Discussion 3

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OXIDATION

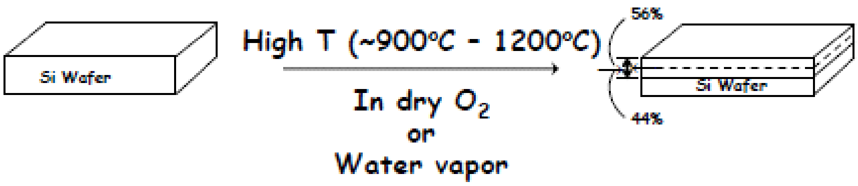
For dry oxygen:

$Si + O_2 \rightarrow SiO_2$

For water vapor:

$Si + 2H_2O \rightarrow SiO_2 + 2H_2$

Schematically:

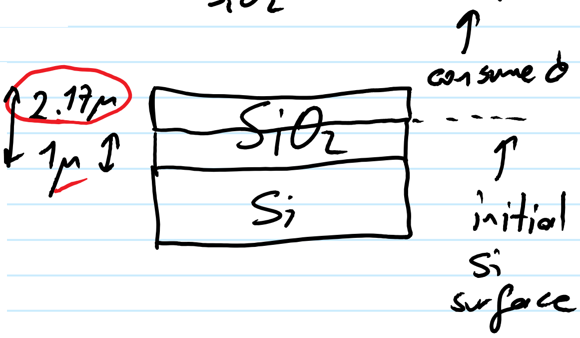


Molecular density

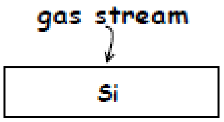
$SiO_2 \rightarrow 2.3e^{22}$ molecules/cm^3

$Si \rightarrow 5e^{22}$ atoms/cm^3

$\therefore V_{SiO_2} = 2.16 \times V_{Si}$

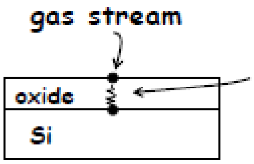


(1) **Initially:** (no oxide @ surface)



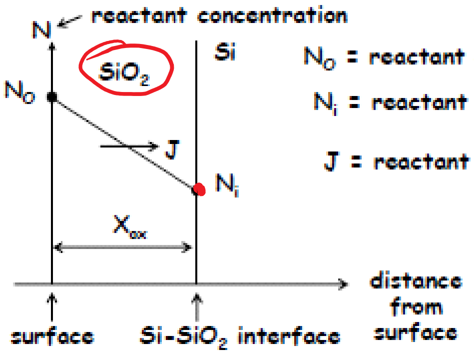
↳ Growth rate determined by reaction rate @ the surface

(2) **As oxide builds up:**



Reactant must diffuse to Si surface where the oxidation reaction takes place

↳ Growth rate governed more by rate of diffusion to the silicon-oxide interface



N_O = reactant conc. at oxide surface [in cm^{-2}]

N_i = reactant conc. at Si-SiO$_2$ interface

J = reactant flux = $-D\dfrac{\partial N(x,t)}{\partial x}$ [Fick's 1st Law of Diffusion]

Diffusion coeff. [in μm/hr or m/s]

In the SiO$_2$: $\boxed{J = D\dfrac{(N_O - N_i)}{X_{OX}}}$ = constant (1)

[in # particles/(cm^2·s)]

Assumption that the reactant does not accumulate in the oxide.

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At the Si-SiO$_2$ interface:

Oxidation rate $\propto$ N$_i$ $\therefore$ J $\propto$ N$_i$ $\Longrightarrow$ $\boxed{J = k_s N_i}$ (2)

conc. Si/SiO$_2$ interface

Reaction rate constant @ Si-SiO$_2$ interface

At steady state

$J_1 = J_2$

Combining (1) and (2):

$$\left[N_i = \frac{J}{k_s}\right] \Rightarrow J = D\left(\frac{N_O - J/k_s}{X_{OX}}\right)$$

$$JX_{OX} = DN_O - \frac{DJ}{k_s} \rightarrow J\left(X_{OX} + \frac{D}{k_s}\right) = DN_O$$

$$\therefore \boxed{J = \frac{DN_O}{X_{OX} + \dfrac{D}{k_s}} = \text{Flux of reactants}}$$

thickness of the grown oxide

$$X_{ox}^2 + AX_{ox} = B(t+\tau)$$

initial condition

$t=0 \rightarrow X_{ox} = X_i$

Result:

additional time required to go from $X_i \rightarrow X_{OX}$

time required to grow X_i [X_i = initial oxide thickness]

$$X_{OX}(t) = \frac{A}{2}\left\{\left[1 + \frac{4B}{A^2}(t+\tau)\right]^{1/2} - 1\right\}$$

A & B depends on the growth conditions. e.g. temperature

where $A = \dfrac{2D}{k_s}$ $\qquad \tau = \dfrac{X_i^2}{B} + \dfrac{X_i}{(B/A)}$

$B = \dfrac{2DN_O}{M}$ $\qquad D = D_O \exp\left(-\dfrac{E_A}{kT}\right)$

[i.e., D governed by an Arrhenius relationship → temperature dependent]

* oxide quality is much better

For shorter times:

$$\left[(t+\tau) << \frac{A^2}{4B}\right] \Rightarrow X_{OX}(t) = \underbrace{\left(\frac{B}{A}\right)}(t+\tau) \Rightarrow$$

oxide growth limited by reaction at the Si-SiO$_2$ interface

Taylor expansion (first term after 1's cancel)

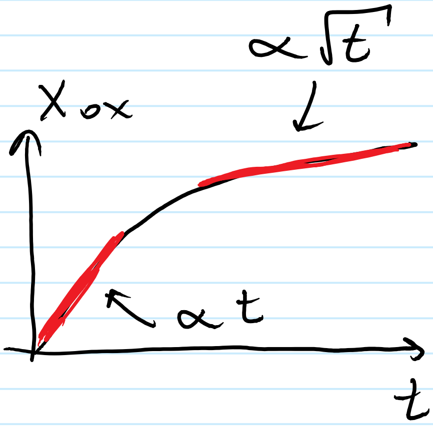
linear growth rate constant

For long oxidation times: oxide growth diffusion-limited

$$\left[(t+\tau) >> \frac{A^2}{4B}\right] \Rightarrow X_{OX}(t) = \sqrt{B(t+\tau)} \approx \sqrt{Bt}$$

$t >> \tau$

Parabolic rate constant



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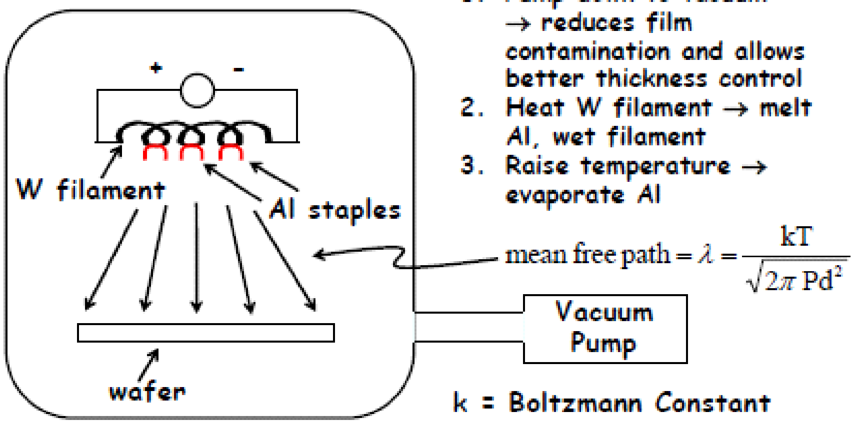
EVAPORATION AND SPUTTER DEPOSITION

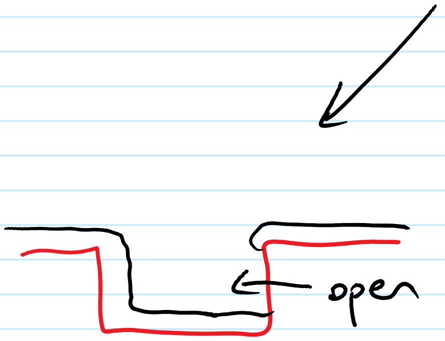
Filament Evaporation System:



1. Pump down to vacuum → reduces film contamination and allows better thickness control
2. Heat W filament → melt Al, wet filament
3. Raise temperature → evaporate Al

