Etching in VLSI Processing

1. Wet Etching
2. Dry Etching
   - Plasma Eching
   - Reactive Ion Etching
   - Sputter etch

Films to be etched :

1. SiO_2, 2. Si_3N_4, 3. Silicon, 4. Polysilicon

5. Metals like : Al, Ti, Mo, W, Va & Copper

6. Alloys & compounds : TiO_2, TiN, Silicides of Mo, Pt

A. Wet Etching

(a) $SiO_2 + 6HF \rightarrow H_2SiF_6 + 2H_2O$

(b) $Si_3N_4 + 6HF \rightarrow H_2SiF_6 + NH_4OH$

Poly is etched in : $HF : HNO_3 : H_2O$ :: 6 : 100 : 40

(c) $HCl + H_2O$ can etch Al

$H_3PO_4 + HNO_3 + H_2O$ can etch Al.

In etching selectivity is major parameter to decide.

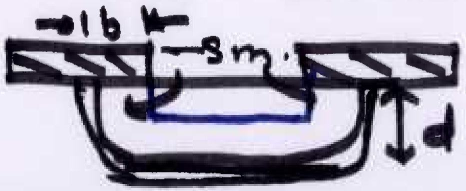
If r_1 is etch rate in film 1 and r_2 is the etch rate in film 2, then Selectivity

$$S = \frac{r_1}{r_2}$$

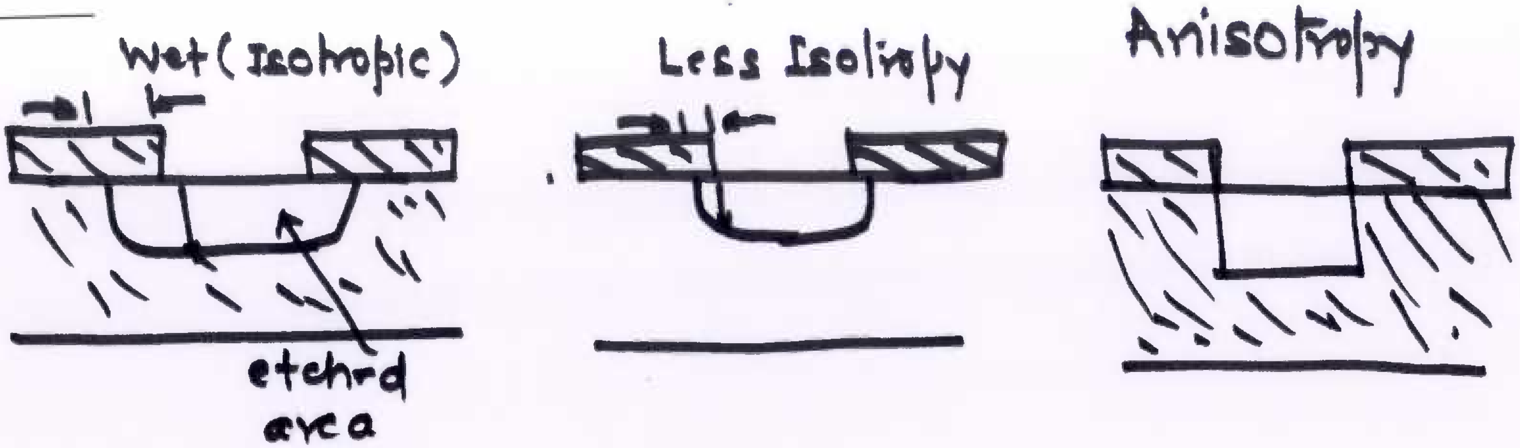
Higher the value of S, we can have ~~specifi~~ specific film etched and other not affected.

Disadvantage of Wet Etching :

Wet Etching is Isotropic in nature and hence creates unwanted etched pattern.



'b' is called Bias.



Anisotropy is defined as

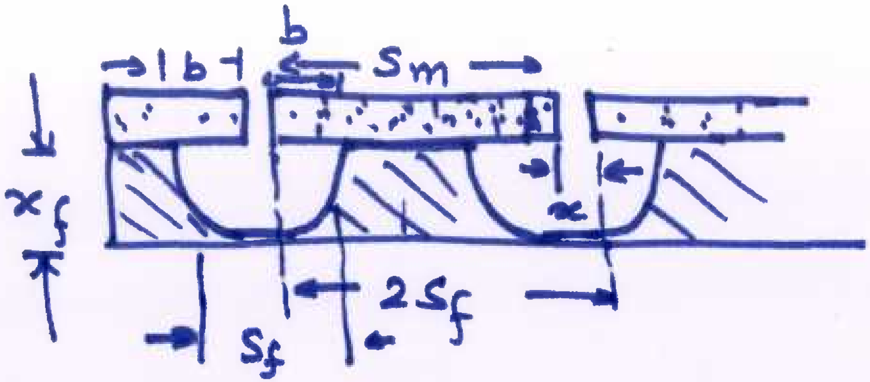
$$A_f = 1 - \frac{r_{lateral}}{r_{vertical}}$$

