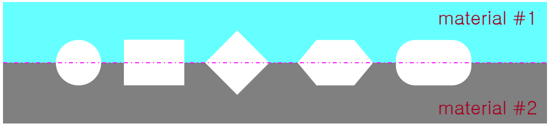
# MicroChannel Fabrication

- **Cross section of possible microchannels**

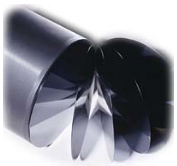



- **Classification of microchannel fabrication**
  - etch rate: Rx = Ry : isotropic etch
  - etch rate: Rx ≠ Ry : anisotropic etch
  - material #1 = material #2 : homogeneous material bonding
  - material #1 ≠ material #2 : nonhomogeneous material bonding

# MicroChannel Fabrication

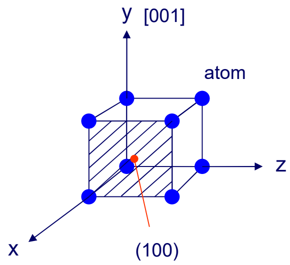
## : Based on Materials

- **Silicon**
- **Glass**
- **Polymer**
- **Metal**



# Silicon
## : Crystallography

**Miller Indices : all lattice planes and lattice directions are described by a mathematical description known as a Miller Index.**



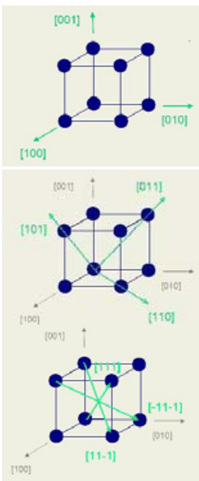

[h,l,k]: particular direction is described with square bracket

<h,l,k>: equivalent sets of [h,l,k] directions

(h,l,k): normal vector of a plane is described with angle bracket

{h,l,k}: equivalent sets of (h,l,k) directions

# Silicon
## : Crystallography

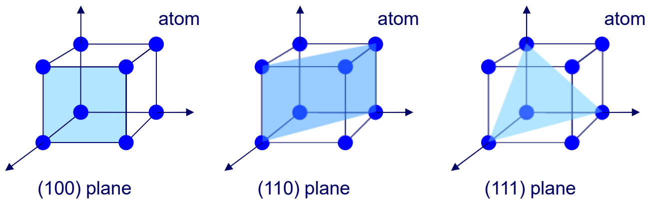


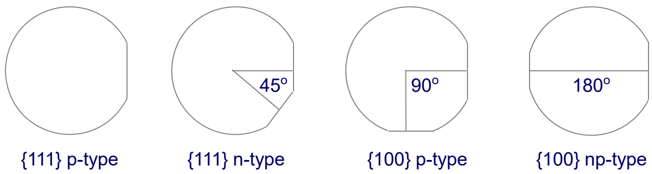

type: <100>
Equivalent directions:
[100],[010],[001]

type: <110>
Equivalent directions:
[110], [011], [101],
[−1−10], [0−1−1], [−10−1],
[−110], [0−11], [−101],
[1−10], [01−1], [10−1]

type: <111>
Equivalent directions:
[111], [−111], [1−11], [11−1]

# Silicon
## : Crystallography

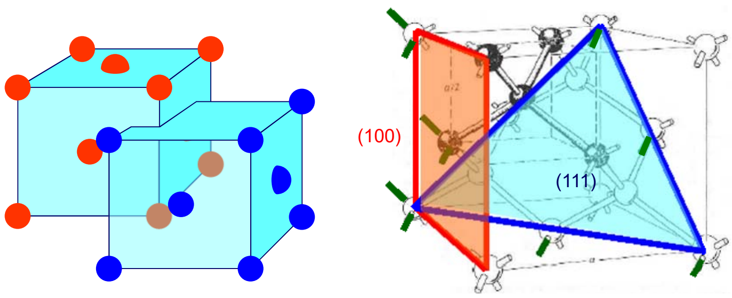



# Silicon Wet Etch

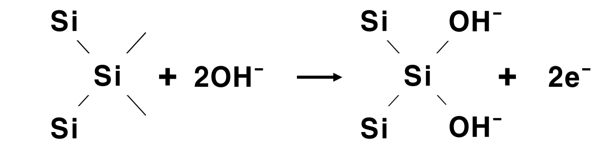
- Wet etch: KOH, $(CH_3)_4NOH$(TMAH)