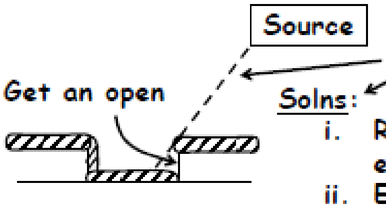
$$\text{mean free path} = \lambda = \frac{kT}{\sqrt{2\pi}\,Pd^2}$$

k = Boltzmann Constant
T = temperature
P = pressure
d = diameter of gas molecule



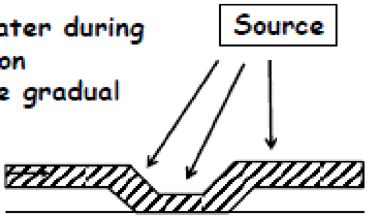
- λ can be ~60m for a 4Å particle at 10^{-4} Pa (-0.75 μTorr)
  ↳ thus, at 0.75 μTorr, get straight line path from Al staple filament to wafer

Problem: Shadowing & Step Coverage



Problem: line of sight deposition

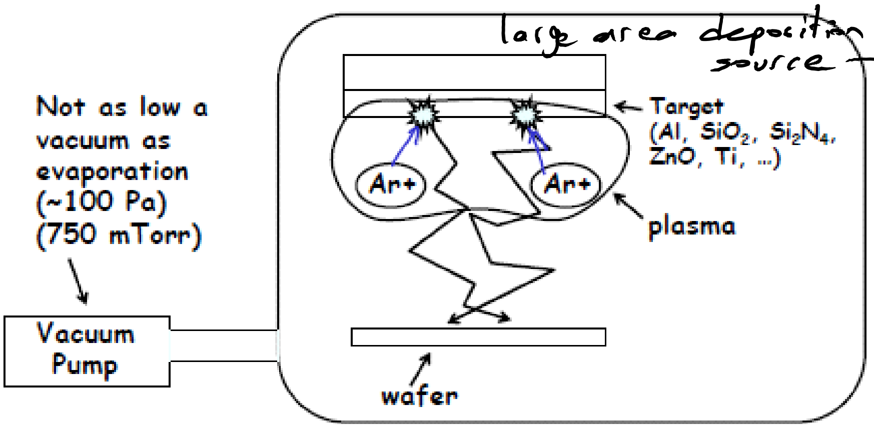
Solns:
- i. Rotate water during evaporation
- ii. Etch more gradual sidewalls



Better Solution: forget evaporation → sputter deposit the film!

- Use an energetic plasma to dislodge atoms from a material target, allowing the atoms to settle on the wafer surface

Not as low a vacuum as evaporation (~100 Pa) (750 mTorr)



→ improves step coverage

λ ↓ less directional

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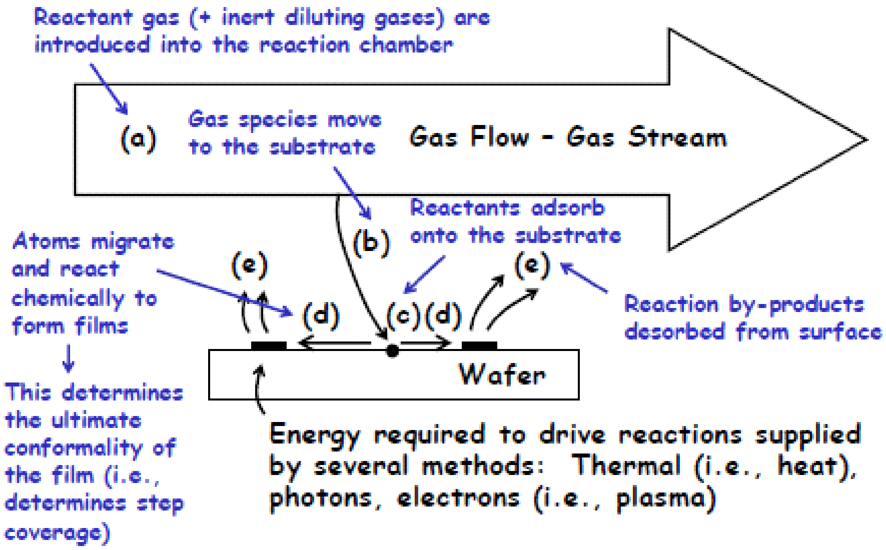
CVD

- Even better conformity than sputtering
- Form thin films on the surface of the substrate by thermal decomposition and/or reaction of gaseous compounds
  - Desired material is deposited directly from the gas phase onto the surface of the substrate
  - Can be performed at pressures for which λ (i.e., the mean free path) for gas molecules is small
  - This, combined with relatively high temperature leads to → higher surface diffusion

Excellent Conformal Step Coverage!

- Types of films: polysilicon, SiO_2, silicon nitride, SiGe, Tungsten (W), Molybdenum (M), Tantalum (Ta), Titanium (Ti), ...



Reactant gas (+ inert diluting gases) are introduced into the reaction chamber

Gas species move to the substrate

Reactants adsorb onto the substrate

Atoms migrate and react chemically to form films

This determines the ultimate conformality of the film (i.e., determines step coverage)

Reaction by-products desorbed from surface

Energy required to drive reactions supplied by several methods: Thermal (i.e., heat), photons, electrons (i.e., plasma)

Step-by-Step CVD Sequence:

Gas phase processes

a) Reactant gases (+ inert diluting gases) are introduced into reaction chamber

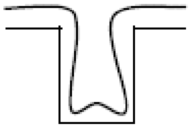
b) Gas species move to the substrate

Surface processes

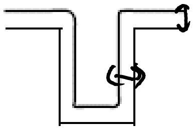
c) Reactants adsorbed onto the substrate

d) Atoms migrate and react chemically to form films

This determines to a large extent whether or not a film is conformal (i.e. better step coverage)



Not Conformal
low T
not enough adatom migration



Conformal
High T
Plenty of adatom migration

e) Reaction by-products desorbed and removed from reaction chamber

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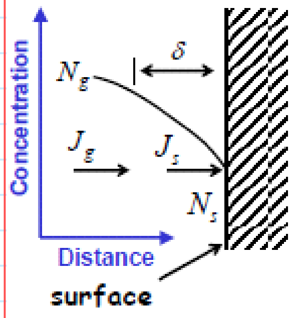
$$R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

Simplified Schematic:



N_g = conc. of reactant molecules in the gas stream

N_s = conc. of reactant molecules at the surface

J_s = flux of gas molecules at the surface

J_g = flux of molecules diffusing in from the gas stream

$$\text{growth rate} = \frac{\text{flux}}{\#\,\text{molecules incorporated/unit volume}} = \frac{J}{N}$$

$$= \frac{J}{N} = \boxed{\frac{k_s h_g}{k_s + h_g}\frac{N_g}{N} = (k_s \parallel h_g)\frac{N_g}{N} = \text{growth rate}}$$

atomic density of the film

$$J_G = h_G(N_g - N_s)$$

$$J_s = k_s N_s$$

$$J_s = J_G = J$$

$$h_G(N_g - N_s) = k_s N_s$$

$$h_G N_g = N_s(k_s + h_G)$$

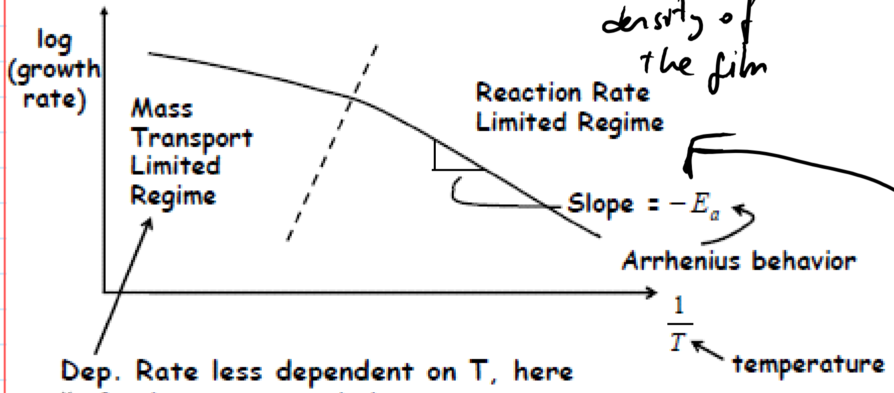
$$\rightarrow J = \frac{k_s h_G}{k_s + k_G} N_g$$

$$\text{growth rate} = \frac{J}{N} = (k_s // h_g)\frac{N_g}{N}$$

$$k_s // h_g$$

$T\uparrow \rightarrow h_g$

$T\downarrow \rightarrow k_s$



$R \propto k_s$

$$k_s = k_0 \exp\frac{-E_a}{kT}$$

$$\rightarrow R \propto e^{-E_a/kT}$$

Dep. Rate less dependent on T, here
↳ for better control, better to operate here (@ higher T)

