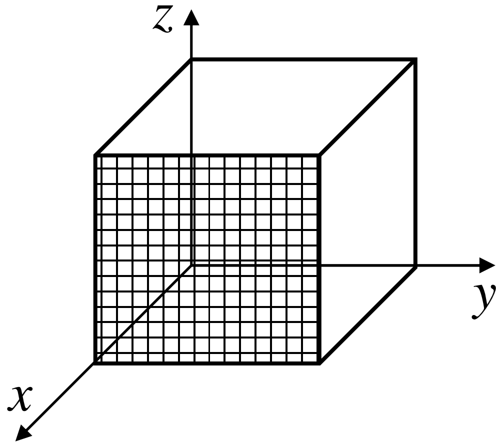
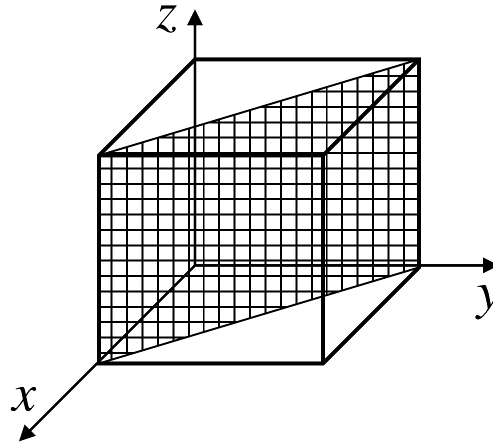
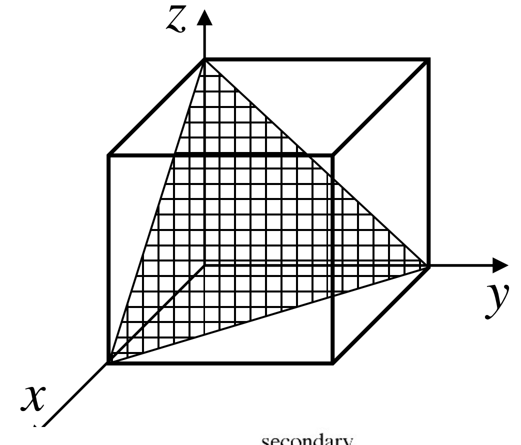
wafer (100)

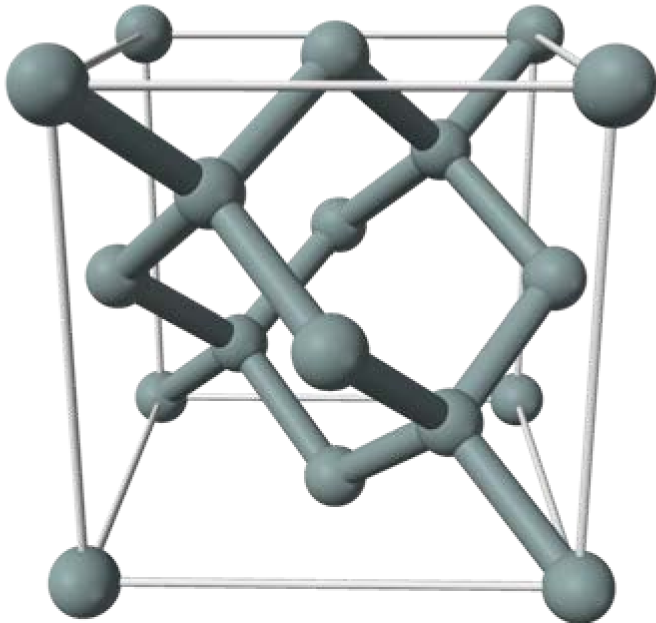


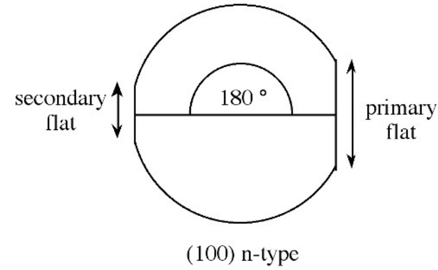
wafer (110)

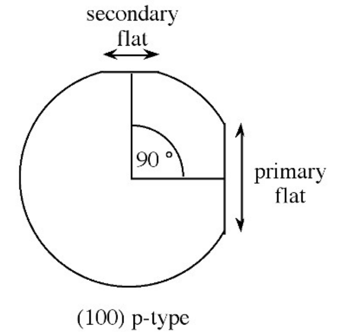


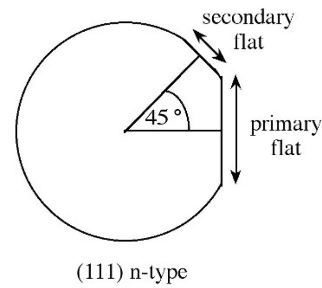
wafer (111)

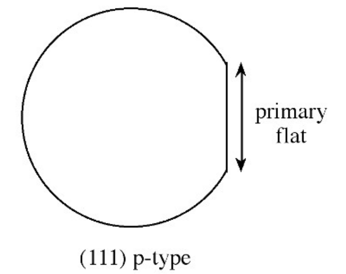


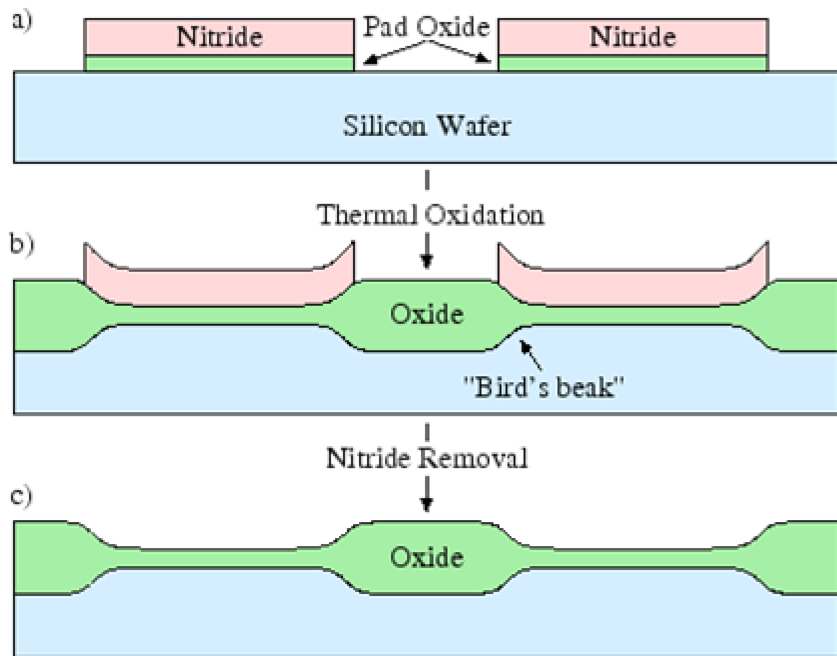


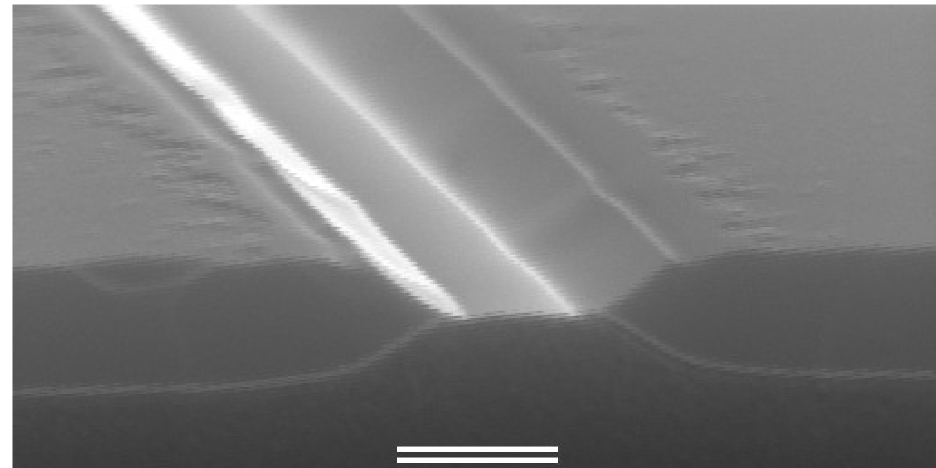




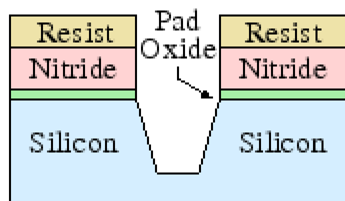




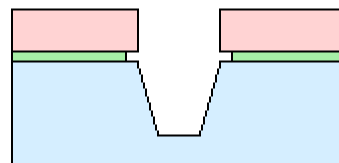




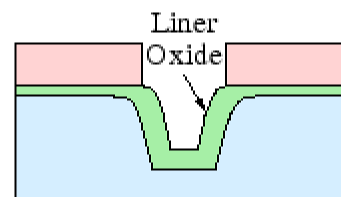
Scanning Electron Microscope (SEM) image