$$Si + 2OH^- + 2H_2O \longrightarrow Si(OH)_2^{2-} + 2H_2$$

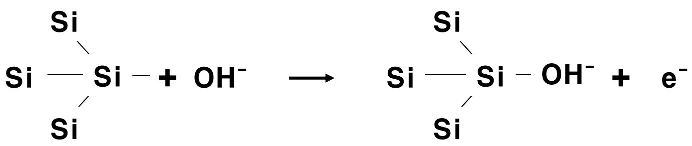


# Silicon Wet Etch

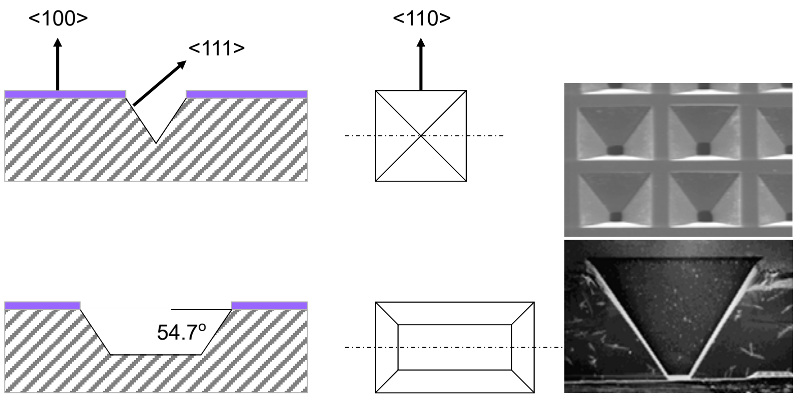
- Etch in (100) direction




- Etch in (111) direction

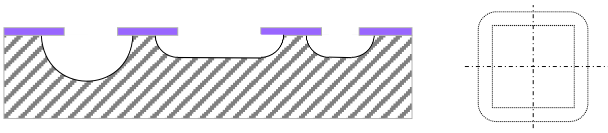


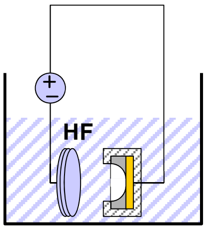

# Anisotropic Silicon Wet Etch

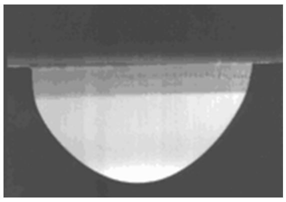


## Isotropic Silicon Wet Etch

- Wet etch: $HF:HNO_3:CH_3COOH:H_2O$

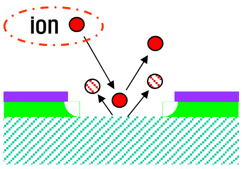




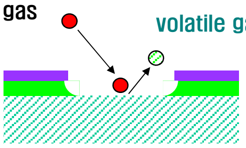



## Anisotropic Silicon Dry Etch

- Physical etch
- Chemical etch
- Physical + chemcial etch → Increase in etch rate




[momentum transferred physical etch]




[surface reaction chemcial etch]

# Anisotropic Silicon Dry Etch

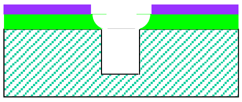
$Ar \longrightarrow Ar^{+} + e$ momentum transfer etch

$e + CF_4 \longrightarrow CF_3 + F^{+} + e$

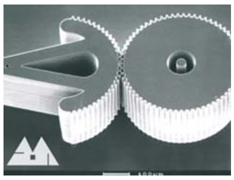
$Si + 4F \longrightarrow SiF_4$ chemical reaction etch

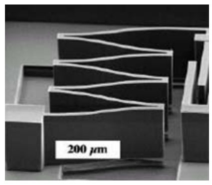
plazma: positive ion of atom + electron

volatile gas



physical + chemical etch



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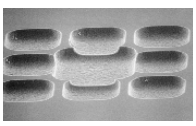
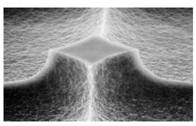
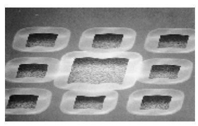
# Isotropic Silicon Dry Etch