$R \propto h_G$

$h_G \propto D$ (gas diff. const.)

$$D = \frac{D_0 T^{3/2}}{P}$$

$$\rightarrow R \propto T^{3/2}$$

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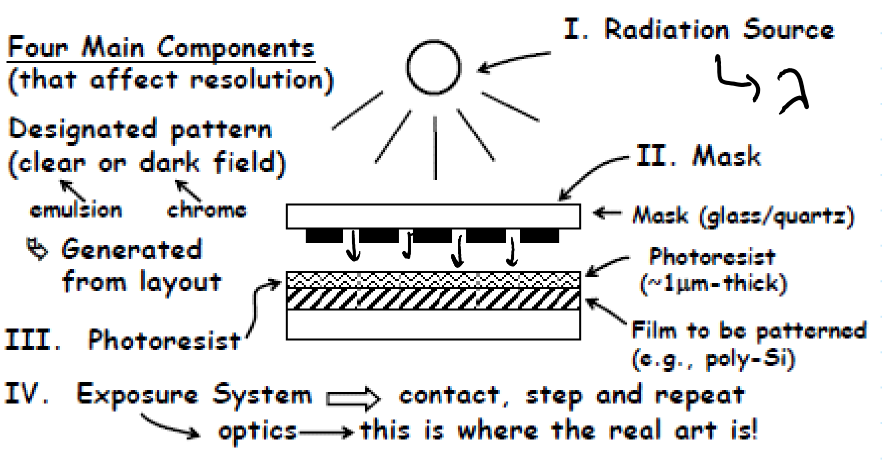
LITHOGRAPY



Four Main Components
(that affect resolution)

I. Radiation Source ↳ λ

II. Mask

Designated pattern (clear or dark field)
emulsion chrome
Generated from layout

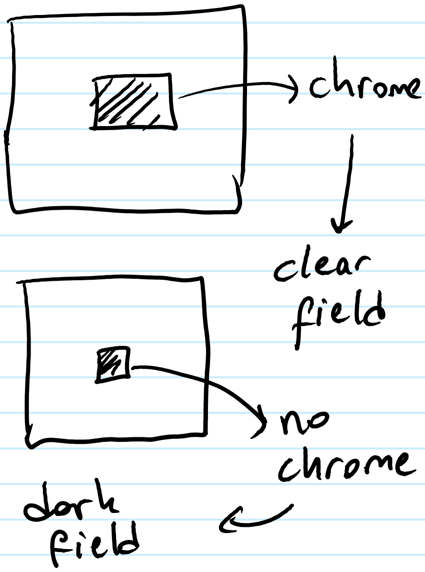
Mask (glass/quartz)

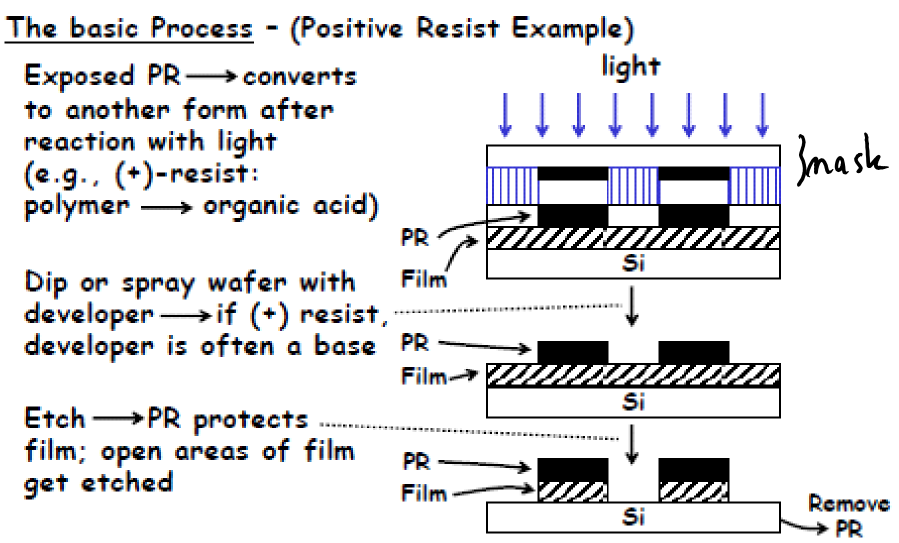
Photoresist (~1µm-thick)

Film to be patterned (e.g., poly-Si)

III. Photoresist

IV. Exposure System ⇒ contact, step and repeat
optics → this is where the real art is!



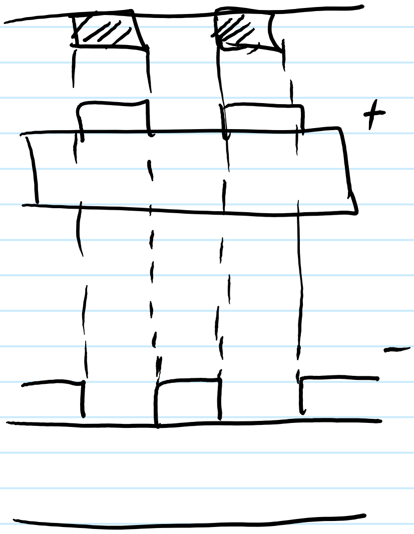


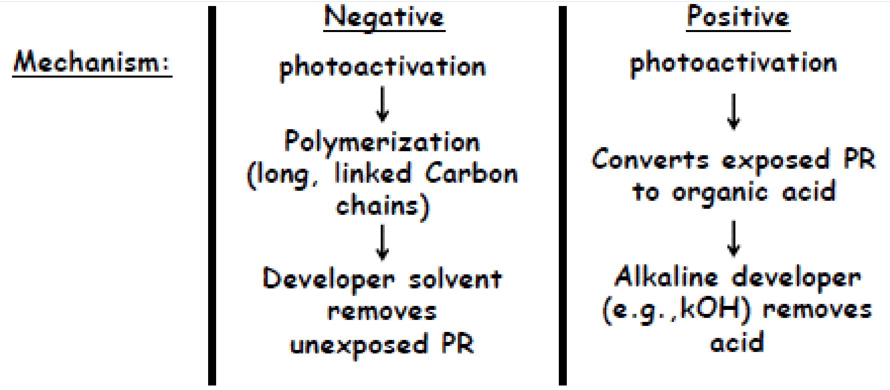
The basic Process - (Positive Resist Example)

Exposed PR → converts to another form after reaction with light (e.g., (+)-resist: polymer → organic acid)

Dip or spray wafer with developer → if (+) resist, developer is often a base

Etch → PR protects film; open areas of film get etched





Mechanism:

Negative	Positive
photoactivation ↓ Polymerization (long, linked Carbon chains) ↓ Developer solvent removes unexposed PR	photoactivation ↓ Converts exposed PR to organic acid ↓ Alkaline developer (e.g.,kOH) removes acid

	+ res	– res
clear field	stay	remove
dark fied	remove	stay

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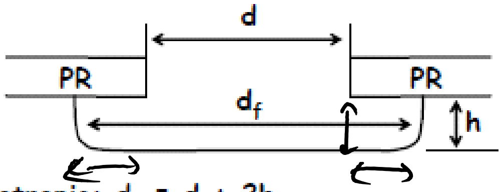
ETCHING

- Removal of material over designated areas of the wafer
- Two important metrics:
  1. Anisotropy
  2. Selectivity

1. Anisotropy -

a) Isotopic Etching (most wet etches)



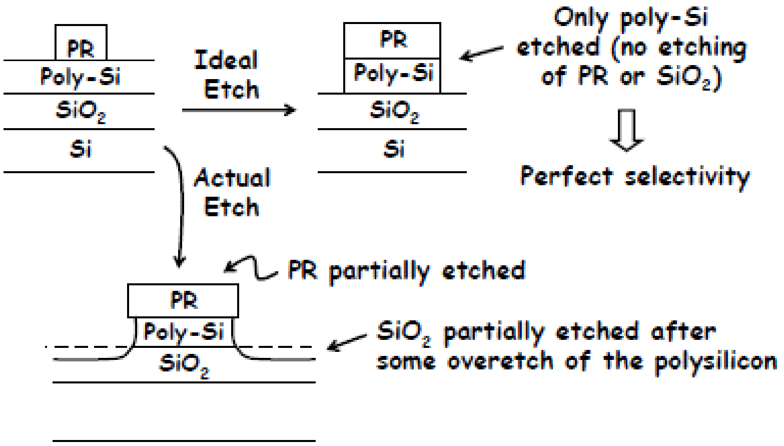
If 100% isotropic: $d_f = d + 2h$

Define: $B = d_f - d$

If $B = 2h$ ⇨ isotropic

$B = 0 \rightarrow d_f = d \rightarrow$ anisotropic

2. Selectivity -



Only poly-Si etched (no etching of PR or SiO_2)