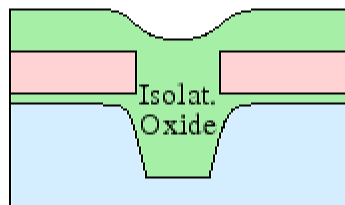
a) Stack and trench etching



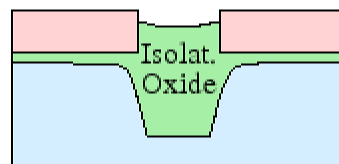
b) Pad oxide underetching



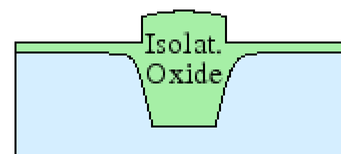
c) Liner oxidation



d) CVD Oxide gap fill



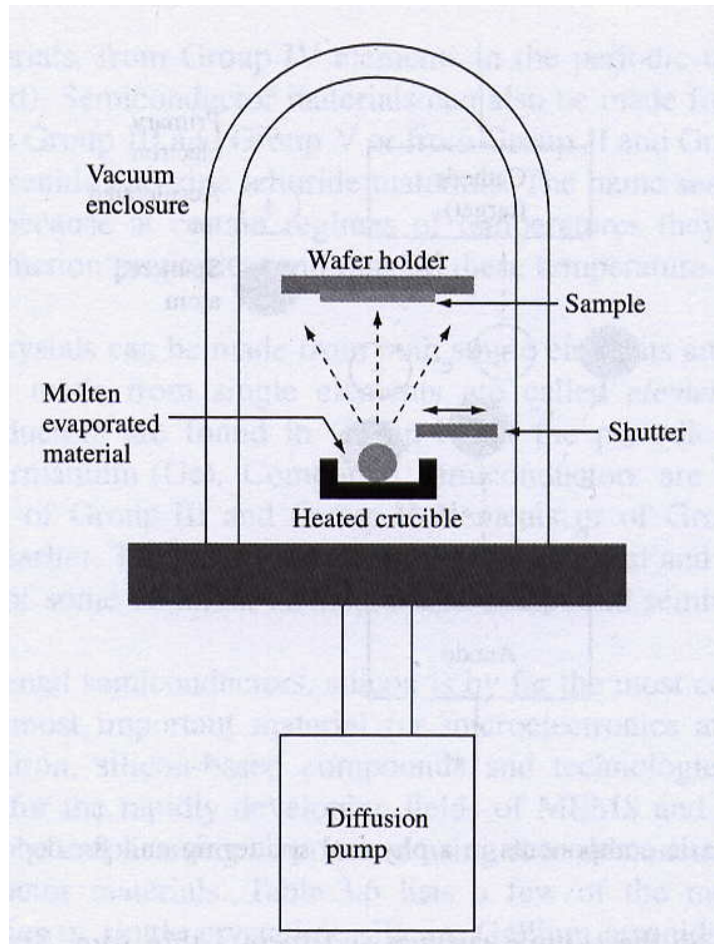
e) CMP



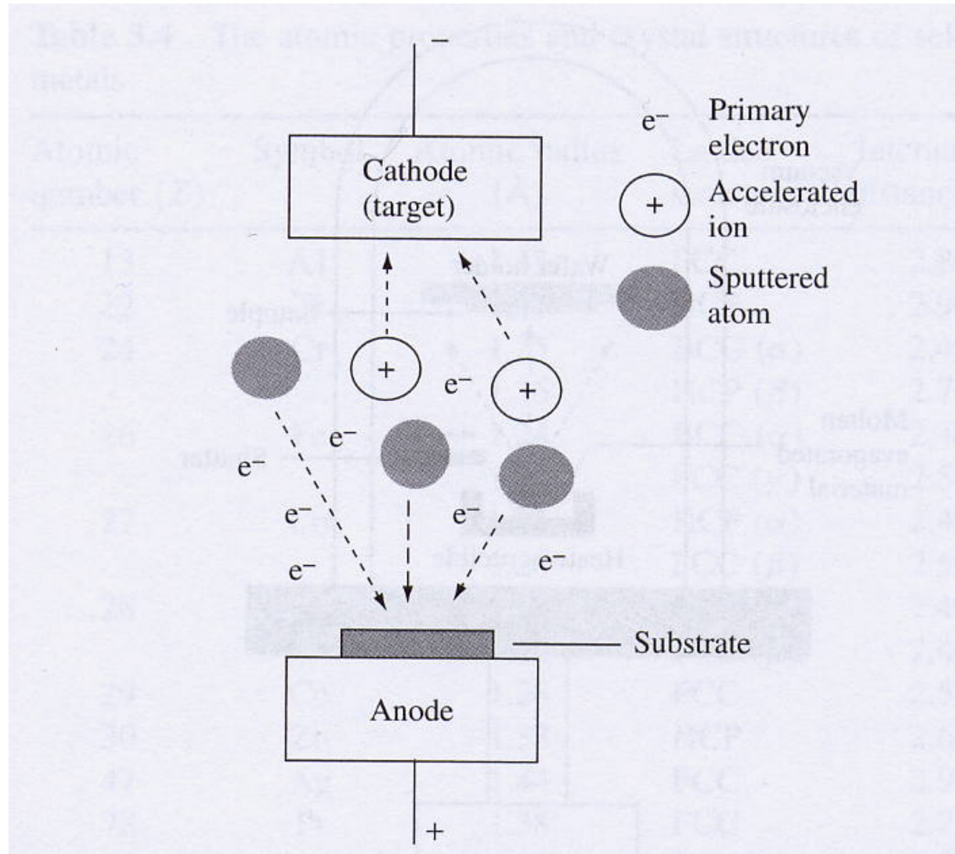
f) Nitride strip

- Processi di deposizione di strati sottili di materiali

i) Physical Vapor Deposition



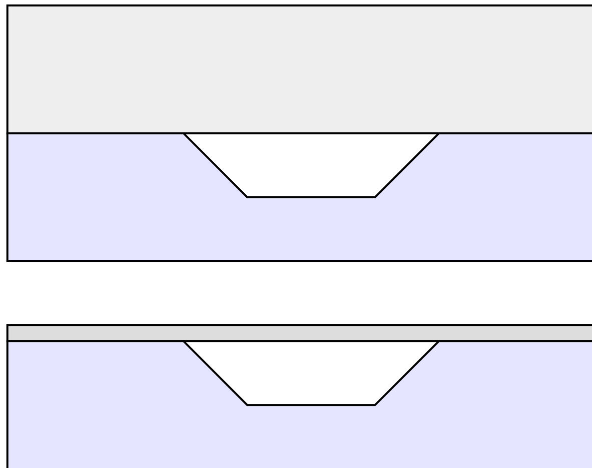
ii) sputtering



A) PROCESSI A LIVELLO DI WAFER

i) adesione diretta

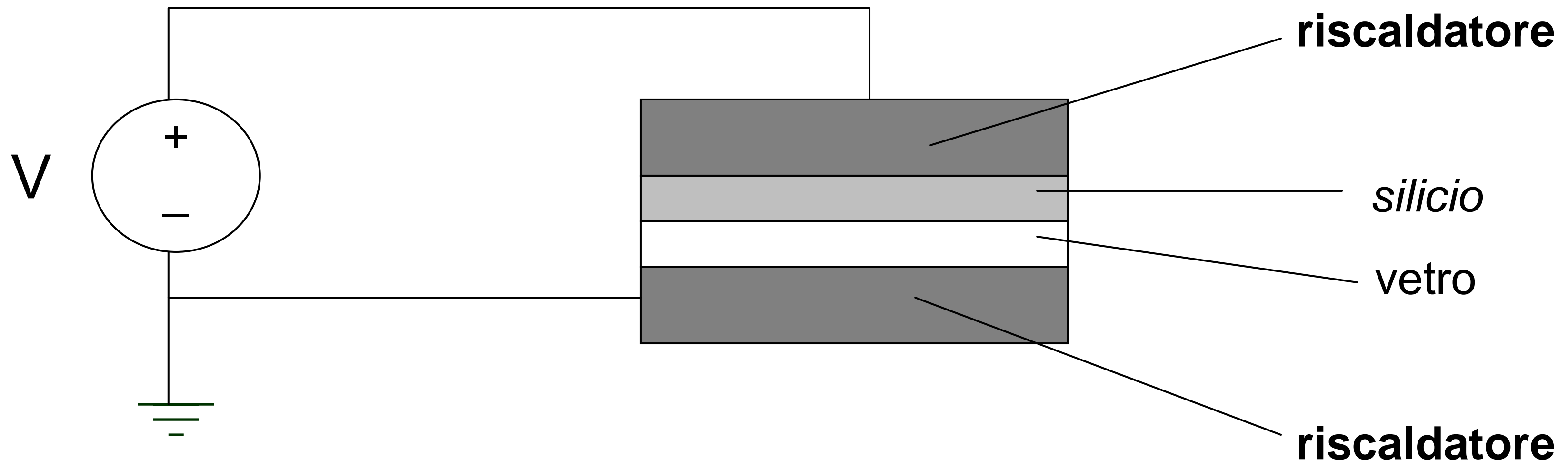
richiede temperature altissime (~1000°C)



A) PROCESSI A LIVELLO DI WAFER

ii) Bonding anodico

questa tecnica di adesione viene usata solo per attaccare certi vetri ai conduttori (o al silicio)



il meccanismo responsabile dell'adesione anodica è la mobilità degli ioni di ossigeno verso l'interfaccia, dove si legano con il silicio (si forma il legame)

T ~ 500° C

V ~ 300 - 700 V

un ottimo candidato è il **Pyrex 7740**

(coeff. di espansione termica simile a quello del Si).

B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

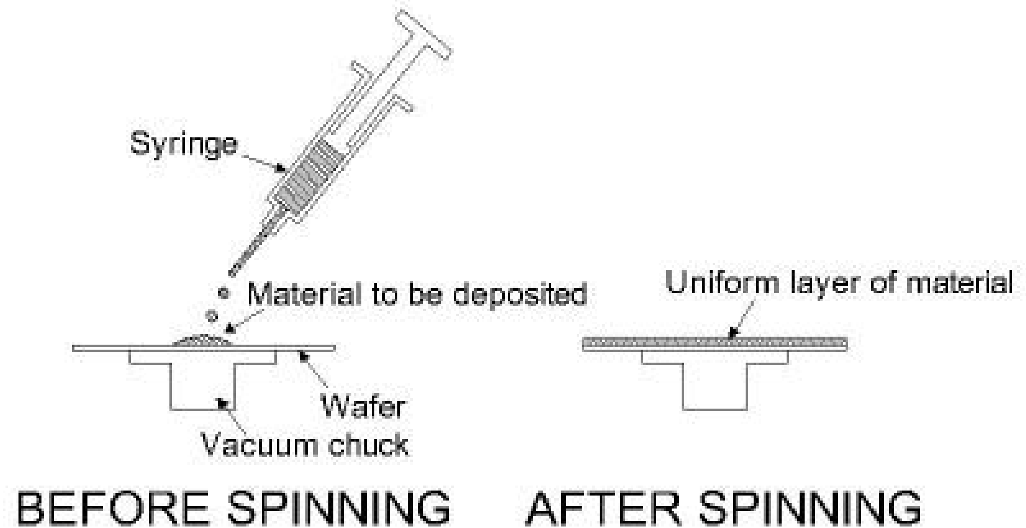
Realizzazione della geometria (layout) desiderata:

1) processo litografico (trasferimento dell’immagine desiderata sul film di fotoresist che copre la fetta di silicio)
2) processo chimico o fisico di rimozione o aggiunta di materiali per creare il dispositivo