$Si + 2XeF_2 \longrightarrow 2Xe + SiF_4$ chemical reaction etch

volatile gas







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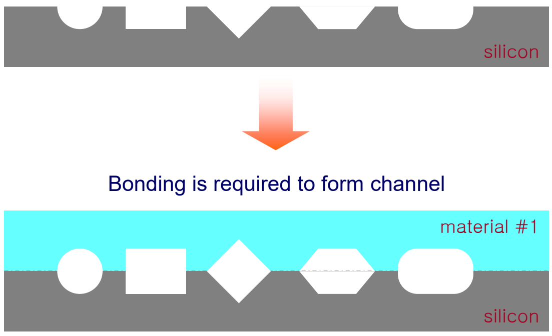
# Various Cross-Section of Silicon Etch

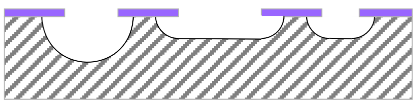



# Glass

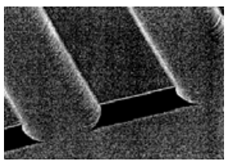
## : amorphous substance

Amorphous solid: no long range order of the positions of the atoms. Most classes of solid materials can be found in an amorphous form. Common window glass is an amorphous ceramic, many polyemr are armorphous.

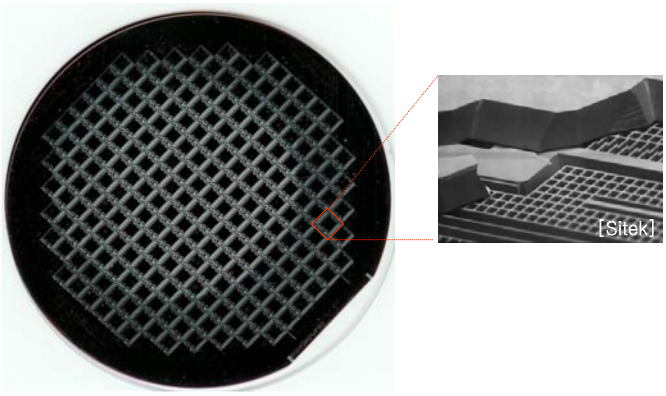
- **Wet etch: Buffered HF**



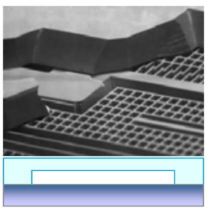
Isotropic etch



## MicroChannel Formation Using Bonding




## Four Common Wafer Bonding Techniques



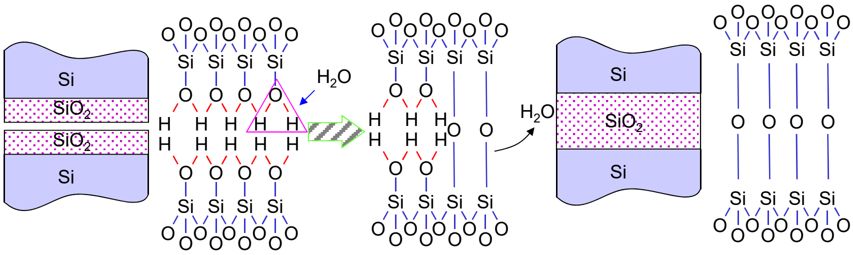
- Silicon fusion bonding
- Anodic bonding
- Eutectic bonding
- Adhesive bonding

**Basic requirements for wafer bonding**

- Surface cleanliness and roughness
- Minimal process-induced residual stress
- Stable and strong bonding strength
- Strain relief

# Silicon Fusion Bonding

## ■ Working principle



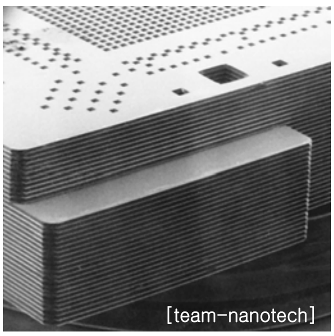

**Preparation** | **Initial bonding** | **Fusion bonding** | **Strong permanent bonding**

- surface must be clean and flat
- surface must be hydrophilic
  : boiling in nitric acid
  : immersion in an $H_2O_2/NH_4OH$
- mechanical contact at ambient
- formation of weak OH bridges

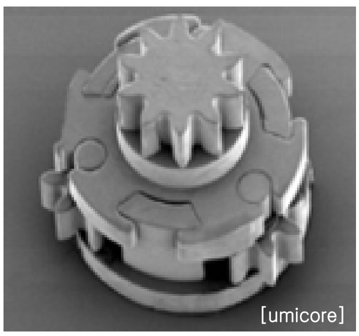
- temperature increase beyond 200°C
- void inspection using IR visualization
- OH groups are replaced by oxigen bridges
- further increase in temperature results in water dissociation
- beyond 1000°C, a maximum fracture strength

