PH515 – Lecture Notes (jb)

MEMS Fabrication Process

27-1-2015

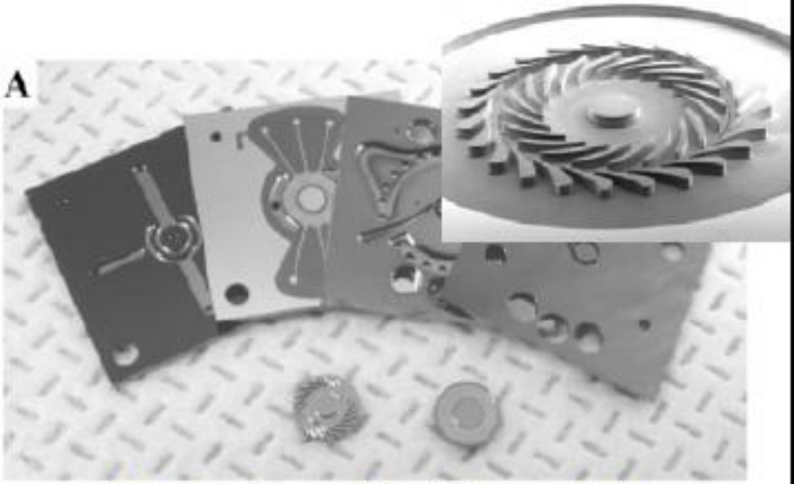
MEMS Fabrication

Consists of four distinct processes

1. Substrate – starting point
2. Patterning – Lithography
3. Additive process - Deposition
4. Subtractive process – Etching.

Together they form what is known as Micromachining ....

Micromachining combines
Lithography,
Thin Film processing and
Sacrificial etching to form
mechanical devices



Microturbine, Schmidt group MIT

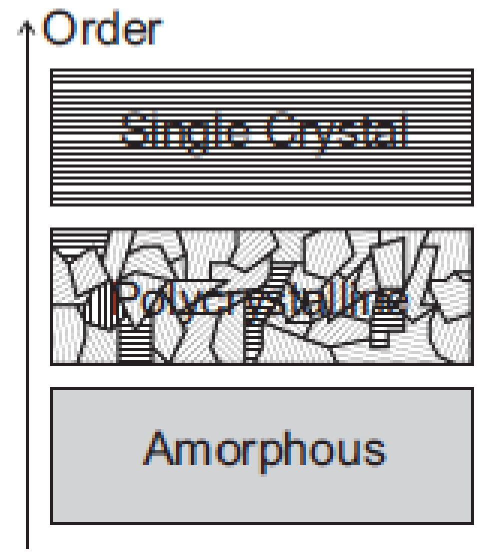
Materials for MEMS

Classified into three categories :

Crystalline material : Highest order. Periodic arrangement of atoms in space following one of the 14 Bravais' lattice. The material properties are highly reproducible . However, the properties will depend on the direction with in the crystal and hence the material is anisotropic.

Amorphous material: Disordered form. Clusters of crystals being of a few atoms only. Properties are more stable and also independent of the direction - material is isotropic.

Polycrystalline material: Material does not crystallize in a continuous film, but in small clusters of crystals called grains, each grain having a different orientation than its neighbour. In general, some grain directions may be preferred depending on the process , and thus the material properties vary considerably with the process.



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Materials for MEMS

MEMS utilizes the same materials used in microelectronics (IC) for device fabrication and we will concentrate o n these materials here

1. Silicon
2. Poly crystalline Silicon
3. Oxides of Silicon
4. Poly crystalline or amorphous dielectric layers
5. Silicon Nitride
6. Polymers
7. Metal thin films.

Materials for MEMS

Choice of Material depends on properties like :

1. Low processing temperature
2. Compatibility with other materials
3. Possibility to obtain thick layers
4. Patterning possibilities

And also application dependent properties :

1. Optics : May need transparent substrate
2. Bio : Compatibility
3. Sensors : Piezoelectric or piezoresistive

Why Silicon?