B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

1) Processo litografico

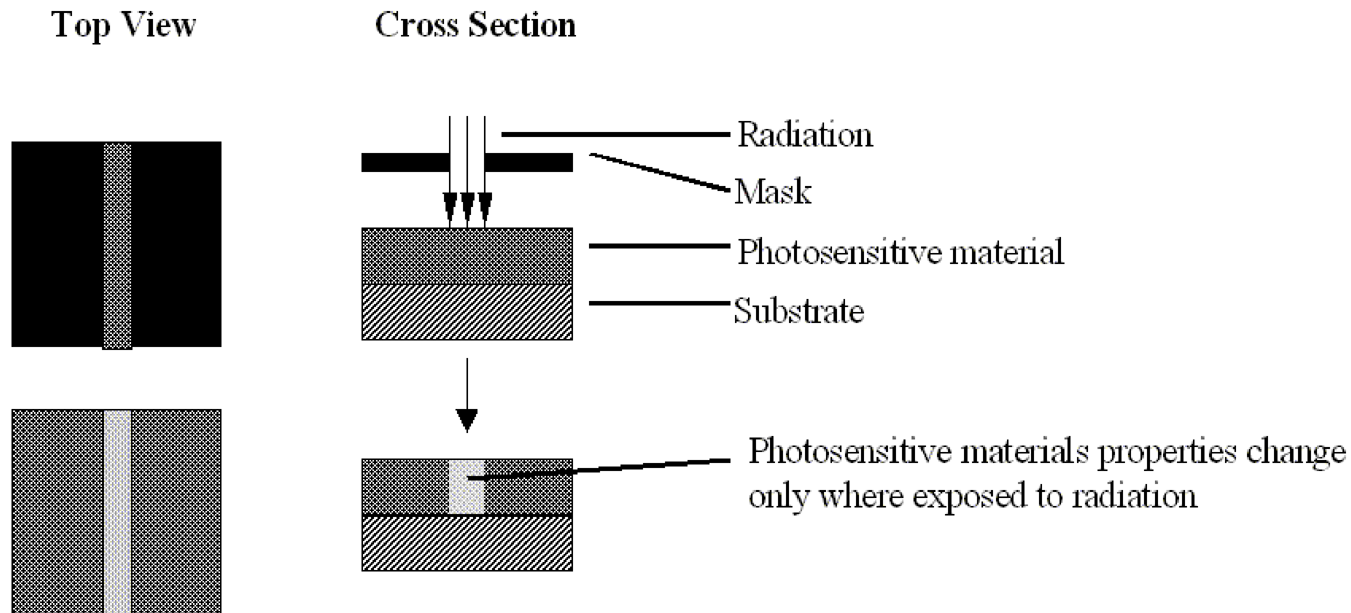
Deposizione del polimero fotosensibile (resist)

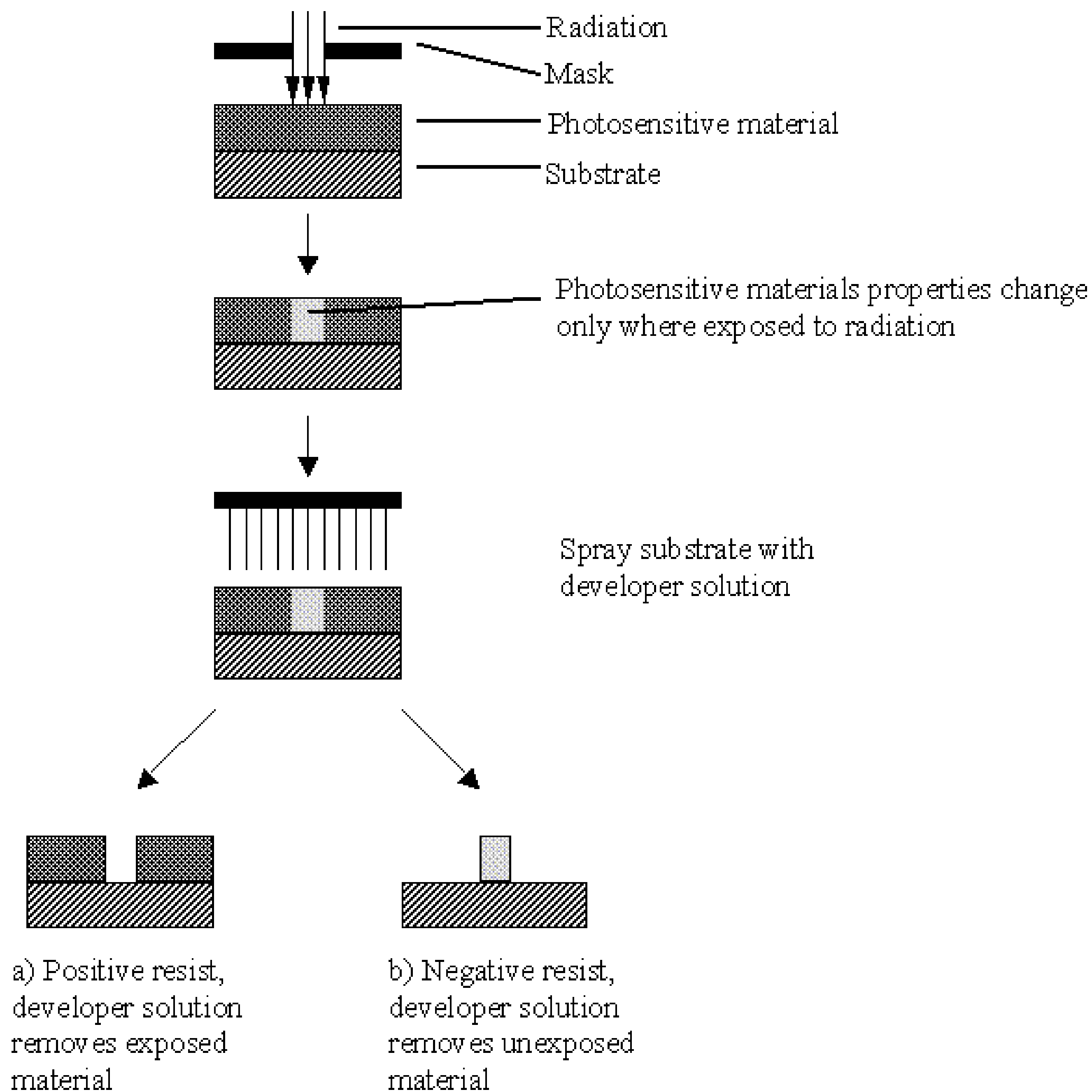


B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

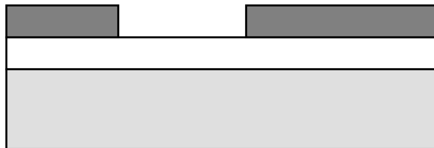
1) Processo litografico

Trasferimento del pattern geometrico al materiale fotosensibile

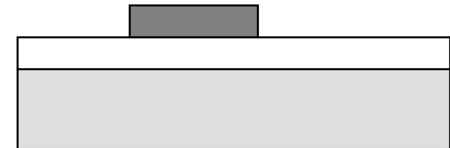


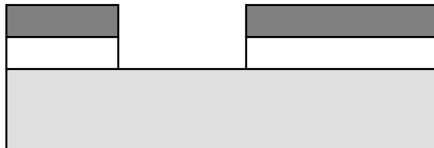

Radiation
Mask
Photosensitive material
Substrate
Photosensitive materials properties change only where exposed to radiation
Spray substrate with developer solution
a) Positive resist, developer solution removes exposed material
b) Negative resist, developer solution removes unexposed material

negative resist *positive resist*

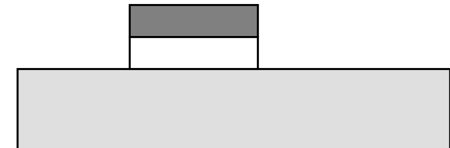


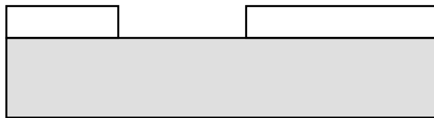
si pulisce la superficie dal resist residuo



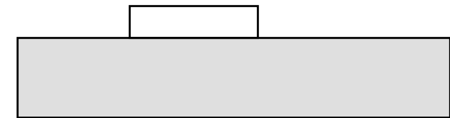


si fa l'attacco chimico dell'ossido





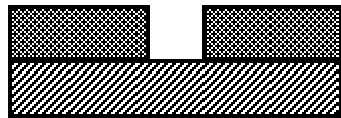
si fa l'attacco chimico del resist indurito

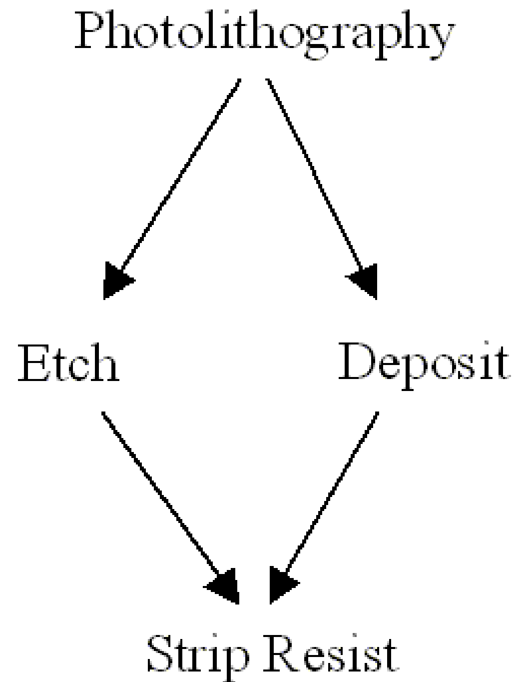


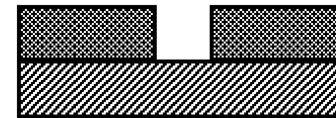
2) processo chimico o fisico di rimozione o aggiunta di materiali: trasferimento del pattern geometrico al wafer