# Silicon Fusion Bonding

## ■ Applications



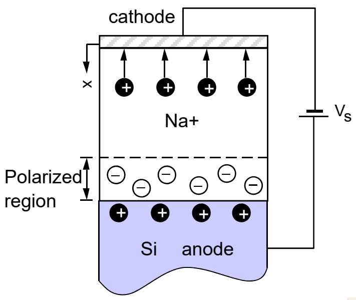

[alligned fusion bonding of 30 silicon plates]

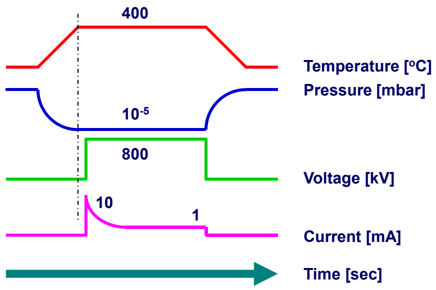



[alligned fusion bonding of 2 SOI plates]

# Anodic Bonding
(Field Assisted Thermal Bonding)

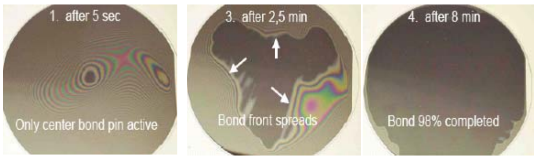
## ■ Working principle




Composition of Pyrex glass

| | |
|---|---|
| $SiO_2$ | 81% |
| $Na_2O$ | 4.0% |
| $K_2O$ | 0.5% |
| $B_2O_3$ | 13% |
| $Al_2O_3$ | 2.0% |

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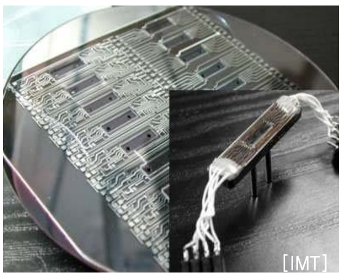
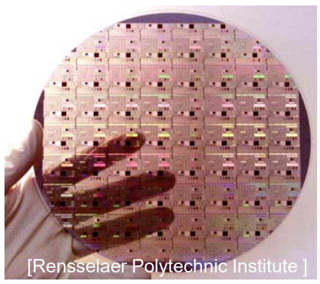
# Anodic Bonding
(Field Assisted Thermal Bonding)

## ■ Applications




[anodically-bonded LOC]




[anodically bonded pressure sensor with copper interconnection]

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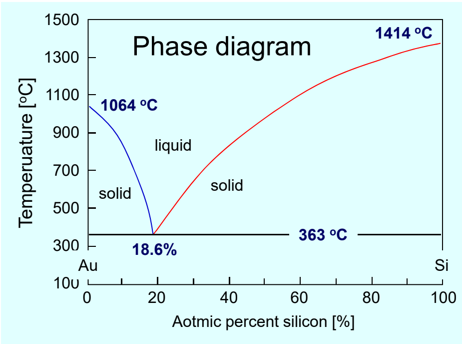
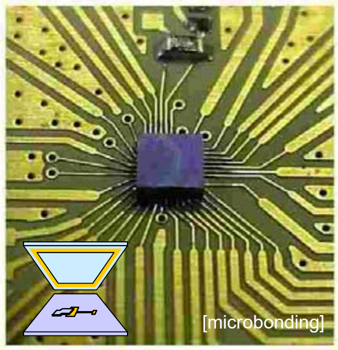
# Eutectic Bonding

## ■ Working principle




- eutctic alloy containing 97.15% Au and 2.85% Si by weight melts at 363 °C

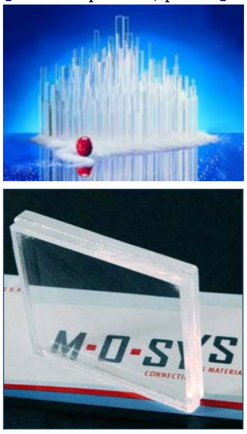
# Adhesive Bonding

- Commercially available adhesive
- Photopatternable polymers
- Generally, under 150 °C use, relatively soft, stress relief
- Unsuitable for hermetic seals and poor theraml stability
- Degrade over long periods of time
- Weak to organic chemicals

# Polymers

[liquid: Elastomer]

[solid: powder/plate]