⇩

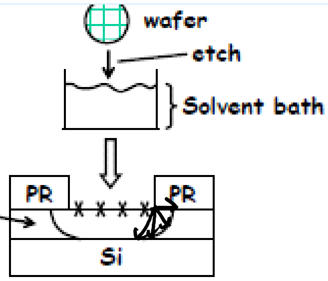
Perfect selectivity

PR partially etched

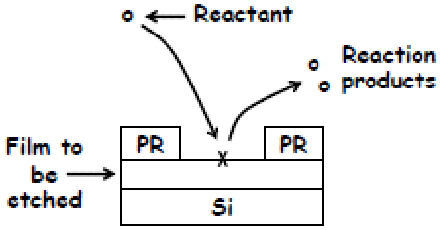
SiO_2 partially etched after some overetch of the polysilicon

$$\frac{\text{Si etch rate}}{\text{SiO}_2\text{ etch}} \neq \infty$$

- Wet etching: dip wafer into liquid solution to etch the desired film
  - Generally isotropic, thus, inadequate for defining features < 3µm-wide



- General Mechanism -



1. Diffusion of the reactant to the film surface
2. Reaction: adsorption, reaction, desorption
3. Diffusion of reaction products from the surface

Silicon Wet Etching

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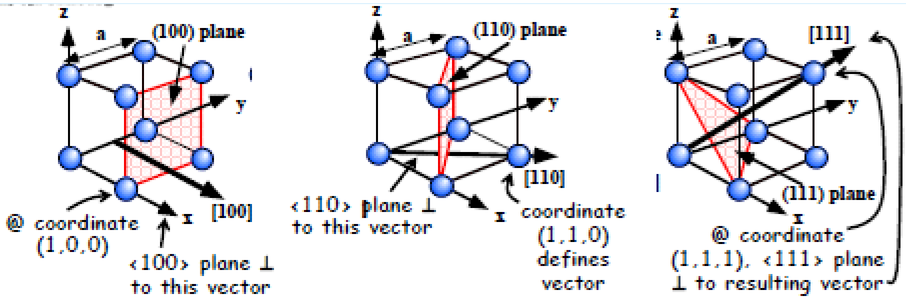
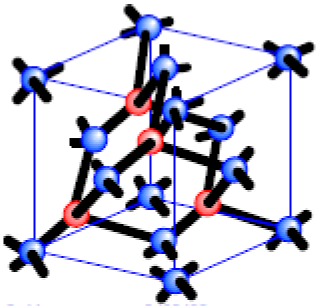
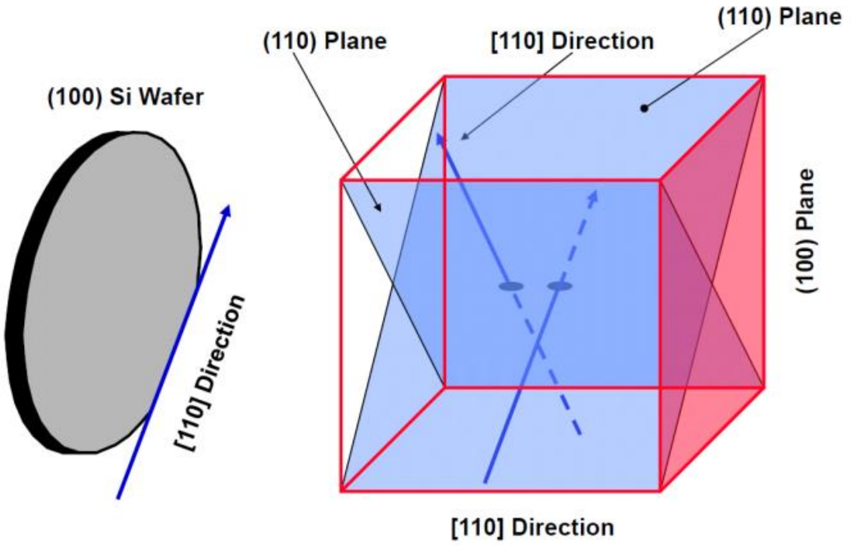
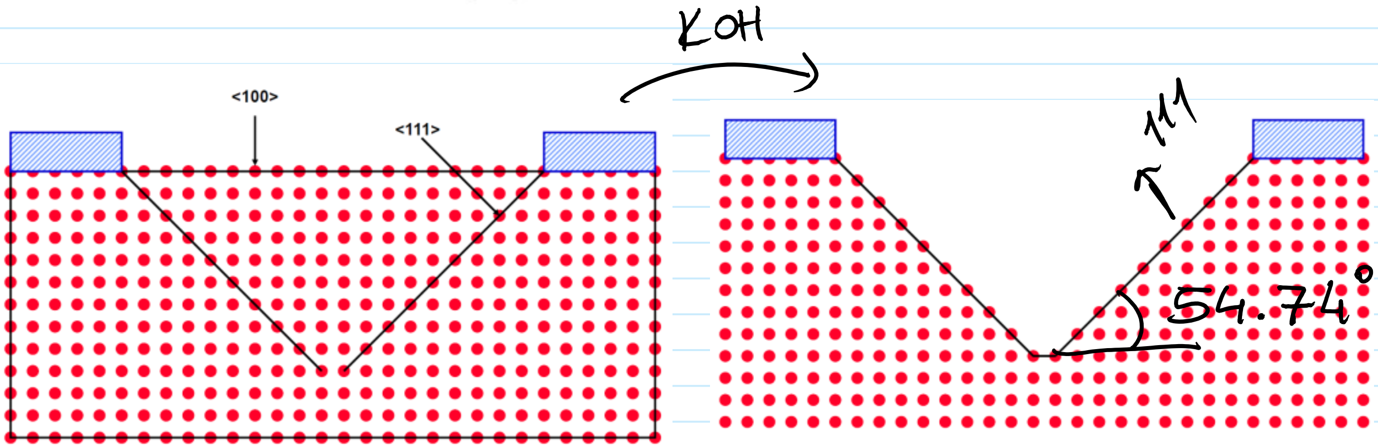


- Silicon has the basic diamond structure
  - Two merged FCC cells offset by (a/4) in x, y, and z axes
  - From right:
    - # available bonds/cm^2 ‹111›
    - # available bonds/cm^2 ‹110›
    - # available bonds/cm^2 ‹100›

↑ Increasing







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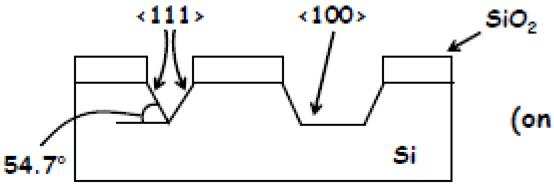
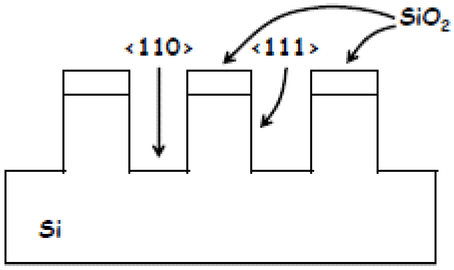
Can get the following:



(on a <100> - wafer)



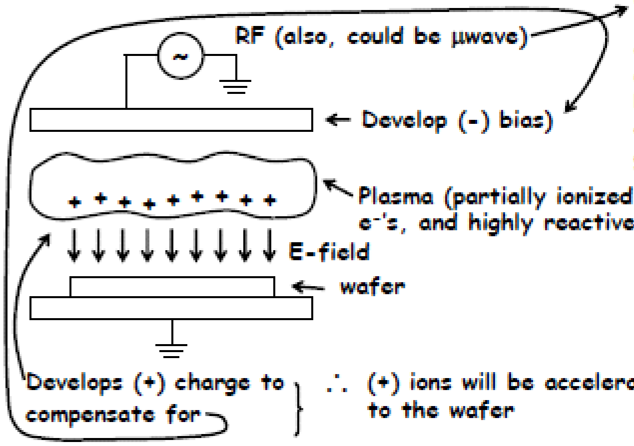
(on a <110> - wafer)

⟹ Quite anisotropic!