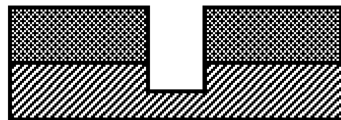
Subtractive Process

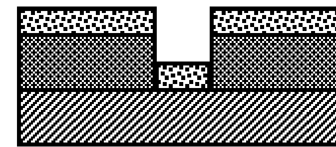
Additive Process

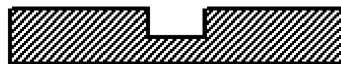


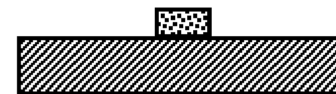












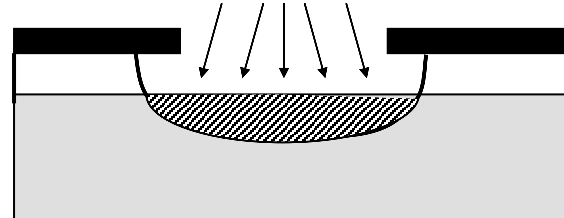
Pattern transfer by etching

Pattern transfer by lift off

B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

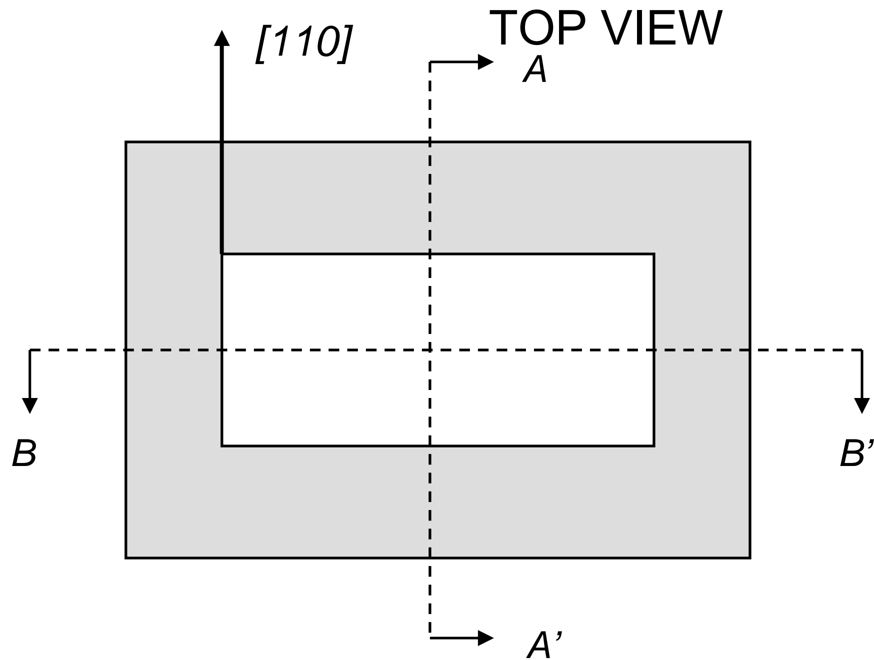
i) *attacco chimico isotropo*:

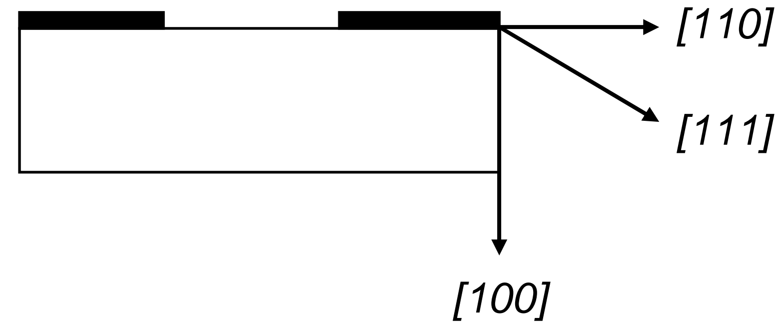
L'aggettivo ***isotropo*** indica che la quantità di materiale rimosso non dipende dall'orientazione del substrato; l'attacco è laterale come verticale

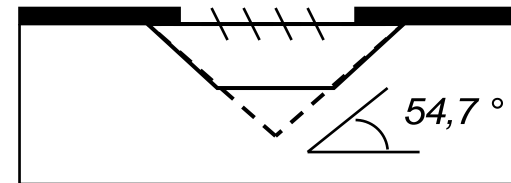


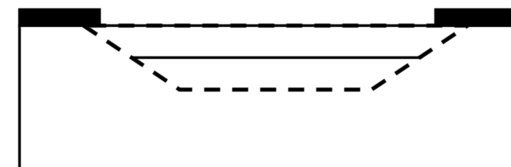
B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

ii) attacco chimico anisotropo:



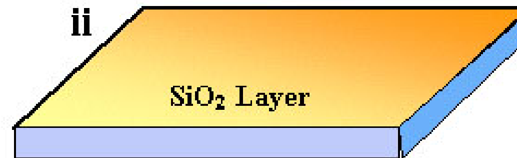


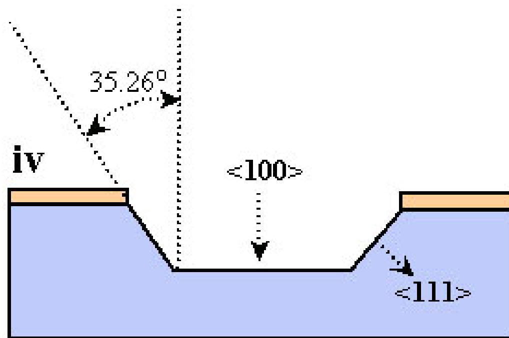


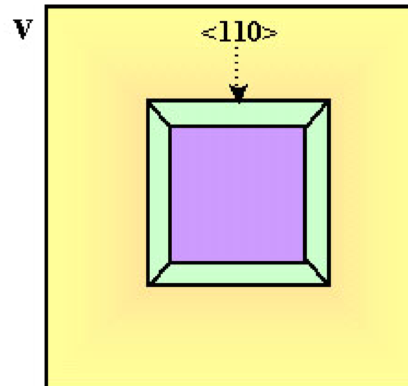


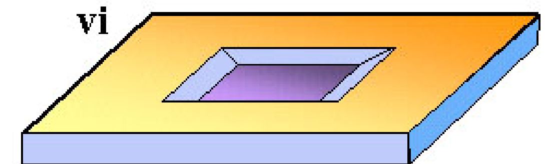
B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

ii) attacco chimico anisotropo:





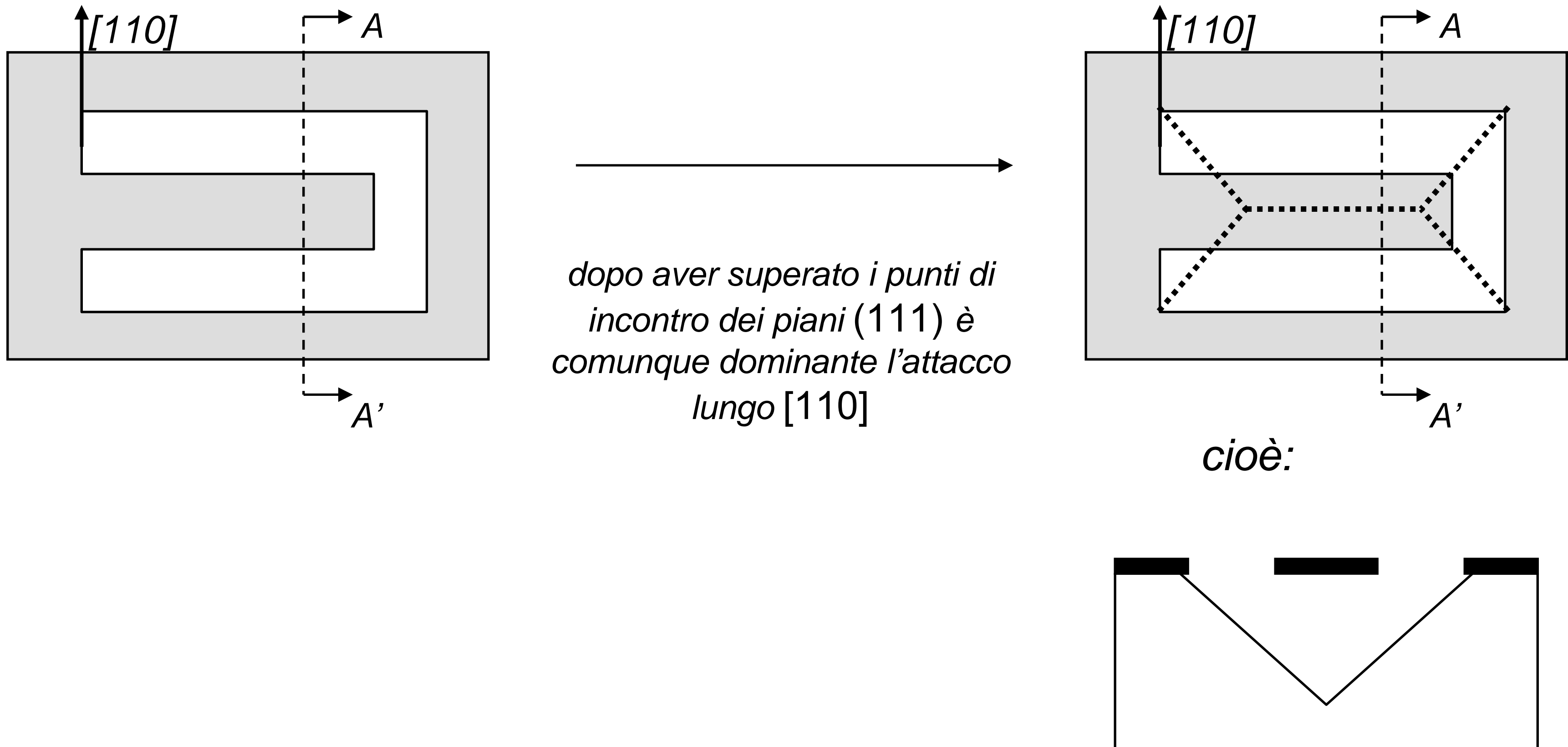




B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

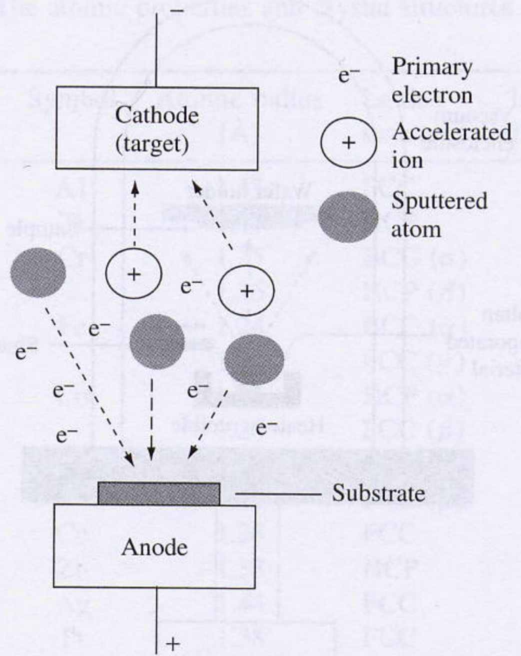
ii) attacco chimico anisotropo:

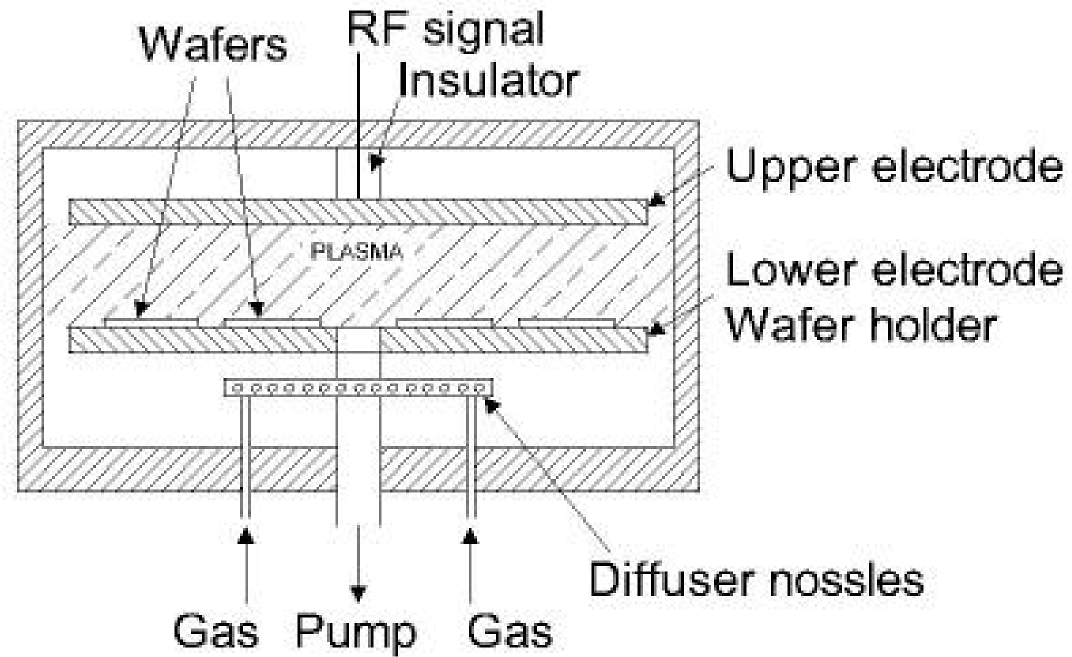
Come usare questa proprietà per creare delle strutture <u>sospese</u>?



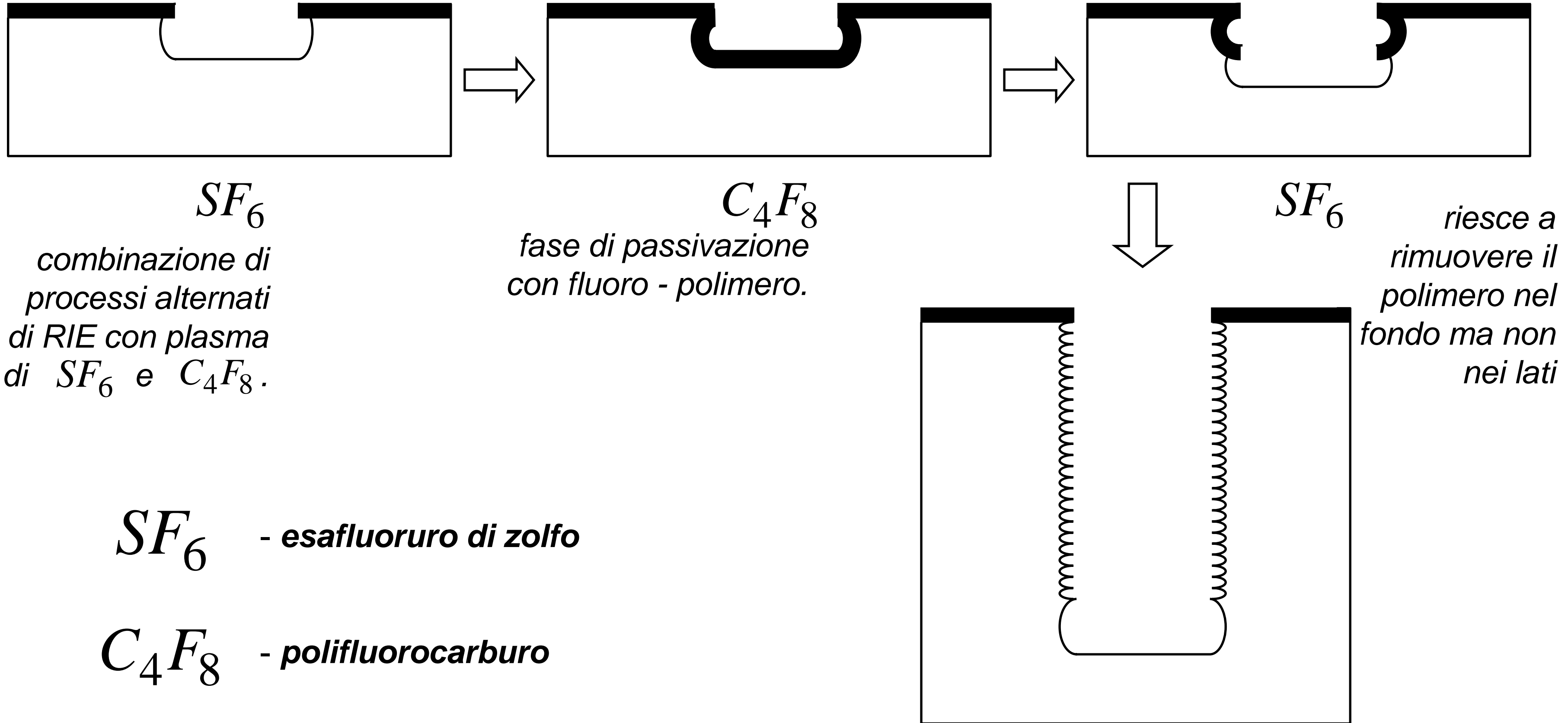
B) PROCESSI DI TRASFERIMENTO DEL PATTERN GEOMETRICO

iii) RIE





DEEP REACTIVE ION ETCHING (DRIE)



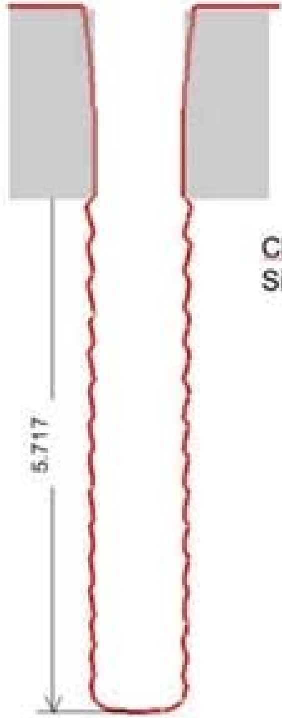
SF_6 - ***esafluoruro di zolfo***

C_4F_8 - ***polifluorocarburo***

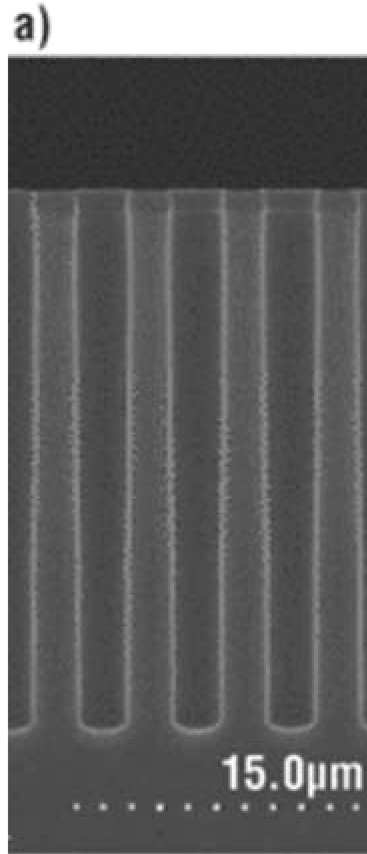
1um/0.2um

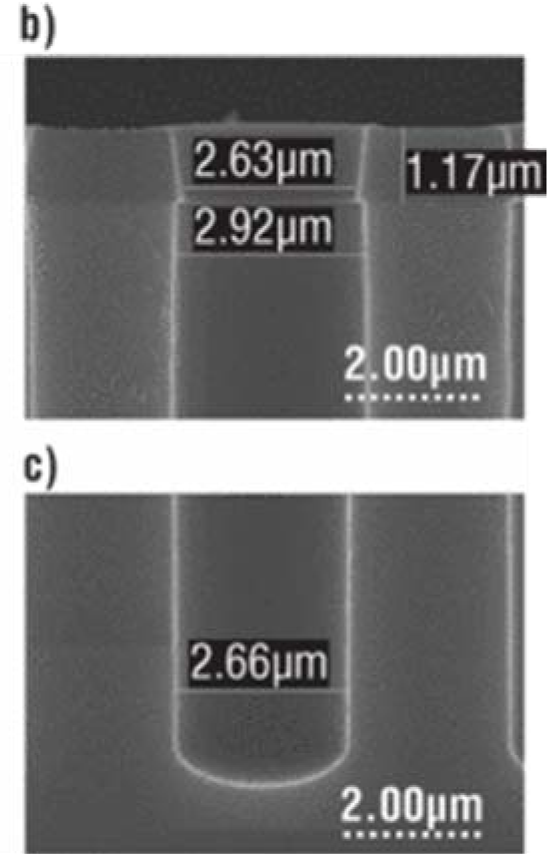
DEEP REACTIVE ION ETCHING (DRIE)

Experimental data
(SEM of Jarecki)



ChISELS
Simulation





Processo di fabbricazione LIGA

LIGA é l’acronimo tedesco di:

LI*thographie*

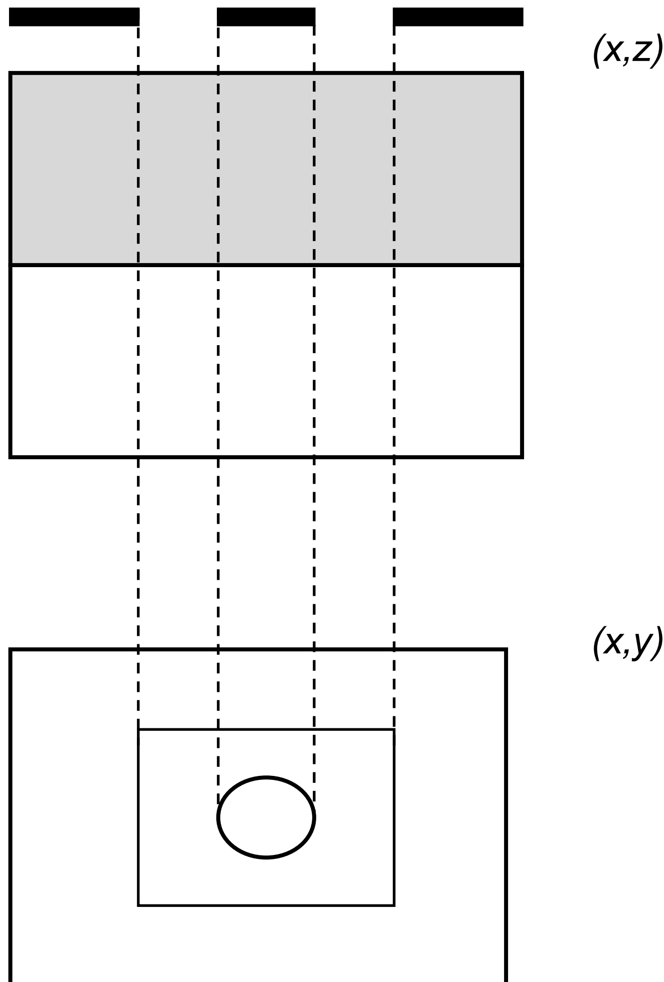
G*alvanoformung*

A*bformung*

Consiste in tre passi:

- litografia
- ricopertura per elettrolisi
- stampo

Processo di fabbricazione LIGA



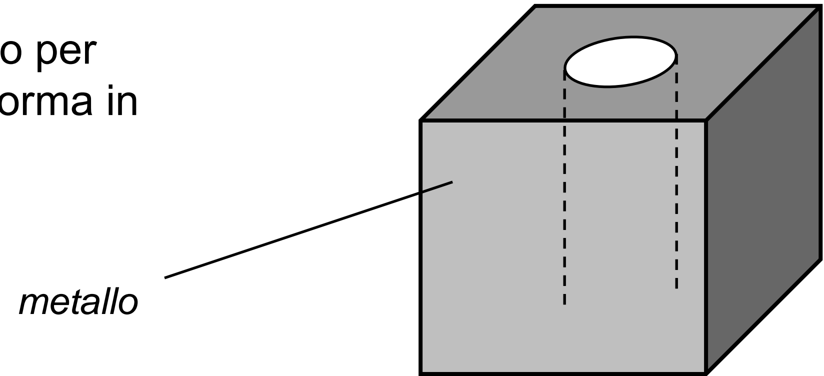
per penetrare il fotoresist fino in profondità e con lati ben definiti si deve usare una luce altamente collimata ad alta energia nell'intervallo dei raggi X

la forma desiderata viene realizzata con alta precisione.

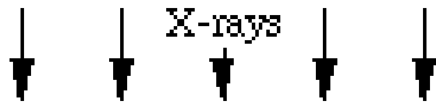
Quando viene eliminata la parte non indurita ho uno stampo in plexiglass della struttura con un'altezza di 300 – 500 µm !

Processo di fabbricazione LIGA

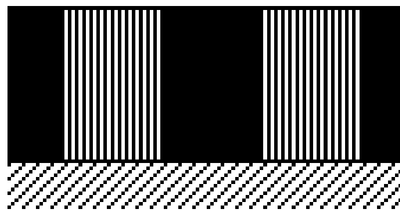
Passo allora a riempire lo stampo con metallo per deposizione elettrochimica ed ottenere una forma in metallo con un fattore di forma altissimo



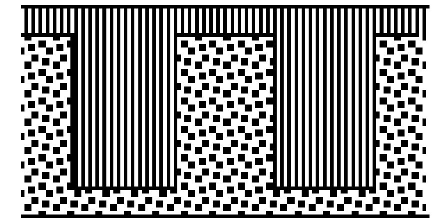
Processo di fabbricazione LIGA



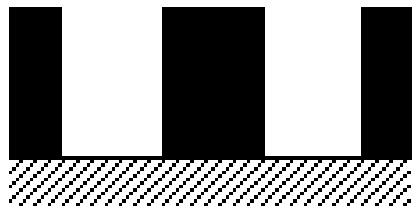
(a)



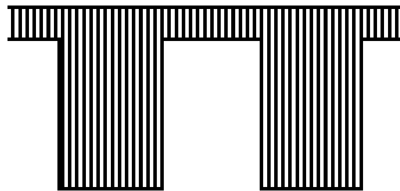
(c)



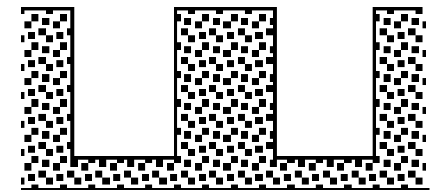
(e)



(b)

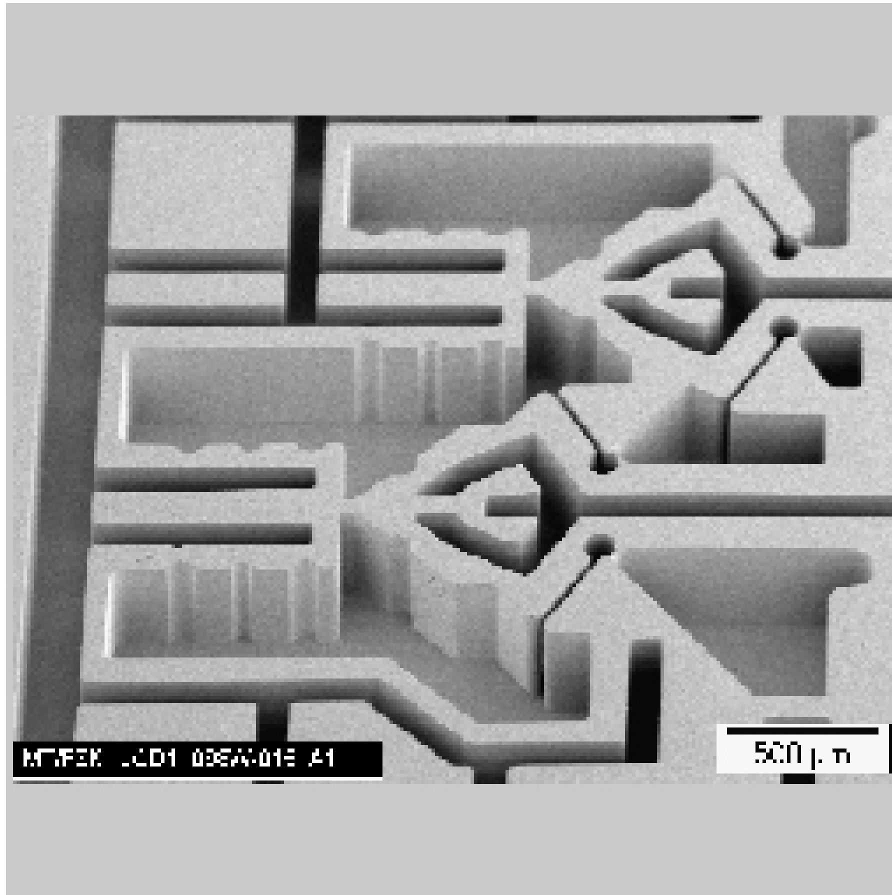


(d)

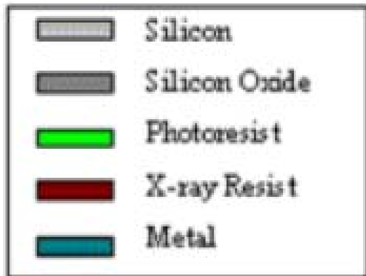


(f)

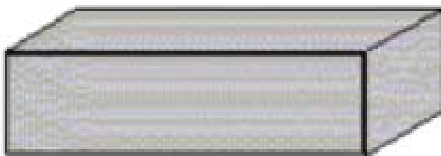
Processo di fabbricazione LIGA



Processo di fabbricazione LIGA

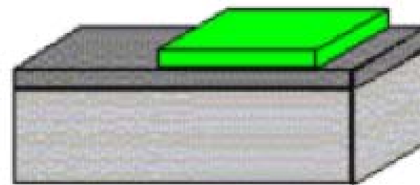


Initial Substrate

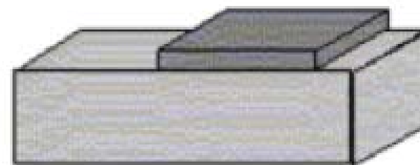


Apply Sacrificial Layer and Photoresist

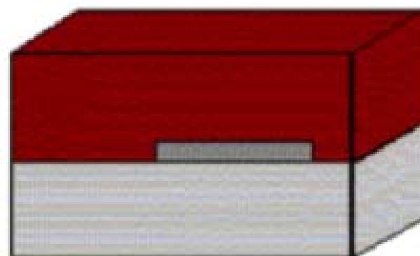
Mask, Irradiate, and Develop Photoresist



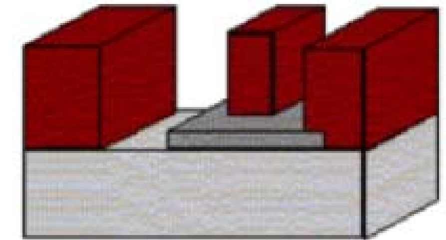
Etch Sacrificial Layer



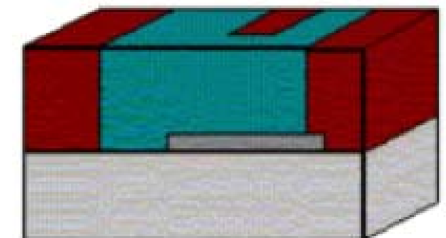
Apply X-ray Resist



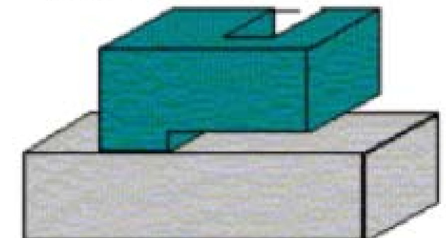
Mask, Irradiate, and Develop X-ray Resist



