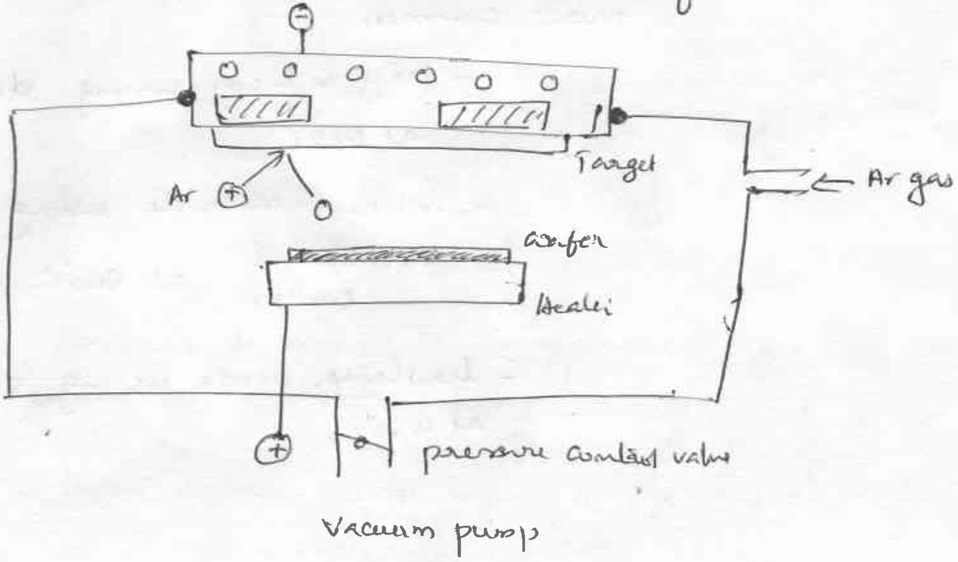
DC Sputtering: Based on glow discharge principle: – plasma created when a low pressure gas is submitted to a large electric field. In the glow discharge when the plasma is ignited, electrons close to the cathode are accelerated by the electric field across the Crooke's dark space until they reach the velocity necessary to ionize gas atoms. When the electrons hit a neutral gas atom they knock electrons out of the atoms outer shell, ionizing them. The positively ionized atoms are in turn accelerated by the electric field and they move towards the cathode.

Here, the positive ions hit the target surface and eject one or more atoms of the target in addition to the secondary electrons. The neutral atoms will then fly through the chamber and land onto the wafer.



DC sputtering schematic

- Most commonly used gas Argon.
- The magnet is used to increase the ionization ~~of~~ yield of gas atoms.
- The magnetic field traps the moving electrons in an helical path, increasing the length of their trajectory and thus increasing the ~~[illegible]~~ chance they hit a gas atom.

RF sputtering for insulating sample

⑫ **Chemical Vapor Deposition:**

- Atomospheric CVD (APCVD)
- Low pressure CVD (LPCVD)
- Ultra high vacuum CVD (UHCVD).

Working principle: decomposition of a gas on the heated surface of the wafer in the absence of any reagent, a phenomenon called pyrolysis.

: performed in a simple furnace with a gas inlet and connected to a vacuum pump to maintain a controlled pressure.

: Depending on the gas or gas mixture it is possible to deposit a wide variety of thin films, most common.

- poly silicon using decomposition of silane (SiH_4) at 620°C.
- Silicon nitride using dichlorosilane (SiH_2Cl_2) and ammonia (NH_3) at 800°C
- Low temp. oxide using silane and oxygen (O_2) at 450°C

Microstructure Release:

(*) The depth of sacrificial layer dissolved under the structure will increase slowly with etching time as

$$d_{release} \propto \sqrt{t_{etch}}$$

i.e. releasing a structure twice as wide will take 4 times more time.