DRY ETCHING

- Physical sputtering
- Plasma etching
- Reactive ion etching

} All based upon plasma processes.



(+) ions generated by inelastic collisions with energetic e^{-1}'s
Get avalanche effect because more e^{-1}'s come out as each ion is generated.

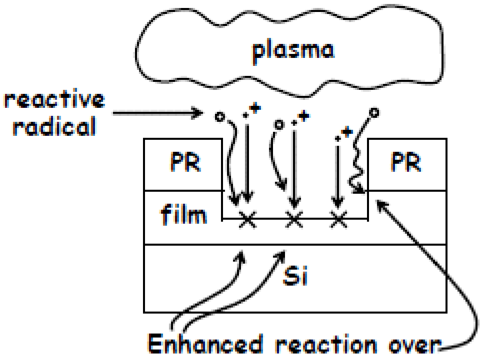
Plasma (partially ionized gas composed of ions, e^-'s, and highly reactive neutral species)

Develops (+) charge to compensate for } ∴ (+) ions will be accelerated to the wafer

Plasma generates:

1) Ions
↳ Sputtering → dir.

2) Activated neutrals
↳ Enhanced chemical reaction → isotr



- Relatively high energy impinging ions (>50 eV) produce lattice damage at surface
- Reaction at these damaged sites is enhanced compared to reactions at undamaged areas

Result: E.R. at surface >> E.R. on sidewalls

DOPING

- **Conductivity Equation**:

charge magnitude on an electron

$$\sigma = q\mu_n n + q\mu_p p$$

conductivity

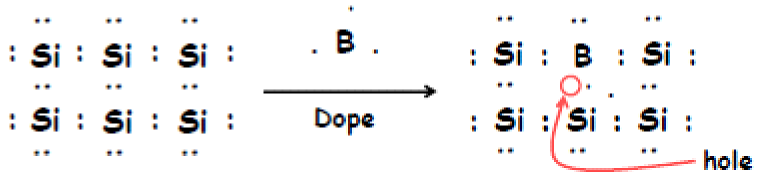
electron mobility

electron density

hole mobility

hole density

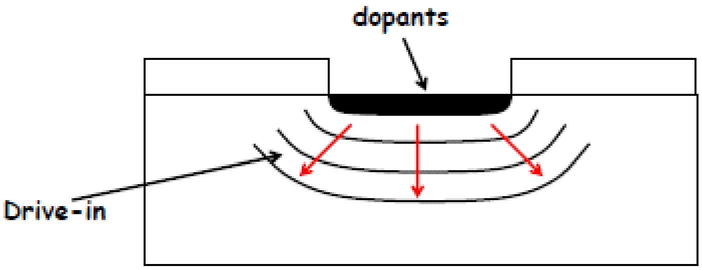
- If fewer e$^-$'s, then the dopant is an acceptor: B



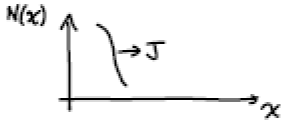
  - Lack of an e$^-$ = hole = h$^+$
  - When e$^-$'s move into h$^+$'s, the h$^+$'s effectively move in the opposite direction → a h$^+$ is a mobile (+) charge carrier

1. Introduce dopants (introduce a fixed dose Q of dopants)
   - (i) Ion implantation
   - (ii) Predeposition
2. Drive in dopants to the desired depth
   - High temperature > 900°C in N_2 or N_2/O_2

- **Result**:



$\boxed{\text{Modeling}}$



⇒ Dopants from points of high conc. more to points of low conc. w/ flux J

⇒ Question: What's $N(x,t)$?

fcn of time

Fick's Law of Diffusion – (1st law)

$$J(x,t) = -D\frac{\partial N(x,t)}{\partial x} \qquad (1)$$

flux [#/cm²·s]

Diffusion Coefficient

Continuity Equation for Particle Flux –

General Form: $\frac{\partial N(x,t)}{\partial t} = -\vec{\nabla}\cdot\vec{J}$

rate of increase of conc. w/ time

negative of the divergence of particle flux

again, Fick's Law of Diffusion

$$J(x,t) = -D\frac{\partial N(x,t)}{\partial x}$$

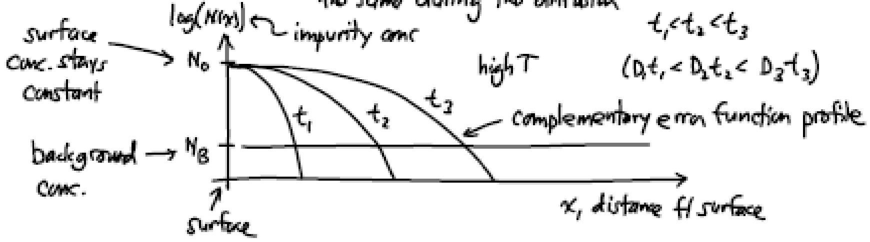
⇒ we're interested for now in the one-dimensional form:

$$\frac{\partial N(x,t)}{\partial t} = -\frac{\partial J}{\partial x} \qquad (2)$$

$$\left[\frac{\partial}{\partial x}(1) \text{ and substitute (2) in (1)}\right] \Rightarrow \boxed{\frac{\partial N(x,t)}{\partial t} = D\frac{\partial^2 N(x,t)}{\partial x^2}}$$ [Fick's 2nd Law of Diffusion in 1-D]

Solutions: → dependent upon boundary conditions
↳ use variable separation or laplace Xform techniques

Case 1: Predeposition → constant source diffusion: surface concentration stays the same during the diffusion



⇒ if plotted on a linear scale, would look like this:

⇒ Boundary Condition:
(i) $N(0,t) = N_0$
(ii) $N(\infty,t) = 0$

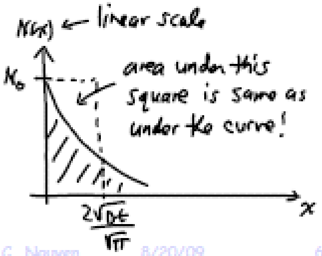
$$\left.\right\} N(x,t) = N_0\left[1 - \frac{2}{\sqrt{\pi}}\int_0^{\frac{x}{2\sqrt{Dt}}} e^{-y^2}dy\right]$$

$$\boxed{N(x,t) = N_0 \,\mathrm{erfc}\left(\frac{x}{2\sqrt{Dt}}\right)}$$ ⇒ again, complementary error function (read tables or graph)

Dose, $Q \triangleq$ total # of impurity atoms per unit area in the Si
= area under the curve

$$Q = \int_0^\infty N(x,t)dx \Rightarrow \boxed{Q(t) = N_0\frac{2\sqrt{Dt}}{\sqrt{\pi}} \text{ cm}^{-2}}$$

$$\boxed{2\sqrt{Dt} \triangleq \text{characteristic diffusion length}}$$



surface concentration
↓

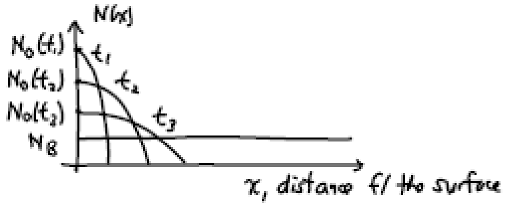
$$N(x,t) = N_0 \,\mathrm{erfc}\left(\frac{x}{2\sqrt{Dt}}\right)$$

↑
solid solubility of the dopant

↓
predeposition dose:

$$Q(t) = \frac{N_0 2\sqrt{Dt}}{\sqrt{\pi}} \text{ cm}^{-2}$$

Case 2: Drive-in → limited source diffusion, i.e., constant dose Q



⇒ Boundary Condition:
(i) $N(\infty,t) = 0$
(ii) $\left.\frac{\partial N(x,t)}{\partial x}\right|_{x=0} = 0$

→ Why? Constant Dose:
$\int_0^\infty N(x,t)dx = Q$ ← const.

→ This is equivalent to saying that there's no flux going out of the Si, i.e.,

and that's what this says!