Silicon is an excellent mechanical material:

1. strong (comparable) as steel but lighter than steel
2. Has large critical stress and can recover from large strain
3. Has large piezoresistive coefficient (Sensor)
4. Transparent at the telecommunication wavelengths (Optical)
5. Young's modulus varies with crystallographic direction

(mechanical)

Silicon Crystal Structure

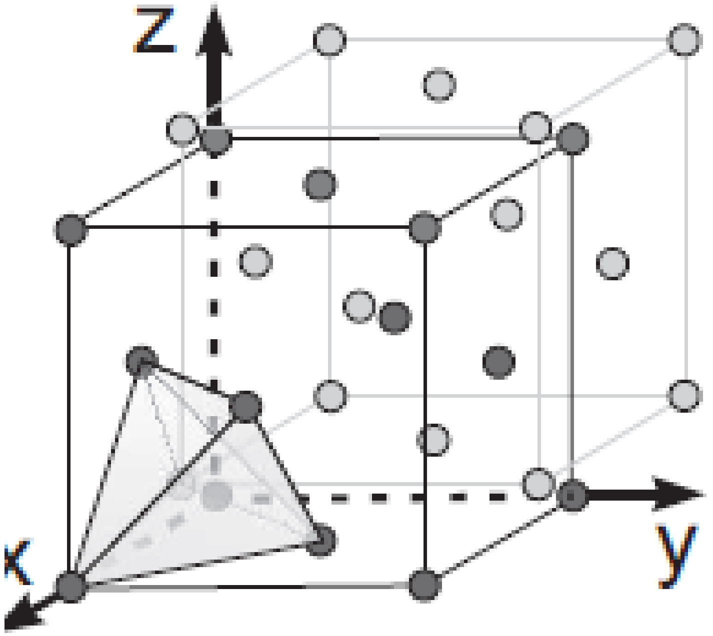
Face centred Cubic lattice

2 atoms per unit cell

Tetrahedron configuration - each Si atom has

four neighbours

Lattice constant = 5 .43A at 300K



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Silicon Crystal Structure

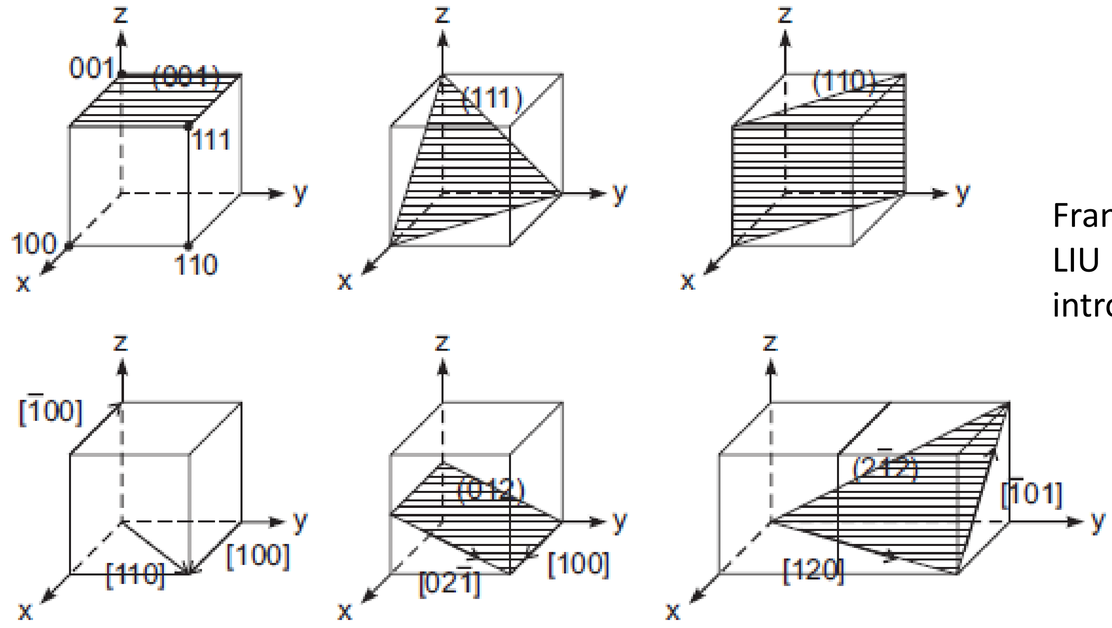

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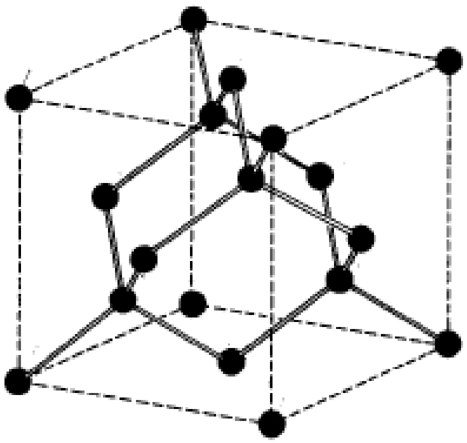
Figure 3.4: Lattice points coordinate, planes and directions in the cubic lattice of silicon.