→ if the etching lasts too long. it may effect the material

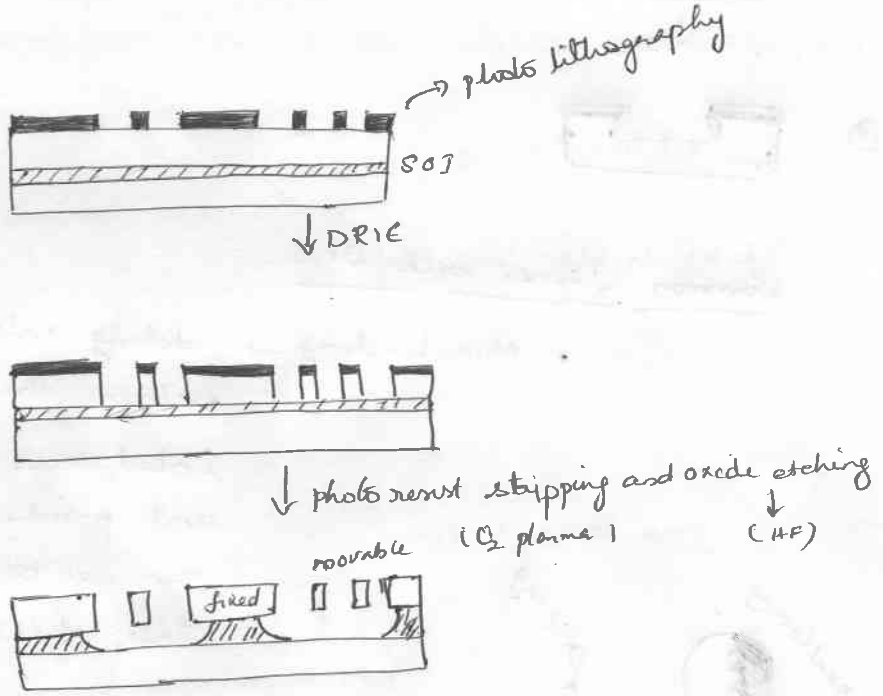
→ Hence it is important to choose compatible materials.

(*). The structure may get pulled down to the substrate while drying - use techniques like super critical drying ($CO_2 > 304.25K$ 7.39 MP

(*) Use dry methods to release - HF vapor

RIE micromachining

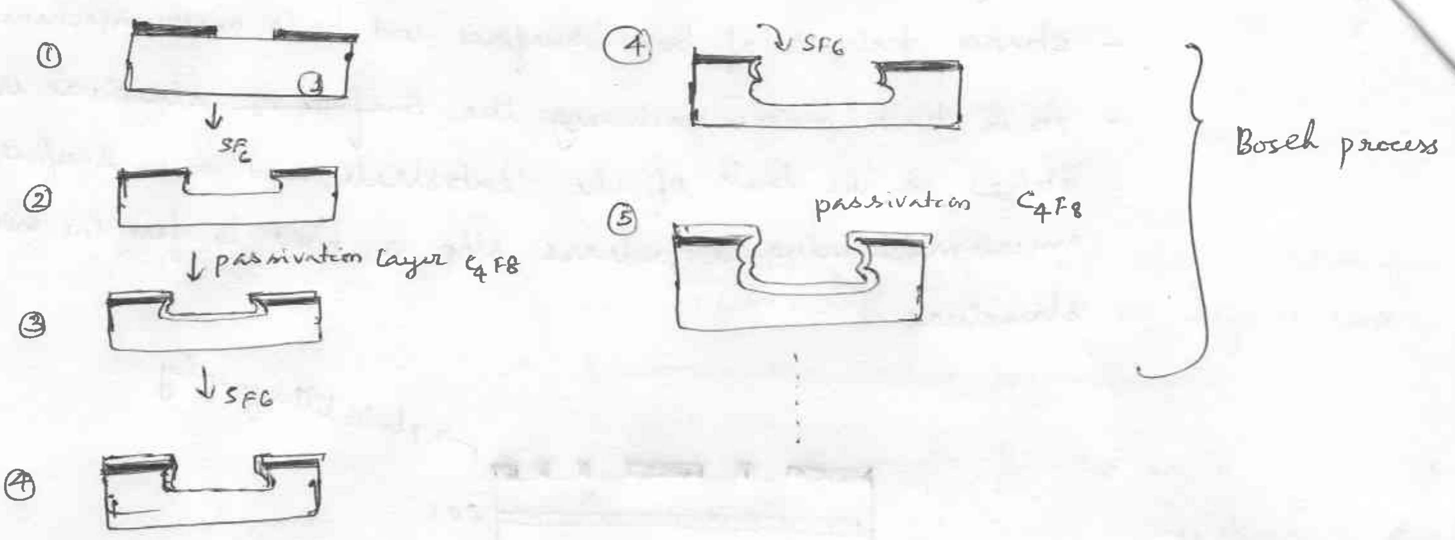
- shares features of both surface and bulk micromachining
- As in bulk micromachining, the ~~surface is~~ structure is etched in the bulk of the substrate, and as in surface micromachining a release step is used to free the micro structure.