# Why Polymers?

[glass bottle] [aluminum bottle] [plastic bottle]

# Advantages of Polymers

- **Transparency**
  
  **Optically transparent down to 300 nm; prepolymers being molded can also be cured by UV cross-linking**
- **Functionality**
  
  **Interfacial properties can be changed readily by treating the surface with plasma to form SAMs**
- **Low cost**
- **Easy prototyping**
- **High volume**

# Shpae Molding of Polymers

[Master] [molding] [curing] [separation]

## Fabrication Techniques

- MicroContact printing
- Hot embossing
- Injection molding
- Replica molding
- Patternable lithography

## MicroContact Printing

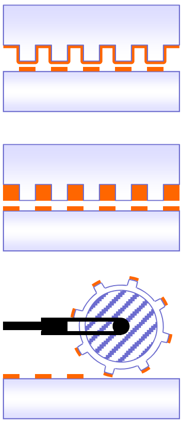
Roll brush painting

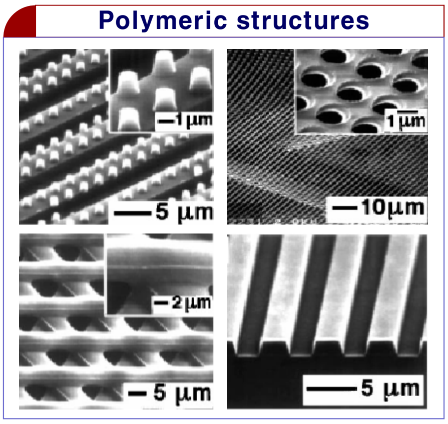
stamping

→ The stamp of elastomer is brought into contact with the substrate

# MicroContact Printing

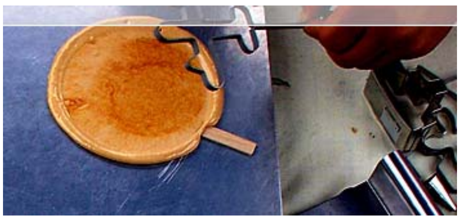
: The stamp of elastomer is brought into the substrate






Whitesides

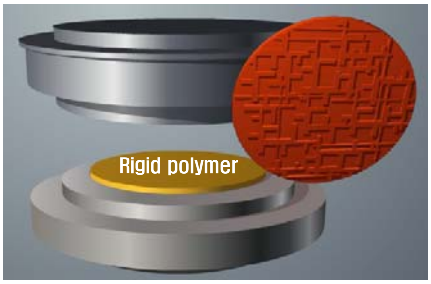
# Hot Embossing

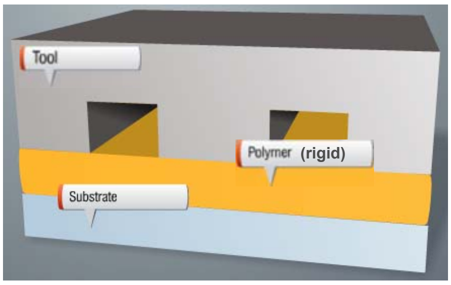


Features patterned on a master are transferred to a rigid polymer instead of elastomers

# Hot Embossing Process

**Step 1** Install rigid polymer sheet and master into the tool

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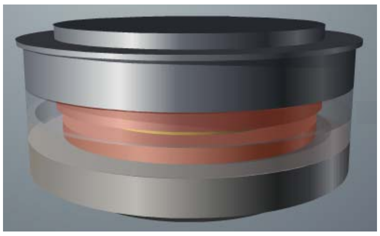
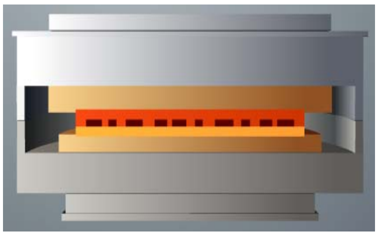
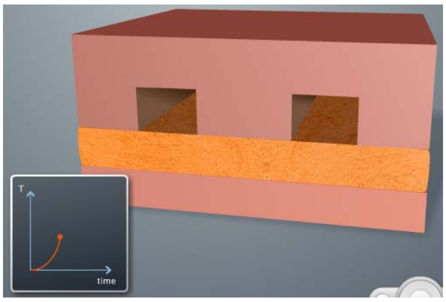
# Hot Embossing Process