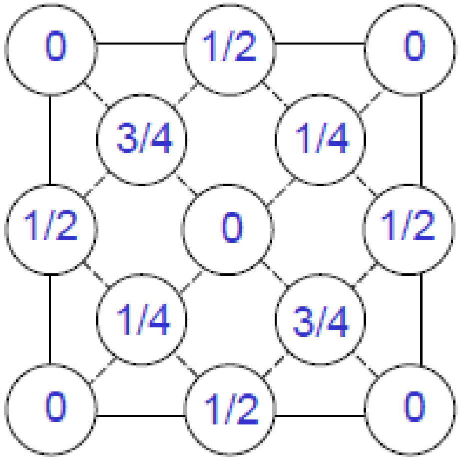
A plane is identified by three indices (hkl), set of equivalent planes {h k l}

Specific directions normal to the plane [h k l], equivalent directions <h k l>

Silicon Crystal Structure

Silicon Crystallography





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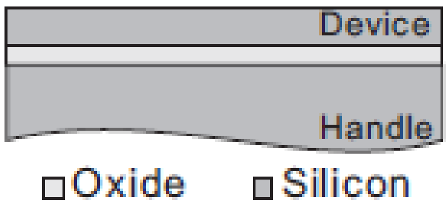
Angle between the planes determined from

$$\alpha = \cos^{-1} \frac{h_1 h_2 + k_1 k_2 + l_1 l_2}{\sqrt{h_1^2 + k_1^2 + l_1^2}\sqrt{h_2^2 + k_2^2 + l_2^2}}$$

Other Materials

Silicon Oxide: Amorphous film – transparent, thermally and electrically insulating
: Smallest coefficient of thermal expansion among all known materials
: Good use in MEMS Fabrication – where oxide support is required e.g. Thermally insulate a pixel of a thermal cameral

Silicon on Insulator: Allows producing complete devices in a simple process
: Optical switch where mobile mirror, actuator and fiber alignment done with single step.



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Silicon Nitride : Stronger than silicon
InP : Photonic capabilities for tunable laser
Quartz : Piezoelectric effect
Glass : Only second to silicon in MEMS use. Can form tight bond with Si and also biocompatible
Polyemer : Bio MEMS – provide biodegradability, thermoplastic property for molding
Metals ; Used when high conductivity is required. Easy to form films.

MEMS Fabrication

Requires Micrometric Features.

Traditional methods

1. Milling
2. Drilling
3. Casting

Can not be used due to the small scale involved.

Feature Size similar to that in ICs Microelectronic fabrication techniques useful.

Will discuss some of these techniques here !!!

MEMS Fabrication

Photolithography:

1. Photo resist spinning
2. Optical Exposure through a mask
3. Developing to dissolve exposed resist
4. Bake to drive off solvents
5. Remove using solvents or plasma etching

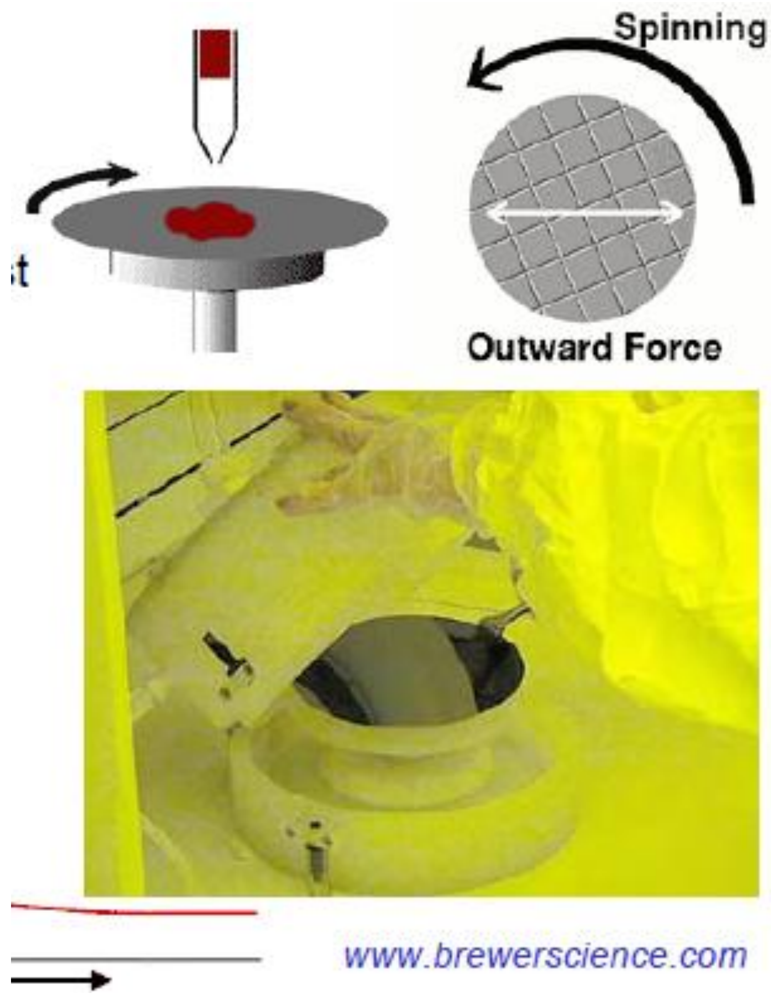
Photo Mask:

1. Lay out of the preferred pattern generated by CAD file
2. Use laser or e-beam to generate the mask on preferred material – generally SiN

MEMS Fabrication

Spin coating resist:

1. Usually a polymer
2. Positive or negative photo resist



Thickness of the resist depends on

1. Concentration
2. Spin speed
3. Spin Time

MEMS Fabrication

Photolithography: Creating the pattern

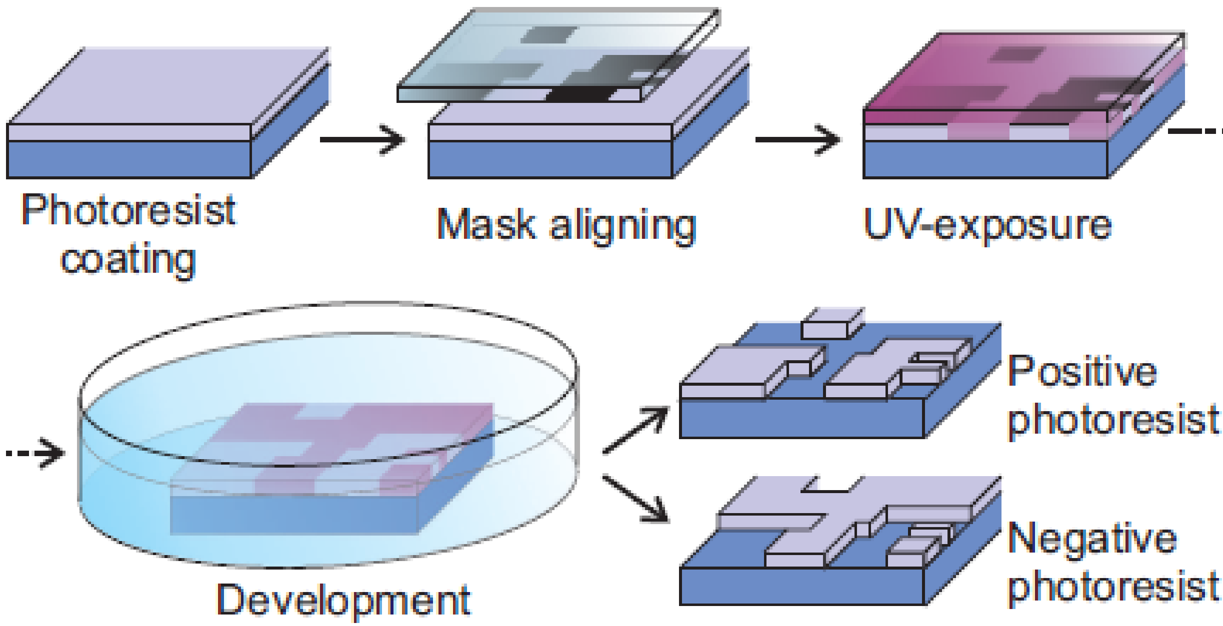


Figure 3.1: Photo-patterning in positive and negative photoresist.

