Heat up the polymer film
- Place mold on top of the mold
- Liquid rises along the walls of the mold.





Lee, Adv. Mater, 2001, 13, 1386, Lee, Adv. Mater, 2004, 176, Han, Polymer, 2005, 11099

Solvent Vapor Assisted Nano Imprint Lithography

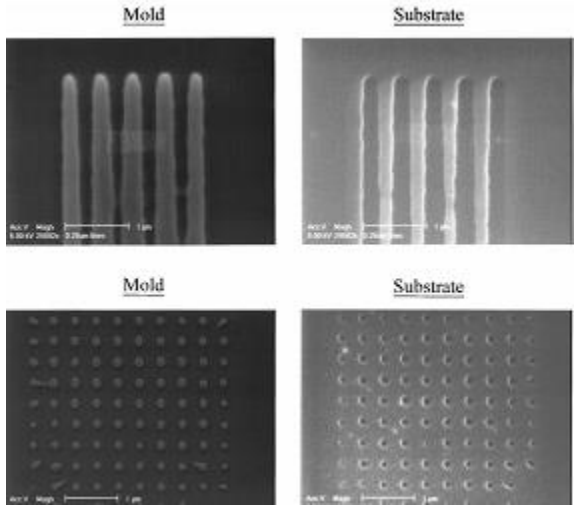


Penetration of solvent molecules into the polymer matrix

Swelling and reduced cohesion

Reduction in Viscosity

Effective reduction in glass transition temperature below room temperature.



Hong Lee: Applied Physics Letters, 76, 870, 2000

Flory – fox Equation

$$\frac{1}{T_G} = \frac{w}{T_G^P} + \frac{1-w}{T_G^S}$$

Where T_G^P is the glass transition temperature of the polymer.

T_G^S is the melting temperayure of the solvent

w is the wt. fraction of the polymer in the swollen film

Soft Lithography Techniques: Classifications

Based on the Pattern Transfer Mechanism:

Chemical Patterns

Are always based on some surface active molecules (Micro Contact Printing) (μCP)

George Whitesides @ Harvard

Topographic Patterns:

Due to **Visco plastic Deformation** of a softened polymer Layer

(Nano Imprint Lithography Group of Techniques) (**NIL**)

Stephen Chou @ Princeton

Or

Due to **Capillary Driven Flow** of a Polymer solution of film in liquid state

(Whitesides, Hong Lee (Korea))

- **CFL** (Capilary Force Lithography)