**Step 2** Vacuum and heat the master up to grass transition temperature of the polymer





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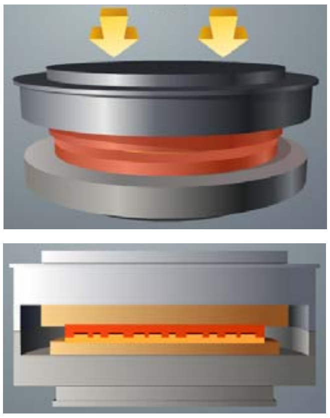
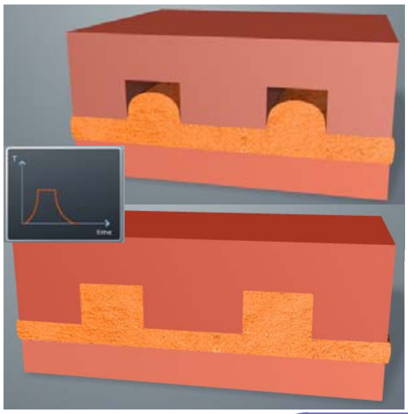
## Hot Embossing Process

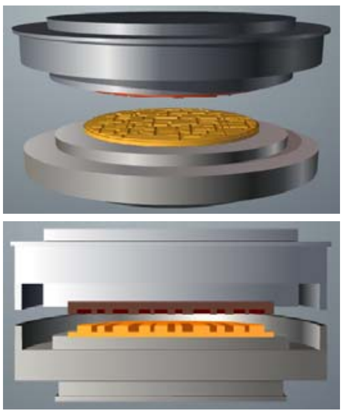
Step 3 Force the upper plate untill the convex micro sturctures is filled perfectly