↓

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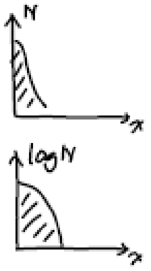
(iii) Usually make delta fcn. approx.: $N(x,0) = Q\,\delta(x)$

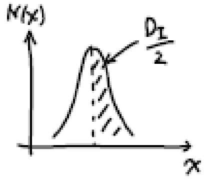
⇒ we can do this, because for sufficiently long diffusion times, no matter what the original shape of the dopant distribution, the diffused distribution will be the same

<u>Get Gaussian Distribution</u>:

$$N(x,t) = \frac{Q}{\sqrt{\pi D t}} \exp\left[-\left(\frac{x}{2\sqrt{Dt}}\right)^2\right]$$

corresponds to a half Gaussian in this equation





when the starting conc. profile is completely contained in the Si, then

$Q = \frac{D_I}{2}$ = half the implant dose

$$N(x,t) = \frac{Q}{\sqrt{\pi (Dt)_{drive\,in}}}\, e^{-\frac{x^2}{4(Dt)_{drive\,in}}}$$

- Two step diffusion procedure:
  - <u>Step 1</u>: predeposition (i.e., constant source diffusion)
  - <u>Step 2</u>: drive-in diffusion (i.e., limited source diffusion)
- For processes where there is both a predeposition and a drive-in diffusion, the final profile type (i.e., complementary error function or Gaussian) is determined by which has the much greater Dt product:

$(Dt)_{predep} \gg (Dt)_{drive\text{-}in}$ ⇨ impurity profile is complementary error function

$(Dt)_{drive\text{-}in} \gg (Dt)_{predep}$ ⇨ impurity profile is Gaussian (which is usually the case)

- For actual processes, the junction/diffusion formation is only one of many high temperature steps, each of which contributes to the final junction profile
- Typical overall process:
  1. Selective doping
     - Implant → effective $(Dt)_1 = (\Delta R_p)^2/2$ (Gaussian)
     - Drive-in/activation → $D_2 t_2$
  2. Other high temperature steps
     - (eg., oxidation, reflow, deposition) → $D_3 t_3$, $D_4 t_4$, ...
     - Each has their own Dt product
  3. Then, to find the final profile, use

$$(Dt)_{tot} = \sum_i D_i t_i$$

in the Gaussian distribution expression.

Thermal budget

$$(Dt)_{effective} = \sum_{step\ i} (Dt)_i$$

$$D = D_o \exp\left(-\frac{E_A}{kT}\right)$$ (as usual, an Arrhenius relationship)

Table 4.1 Typical Diffusion Coefficient Values for a Number of Impurities.

Element	D_0(cm²/sec)	E_A(eV)
B	10.5	3.69
Al	8.00	3.47
Ga	3.60	3.51
In	16.5	3.90
P	10.5	3.69
As	0.32	3.56
Sb	5.60	3.95

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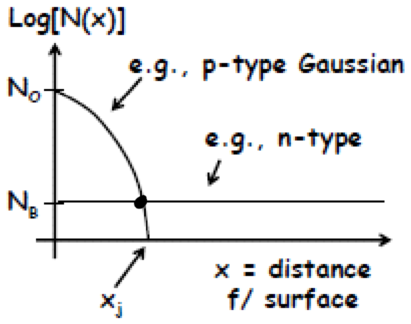
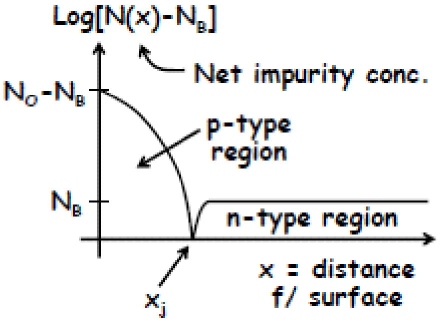
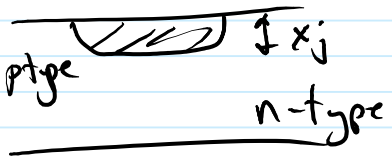
x_j = point at which diffused impurity profile intersects the background concentration, N_B







- Assuming a Gaussian dopant profile: (the most common case)

$$N(x_j,t)=N_o\exp\left[-\left(\frac{x_j}{2\sqrt{Dt}}\right)^2\right]=N_B \rightarrow \underline{x_j=2\sqrt{Dt\ln\left(\frac{N_o}{N_B}\right)}}$$

- For a complementary error function profile:

$$N(x_j,t)=N_o\,\mathrm{erfc}\left(\frac{x_j}{2\sqrt{Dt}}\right)=N_B \rightarrow \underline{x_j=2\sqrt{Dt}\,\mathrm{erfc}^{-1}\left(\frac{N_B}{N_o}\right)}$$

- For diffused layers:

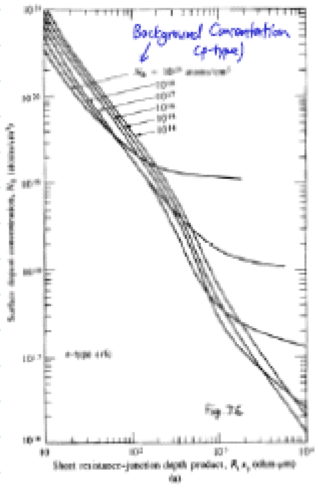
$$\overset{\text{Sheet resistance}}{R_s}=\frac{\overset{\text{Effective resistivity}}{\bar{\rho}}}{x_j}=\left[\int_o^{x_j}\sigma(x)dx\right]^{-1}\underset{\text{[extrinsic material]}}{=}\left[\int_o^{x_j}q\overset{\text{Majority carrier mobility}}{\underline{\mu}}\overset{\text{Net impurity concentration}}{\underline{N(x)}}\underline{dx}\right]^{-1}$$

IRVIN'S CURVES

⇨ Illuminates the dependence of R_s on x_j, N_o (the surface concentration), and N_B (the substrate background conc.)

p-type	erfc
n-type	erfc
p-type	half-gaussian
n-type	half-gaussian

y axis: → surface dopant concentration



p-type half-gaussian

n-type half-gaussian

concentration

x axis: $R_s \cdot X_j$

Surface Micromachining

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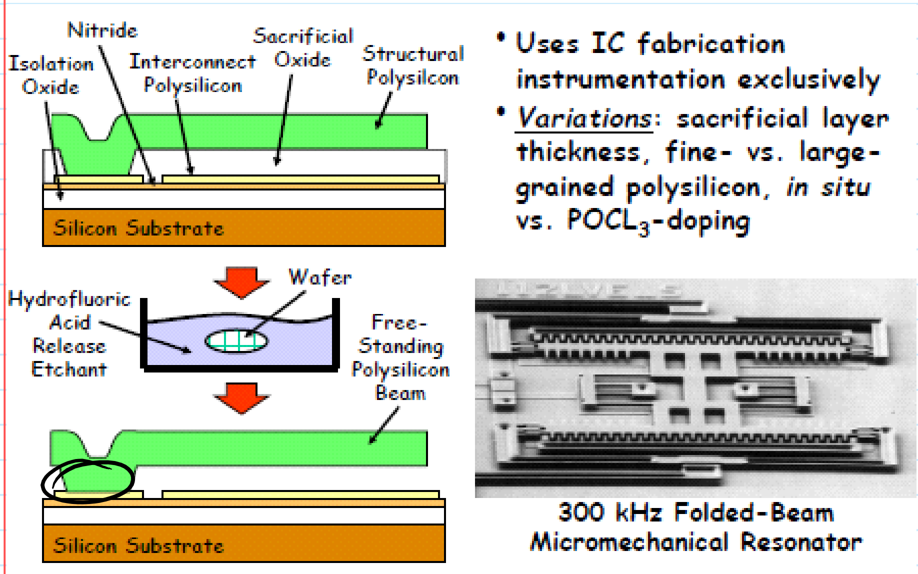
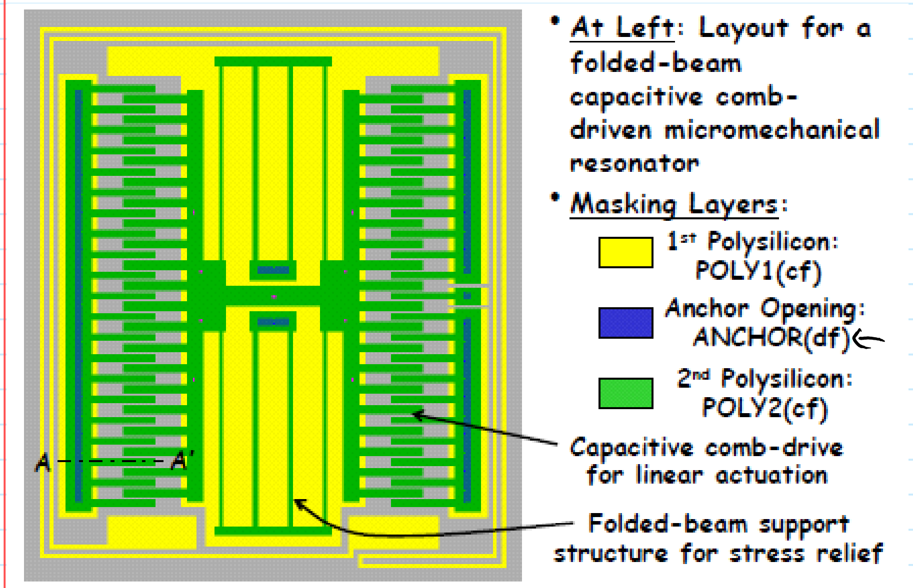