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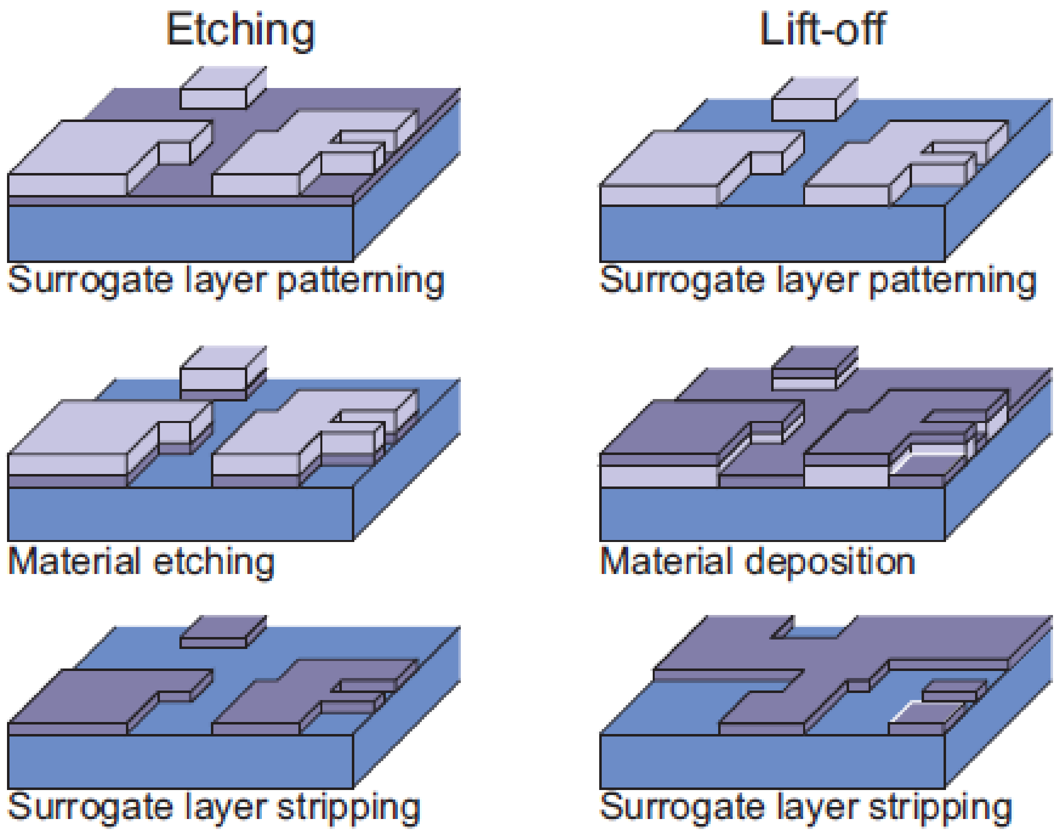
MEMS Fabrication

Photolithography: Transferring the pattern



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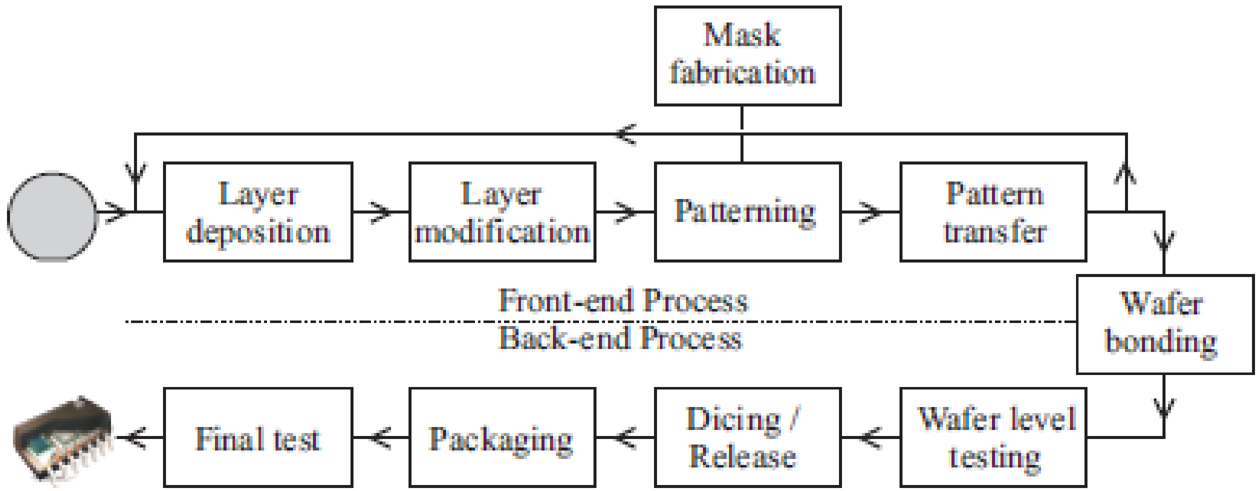

Figure 3.3: General view of MEMS production process.

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