Deposit Metal



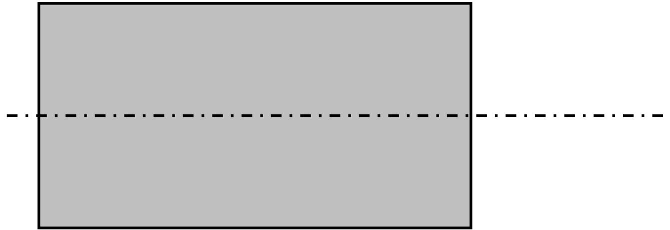
Remote X-ray Resist and Sacrificial Layer

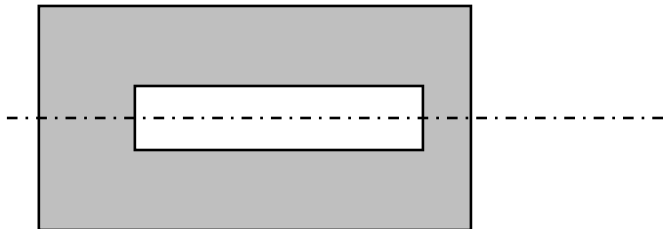


SURFACE MICROMACHINING

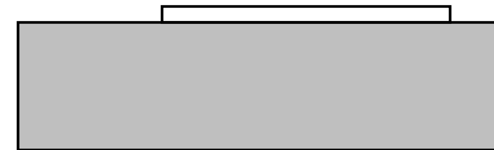
TOP VIEW
(x,y)

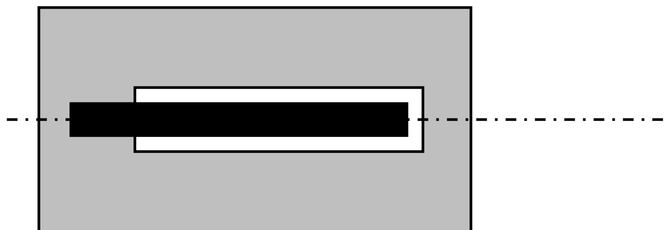
CROSS SECTION
(x,z)



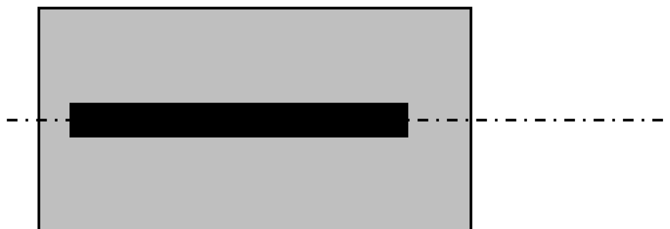


ossido
superficiale





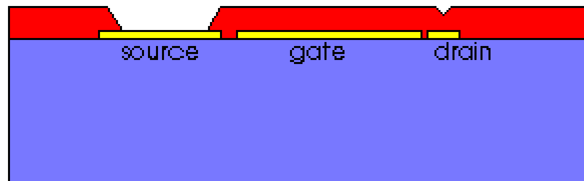
silicio poly

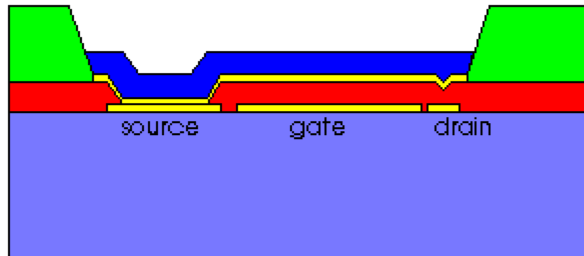


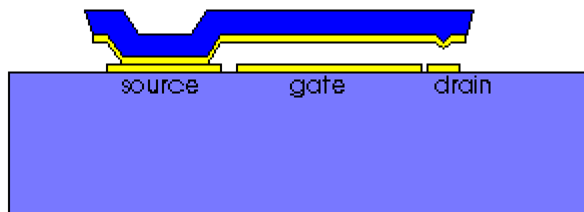
attacco
chimico
isotropo
selettivo

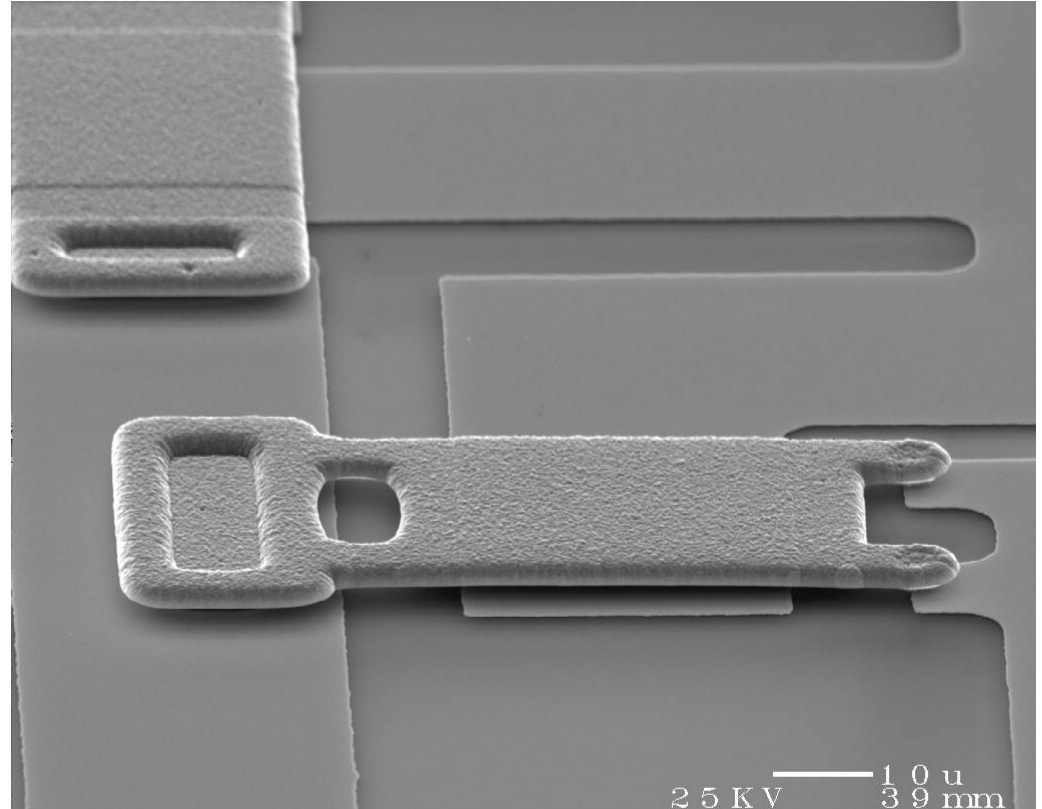
realizzazione
di una trave
in silicio poly

Electrostatically actuated micromechanical switches using surface micromachining









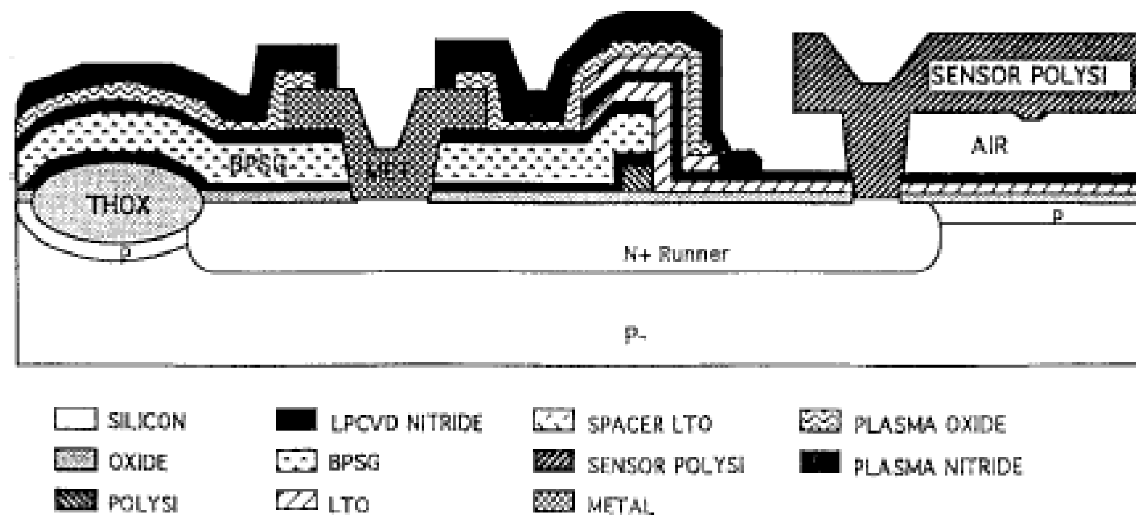


Fig. 5. Cross-section illustration of the Analog Devices BiMEMS integrated MEMS technology. Electrical connections to the structural device are made using the diffused n^+ runner [25].