- Uses IC fabrication instrumentation exclusively
- *Variations*: sacrificial layer thickness, fine- vs. large-grained polysilicon, *in situ* vs. $POCL_3$-doping

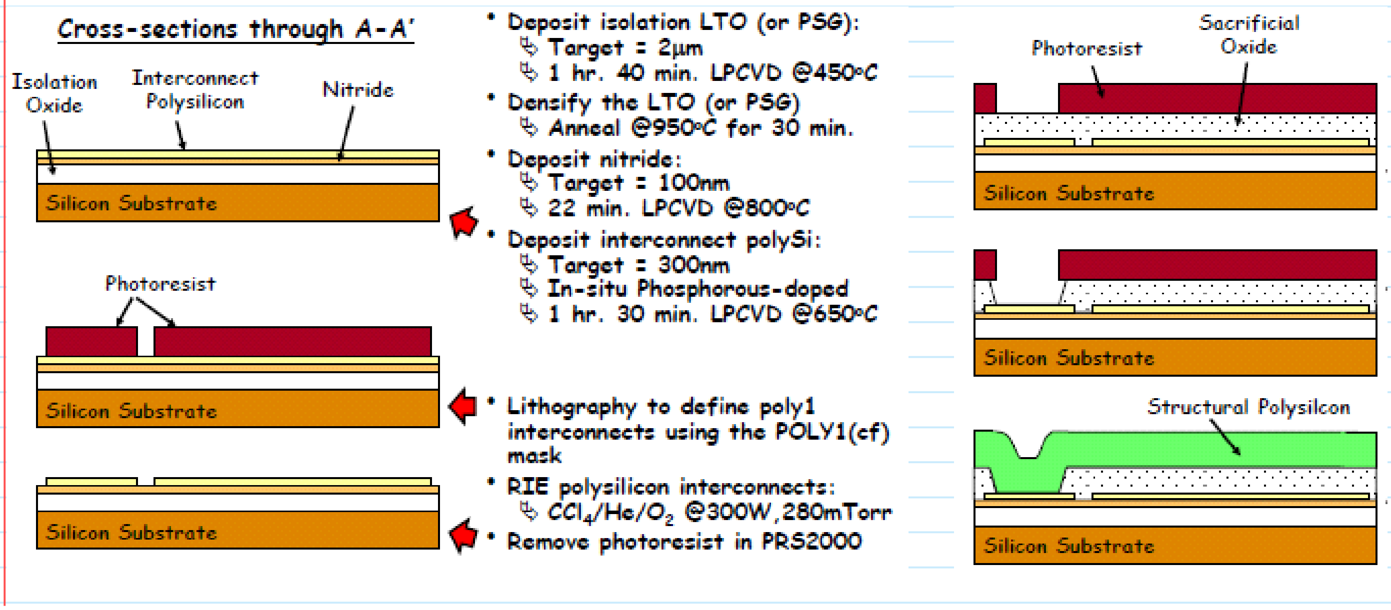
300 kHz Folded-Beam Micromechanical Resonator



- At Left: Layout for a folded-beam capacitive comb-driven micromechanical resonator
- Masking Layers:
  - 🟨 1st Polysilicon: POLY1(cf)
  - 🟦 Anchor Opening: ANCHOR(df)←
  - 🟩 2nd Polysilicon: POLY2(cf)

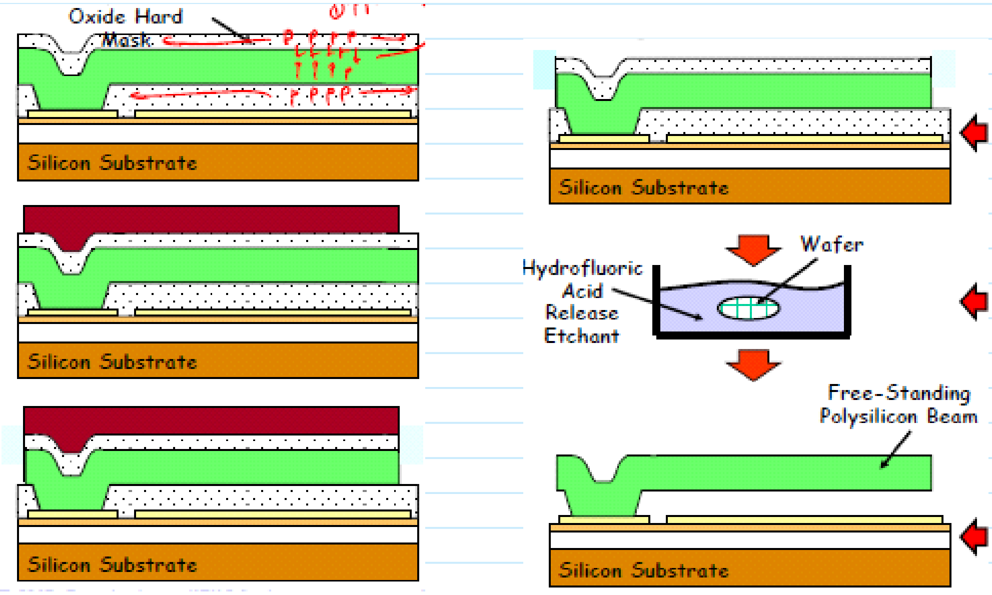
Capacitive comb-drive for linear actuation

Folded-beam support structure for stress relief

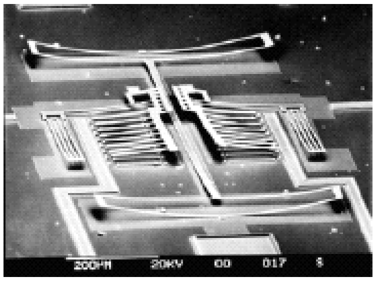


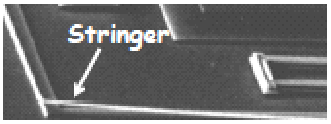
Cross-sections through A-A'

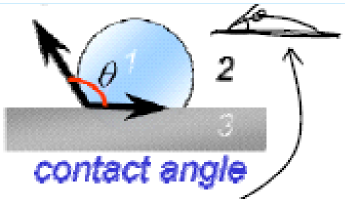
- Deposit isolation LTO (or PSG):
  - Target = 2μm
  - 1 hr. 40 min. LPCVD @450°C
- Densify the LTO (or PSG)
  - Anneal @950°C for 30 min.
- Deposit nitride:
  - Target = 100nm
  - 22 min. LPCVD @800°C
- Deposit interconnect polySi:
  - Target = 300nm
  - In-situ Phosphorous-doped
  - 1 hr. 30 min. LPCVD @650°C
- Lithography to define poly1 interconnects using the POLY1(cf) mask
- RIE polysilicon interconnects:
  - $CCl_4/He/O_2$ @300W,280mTorr
- Remove photoresist in PRS2000

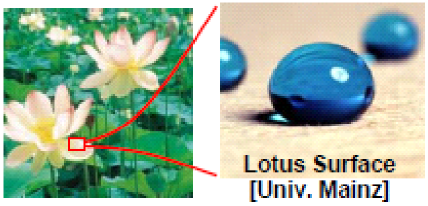


- **Stiction**: sticking of released devices to the substrate or to other on-chip structures
  - Difficult to tell if a structure is stuck to substrate by just looking through a microscope
- Residual Stress in Thin Films
  - Causes bending or warping of microstructures
  - Limits the sizes (and sometimes geometries) of structures
- Topography
  - Stringers can limit the number of structural levels



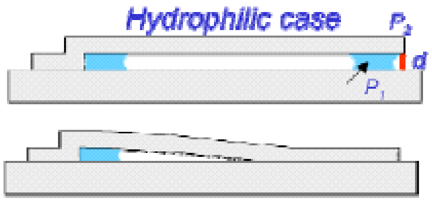






Lotus Surface
[Univ. Mainz]

- **Hydrophilic**:
  - A surface that invites wetting by water
  - Get stiction
  - Occurs when the contact angle $\theta_{water} < 90°$
- **Hydrophobic**:
  - A surface that repels wetting by water
  - Avoids stiction
  - Occurs when the contact angle $\theta_{water} > 90°$