- Inorder to increase the anisotropy for deep etch, DRIE usually adopts the patented '**Bosch process**'
- Bosch process is a repetition of two alternating steps:
  (1) passivation
  (2) etching

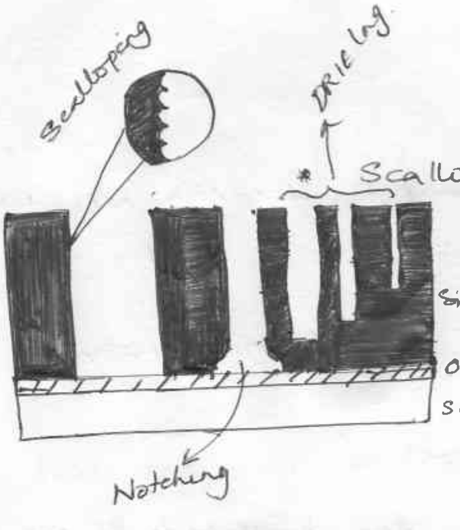
* In the passivation step, C_4F_8 gas flows into the chamber forming a polymer protective layer ($n(-CF_2-)$) on all the surfaces.

* In the next step, SF_6 gas in the plasma chamber is dissociated to F- radicals and ions. The vertical ion bombardment sputter away the polymer at the trench bottom, while keeping the sidewall untouched and still protected by the polymer. The radicals then chemically etch the silicon on the bottom making the trench deeper. By carefully controlling the duration of the etching and passivation steps, trenches with aspect ratio 25:1 are easily fabricated.



Common Issues with DRIE

* Microloading → etching rate is slower for high density patterns than for low density ones which is linked with the transport speed of reactan and products to and from the surface. This can be improved by increasing the flow rate of the gas.



* Scalloping → Presence of regular ripples with an amplitud over 100 nm on the vertical edge of trenches. The ripples come due to isotropic etching and passivating steps.

- Can be removed by shortening the etch step to 1 s, instead of standard 7 s and by reducing the passivation step duration accordi

* DRIE lag → In narrow trenches, ion charging at the side wall lowers the energy of the ions, decreasing etching rate as compared to what happens in wide trenches. (aspect-ratio dependent etching effect)

*1 Notching → After the silicon is completely etched, the oxide layer is exposed and positive charge build up to the insulating layer. The local charge deviates the incoming ions laterally, causing an increased etch at the lower portion of the side wall of the trench