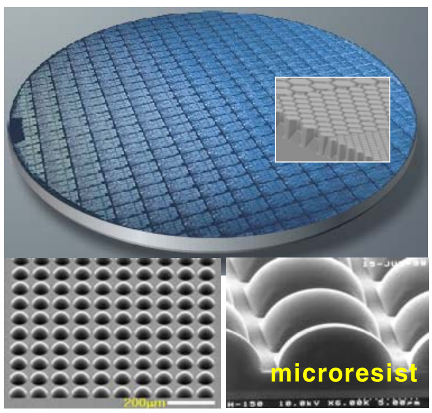




## Hot Embossing Process

Step 4 Delaminate the polymer plate from the master

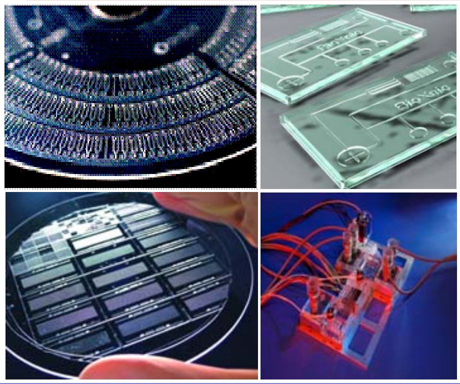




## Hot Embossing Platfoam

Hot embossing

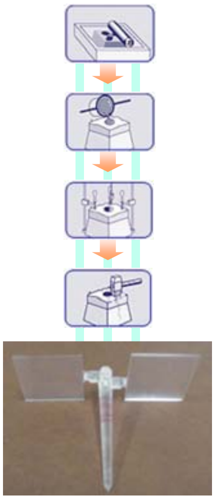

Polymeric structures

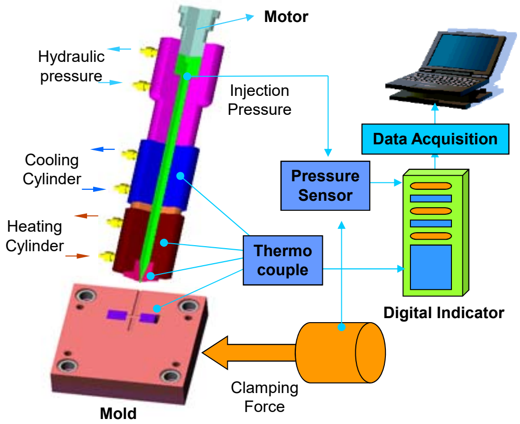


## Injection Molding

Feature is formed by the injected resin
into the patterned mold

# Injection Molding Machine

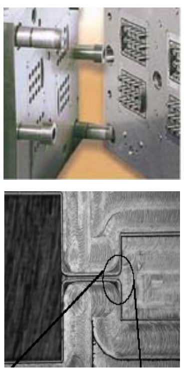




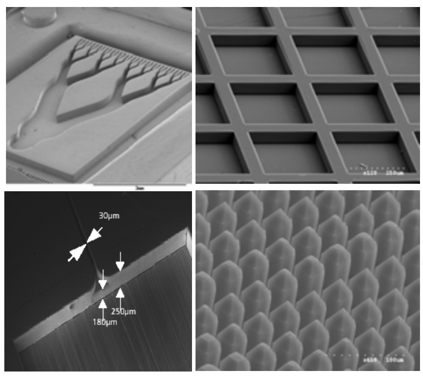



# Injection Molded Polymers

mold



Polymeric structures

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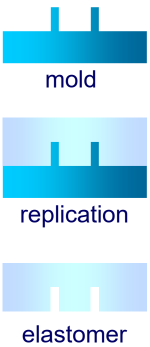
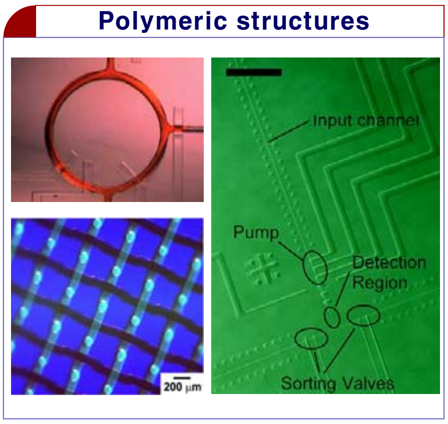
# Replica Molding

→ **Feature is formed by the injected resin into the patterned mold**

# Replica Molding

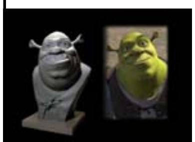


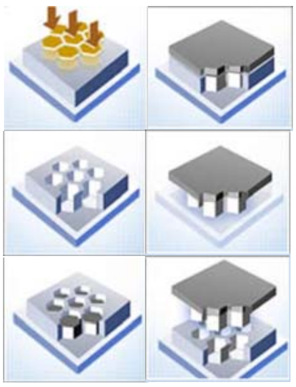



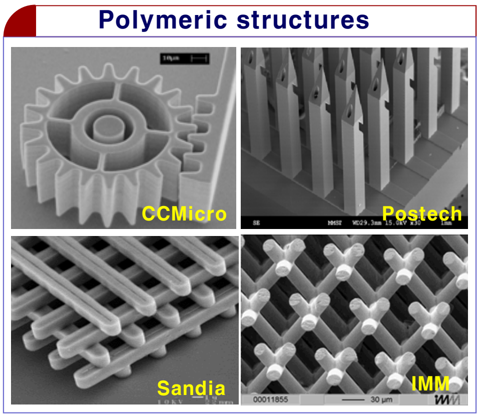
## Patternable Lithography

Feature is transferred to the photopatternable resin by photolithograpy

## Patternable Lithography



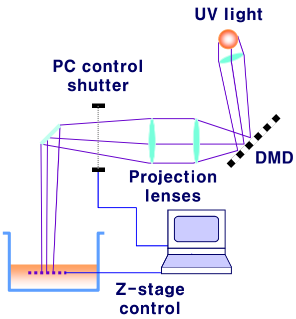


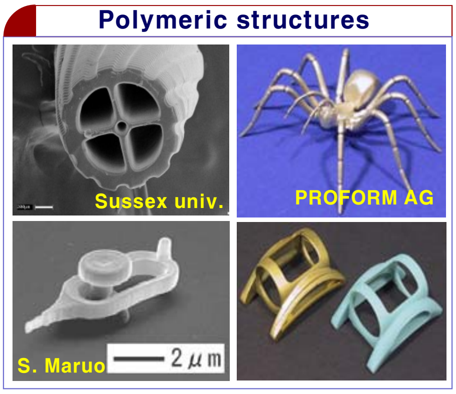



LIGA(lithographie, Galvanoformung Abformung)