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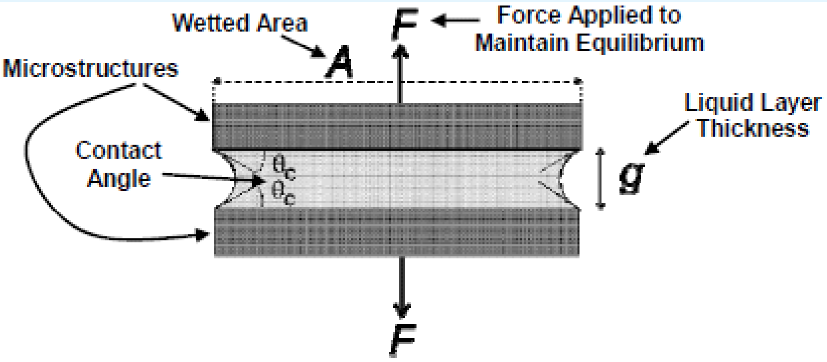
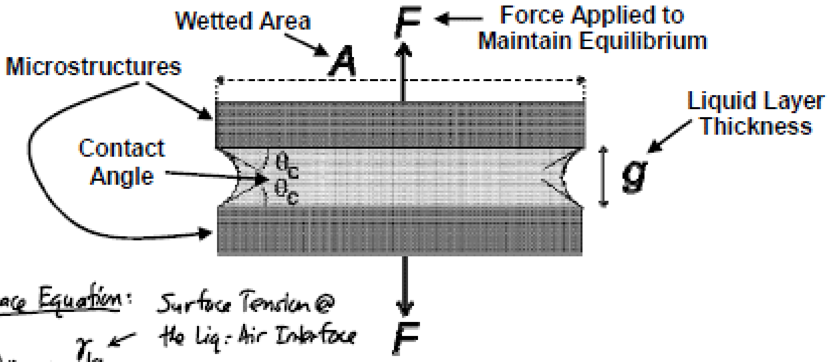


- Thin liquid layer between two solid plates ⇨ adhesive
- If the contact angle between liquid and solid $\theta_c < 90°$:
  - Pressure inside the liquid is lower than outside
  - Net attractive force between the plates
- The pressure difference (i.e., force) is given by the Laplace equation



Laplace Equation:

$$\Delta p_{la} = \frac{\gamma_{la}}{r}$$

γ_{la} ← Surface Tension @ the Liq-Air Interface

r ← Radius of Curvature of the Meniscus ((-) if concave)

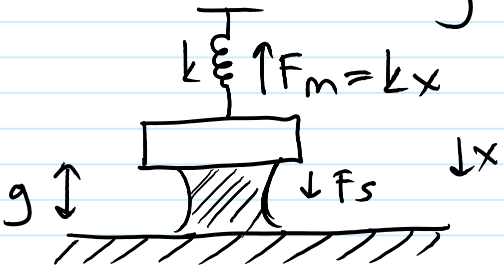
Δp_{la}: Pressure Difference @ the Liquid-Air Interface

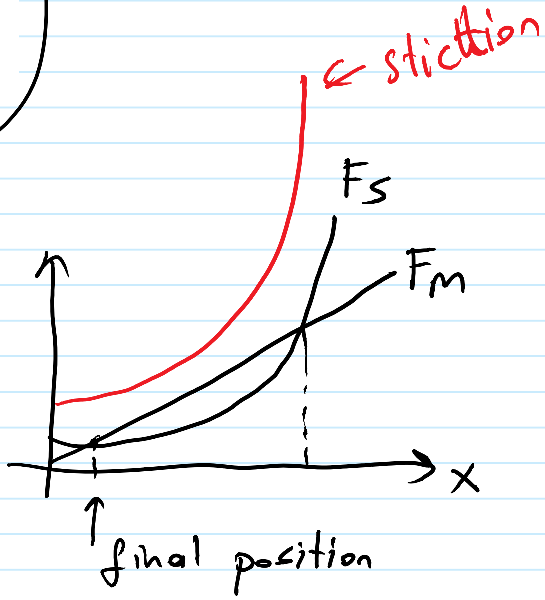
$$\left[r = -\frac{(g/2)}{\cos\theta_c}\right] \Longrightarrow \boxed{F = -\Delta p_{la} A = \frac{2A\gamma_{la}\cos\theta_c}{g}}$$

← Force needed to keep the plates apart
⇒ (+) force means a (-) Laplace pressure

$$\rightarrow F = \frac{2A\gamma_{la}\cos\theta_c}{g}$$

$$\frac{2A\gamma_{la}\cos\theta_c}{g-x} = F_x$$





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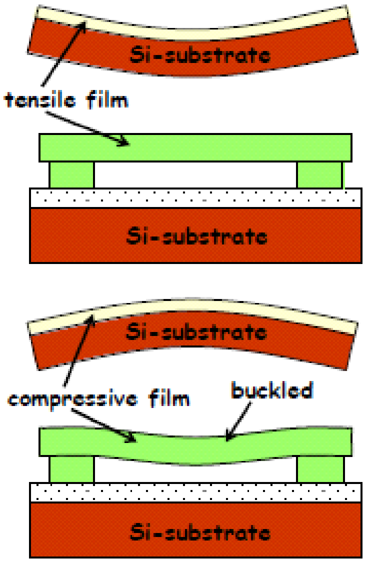
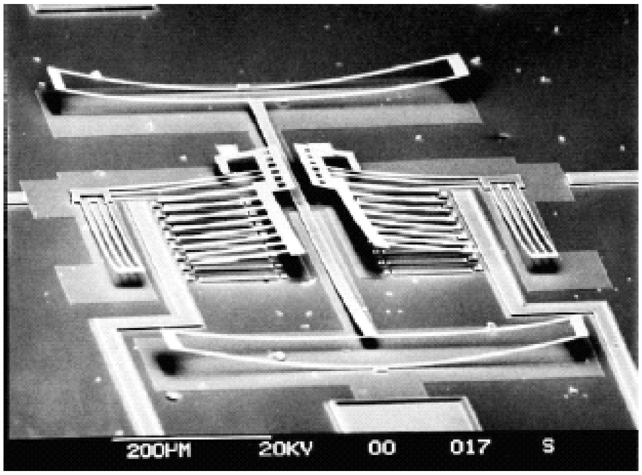
STRESS

- Under tensile stress, a film wants to shrink w/r to its substrate
  - Caused, e.g., by differences in film vs. substrate thermal expansion coefficients
  - If suspended above a substrate and anchored to it at two points, the film will be "stretched" by the substrate
- Under compressive stress, a film wants to expand w/r to its substrate
  - If suspended above a substrate and anchored to it at two points, the film will buckle over the substrate

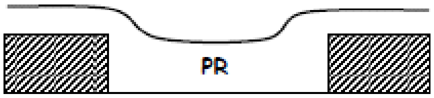


- Variation of residual stress in the direction of film growth
- Can warp released structures in z-direction

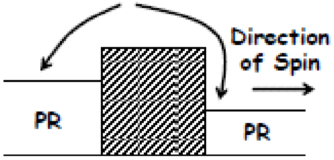


TOPOGRAPHY

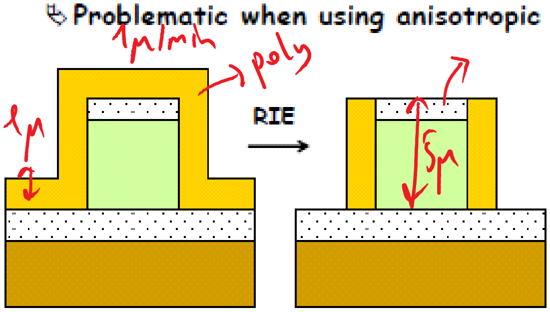
- Degradation of lithographic resolution
  - PR step coverage, streaking

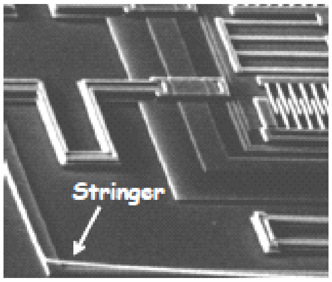


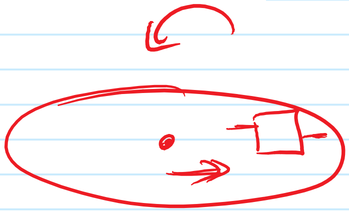
Thickness differences pose problems for reduction steppers



- Stringers
  - Problematic when using anisotropic etching, e.g., RIE







CMP
↳ to make flat surface