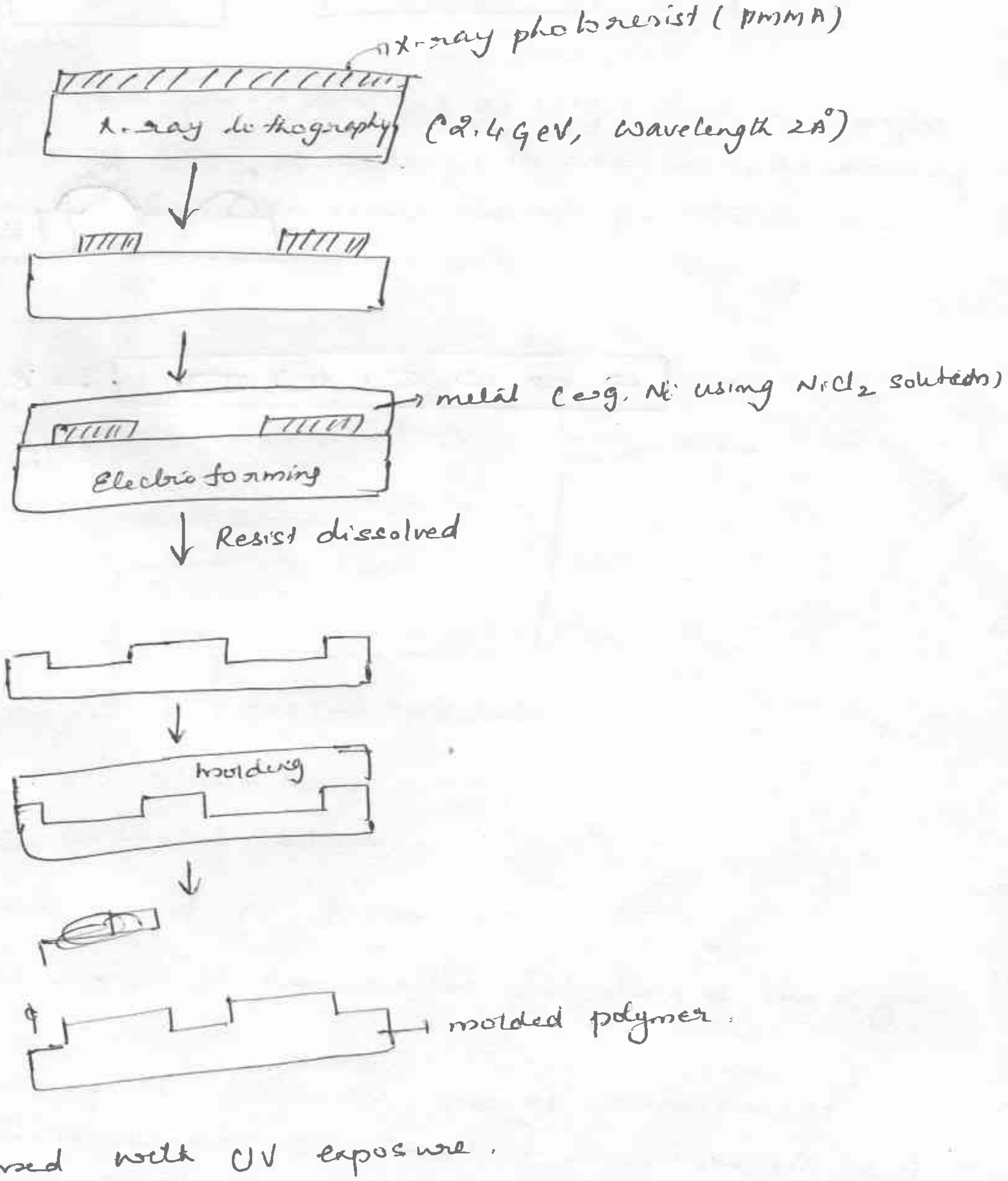
Other microfabrication techniques:

(1). Micro-molding and LIGA: (Lithography, electro forming (Galvanoforming) and molding (Abformung))

→ No material is removed but simply molded.

→ 3D microstructures with non-silicon materials like metals, plastics or ceramics, using replication or molding.

→



can also be used with UV exposure.

(2). Polymer MEMS:-

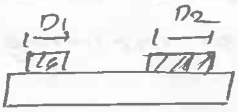
- Bulk and surface micromachining can be classified as direct etch method, where the device pattern is obtained by removing material from the substrate or from deposited layers

- Etching → lithography → pattern photoresist

- why can't we use the pattern present in photoresist

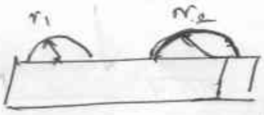
→ lithography for mems using ultra-thick photoresist that can be spun upto ~~100~~ several 100 μm and exposed with standard mask aligner, providing quick way to the production of microparts.

e.g. fabrication of microlenses.



place
→ at temp. higher than glass transition temp of the polymer.

↓ the polymer melts.



← and will assume spherical shape

→ By varying diameter of pillar diff. radius of curvature