LIGA-like photolithography

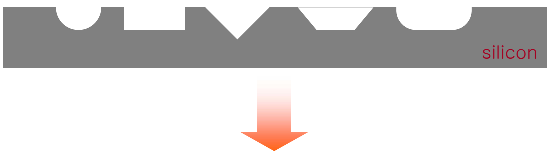
# Patternable Lithography



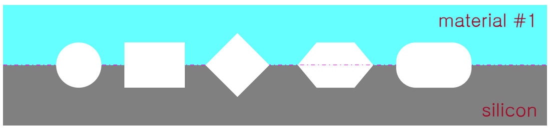




Microsterolithography

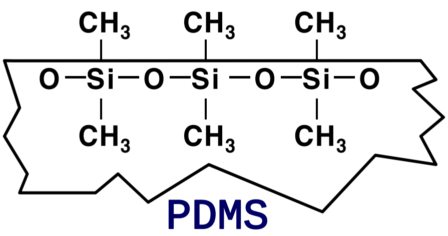
# Various Cross-Section of Polymer molding




Bonding is required to form channel

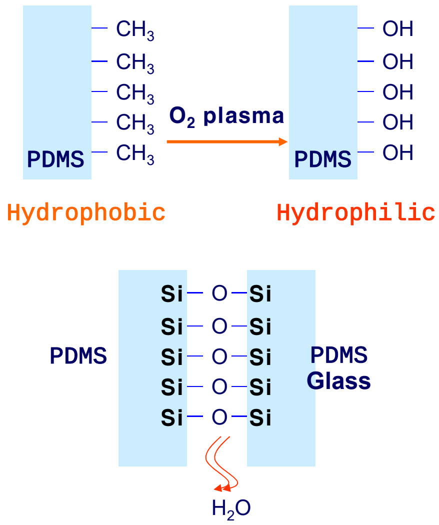


# Polydimthylsiloxane(PDMS)

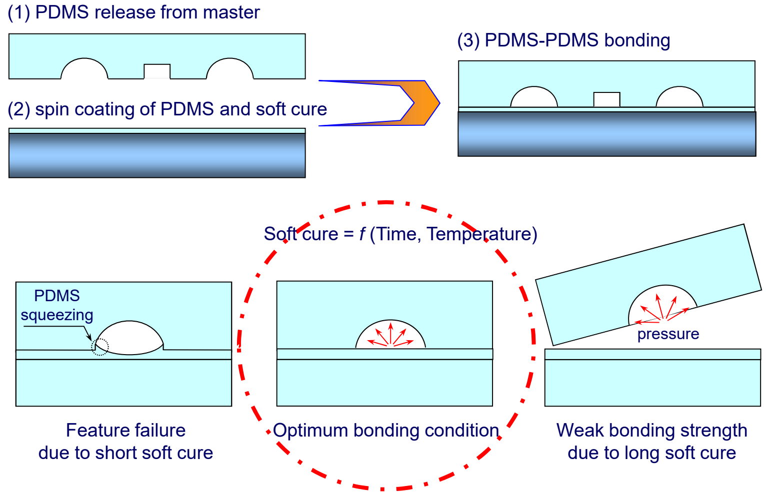



| property | value |
|---|---|
| color | clear |
| viscosity | 3.9Pa s |
| specific gravity | 1.08 |
| gt temperature | 150K |
| Thermal conductivity | 0.18Wm°K |

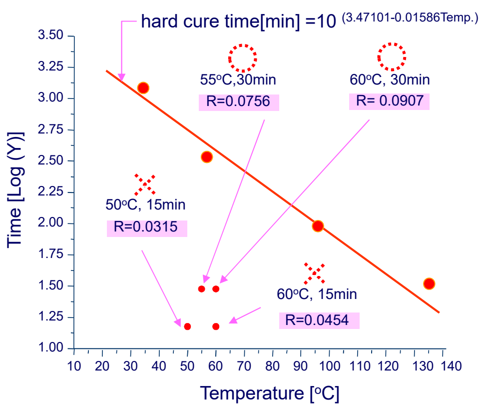
# PDMS-PDMs covalent Bonding

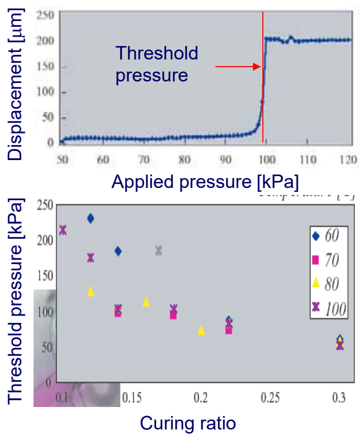


# PDMS-PDMs Bonding




# PDMS-PDMs Bonding Condion




Soft cure = *f* (Time, Temperature)

One dimensional parameter: **Curing Ratio** $R = \frac{\text{soft cure time}}{\text{hard cure time}}$

# PDMS-PDMs elastomeric Bonding