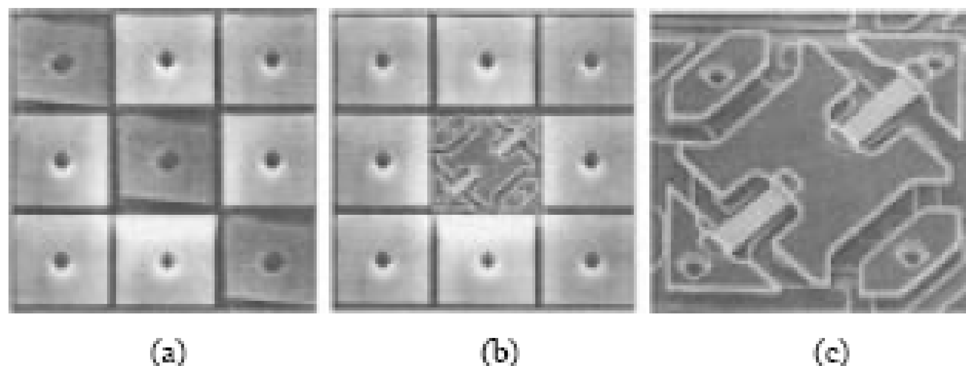
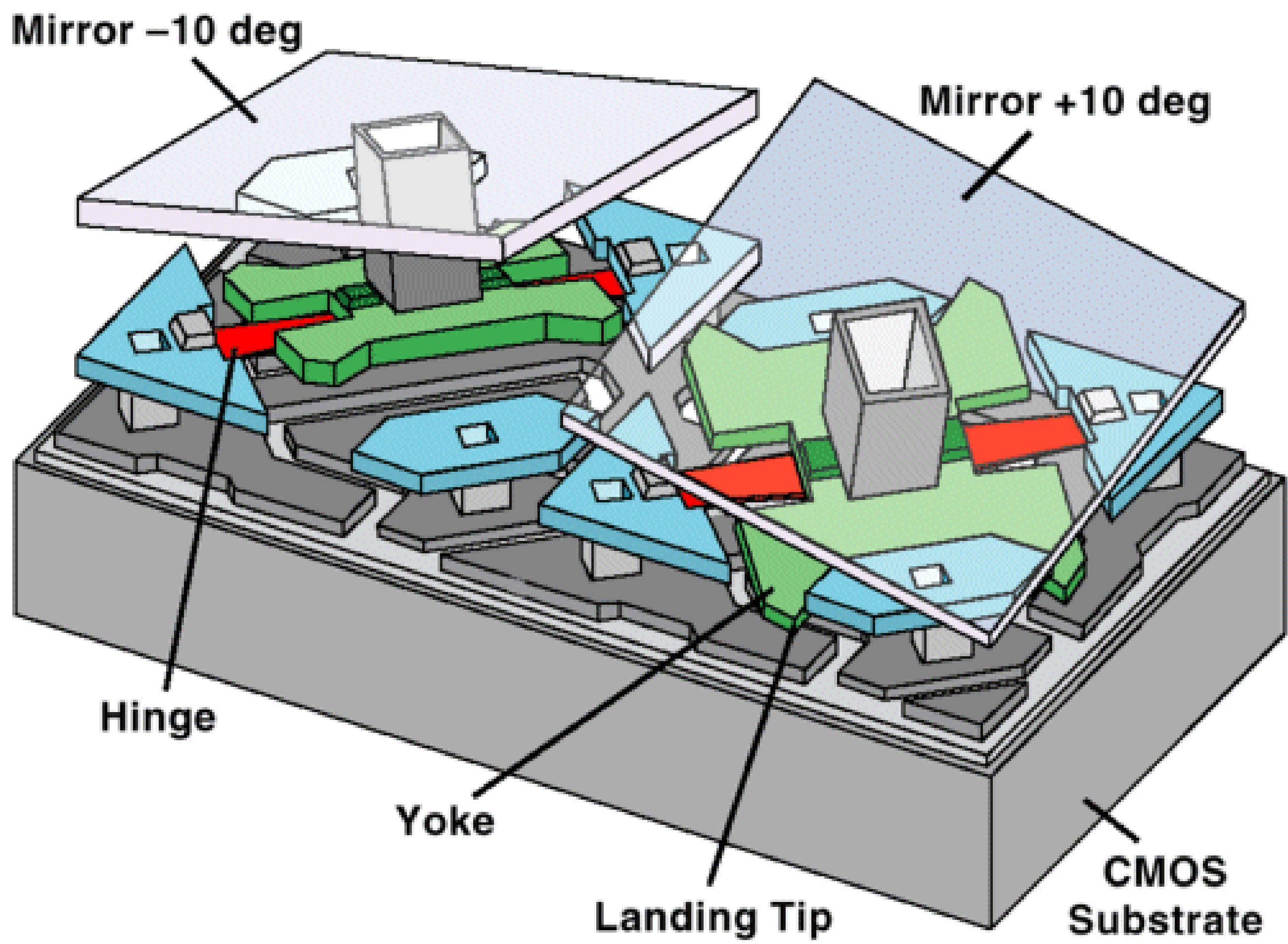
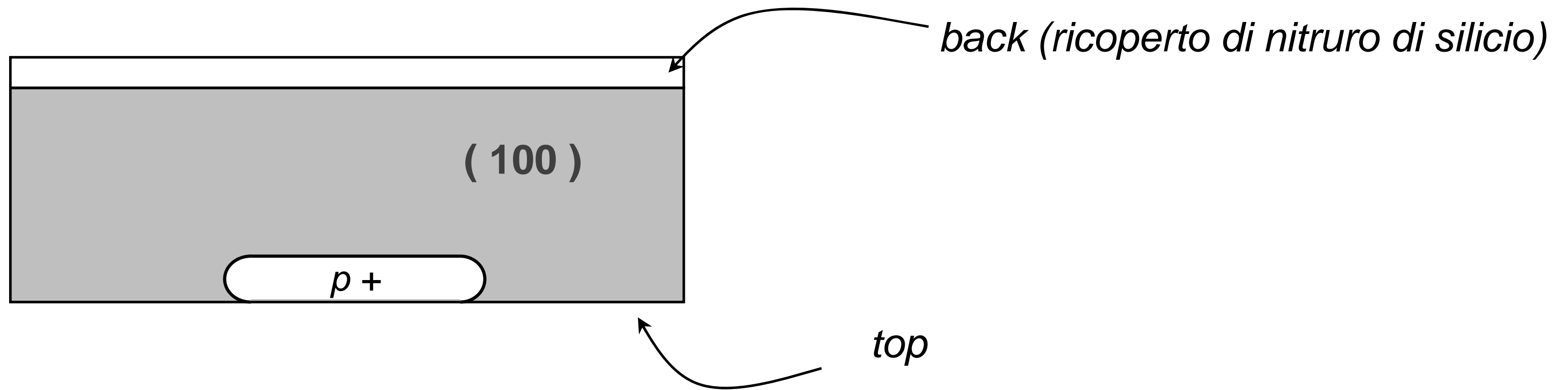


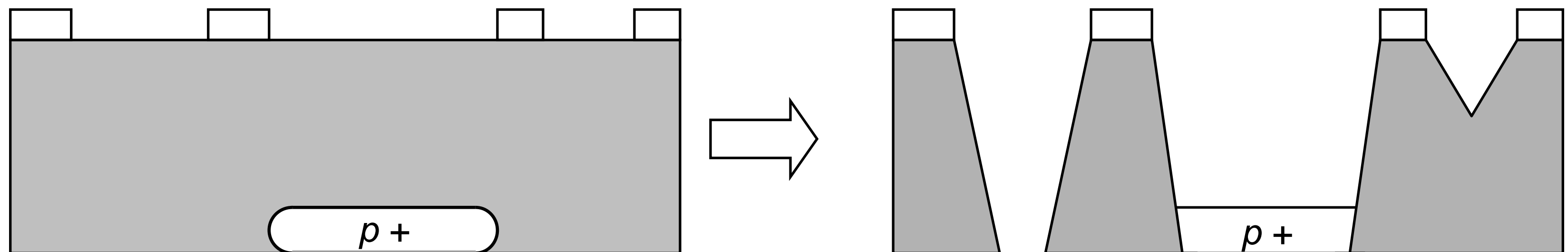
Fig. 16. Closeup photographs of aluminum mirrors on the surface of a DMD and the underlying substructure. View (a) shows nine mirrors with three mirrors tilted to the on position, $+10^\circ$. In View (b), the central mirror is removed to expose the underlying, hidden-hinge structure. View (c) shows a closeup view of the mirror substructure. (Figure details as described in [132].)



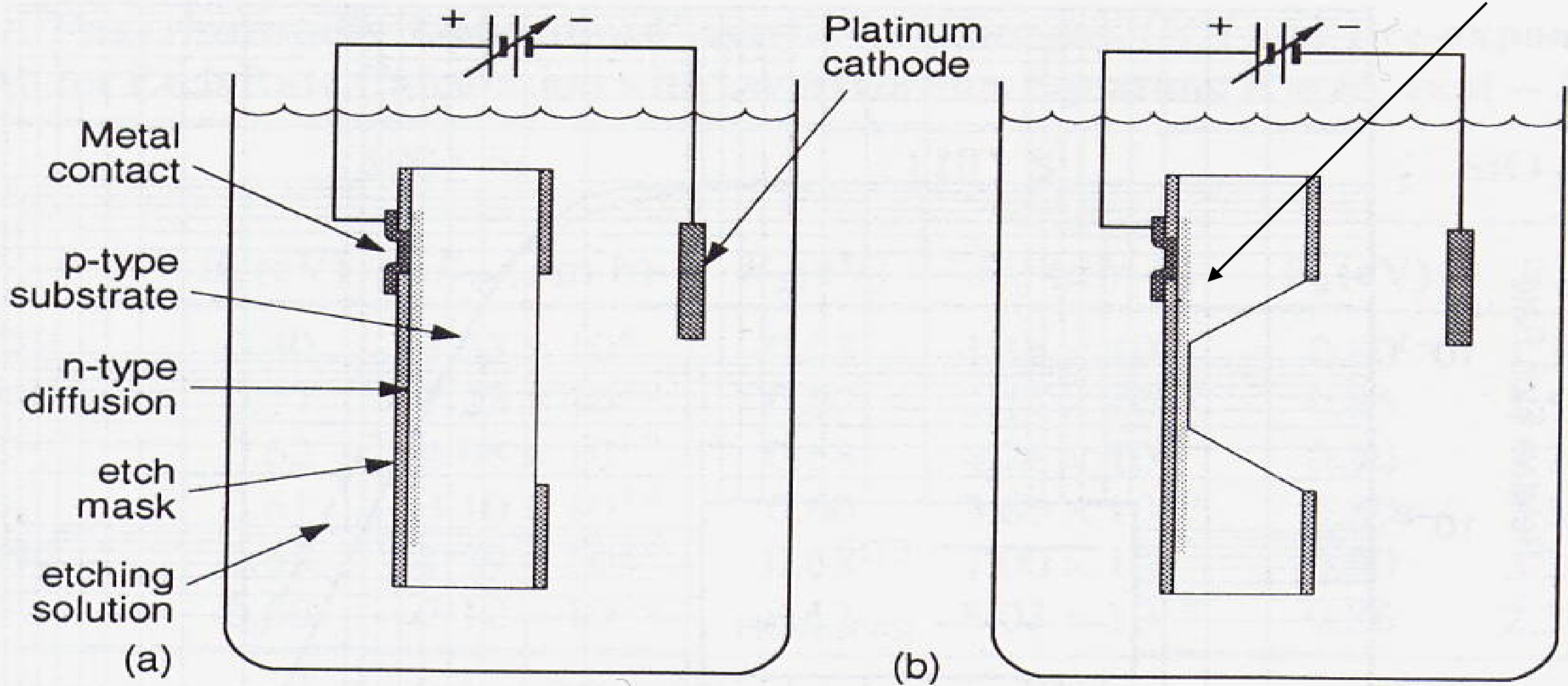
Mirror –10 deg
Mirror +10 deg
Hinge
Yoke
Landing Tip
CMOS
Substrate

BULK MICROMACHINING





BULK MICROMACHINING



BULK MICROMACHINING