'r' is Etch rate

From earlier figure if time of etching is t

then $b = r_{lateral} \cdot t$ & $d = r_{vertical} \cdot t$

$$\therefore \quad A_f = 1 - \frac{b}{d}$$



x = Distance between Mask edges

S_m = Mask Width

① clearly $2S_f - S_m = x$ ② $S_m = S_f + 2b$

③ $S_m = S_f + x_f(1 - A_f) \times 2$

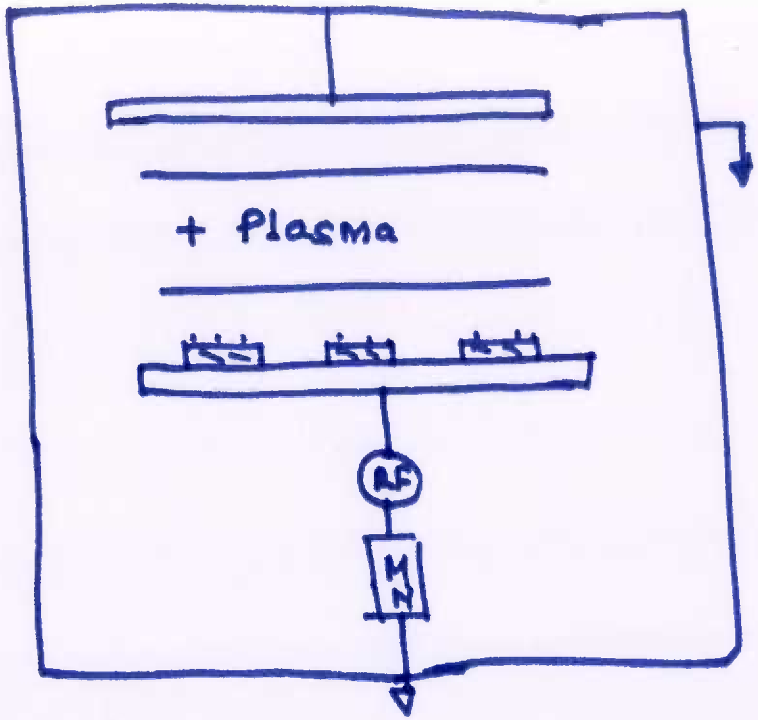
④ $A_f = 1 - \dfrac{b}{x_f}$ where b is Bias.
and x_f is Film thickness

or $\dfrac{b}{x_f} = (1 - A_f)$ or $b = x_f(1 - A_f)$

⑤ $\therefore x = 2S_f - S_f - 2x_f(1 - A_f)$

$x = S_f - 2x_f(1 - A_f)$ or $S_f = x + 2x_f(1 - A_f)$

S_f = Film width & spacing after etching



R.I.E.

RF causes ions & electrons to change their direction of motion as per field. However Ions are heavier and hence cannot move as fast as electrons. Some of the electrons are absorbed at the wafer surface and it becomes -vely charged. Plasma has now more +tive (ions) charge. The field direction is such that Reactive ions are brought to the wafer surface. This chemical etching process is directed as the field, vertically down causing Anisotropic Etching.

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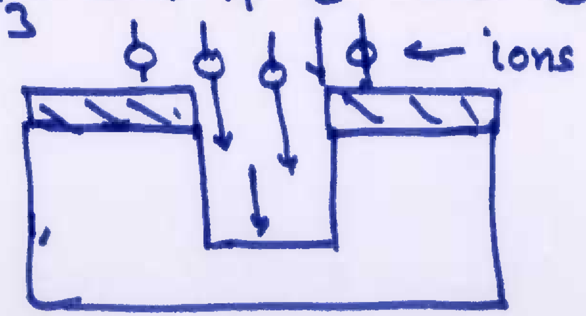
Freon or similar Florine based compound gases are used in most film etching. However other halid containing species such as Cl_2, HBr, & F.

Silicon etching is possible using nascent F created, by reaction $Si + 4F \rightarrow SiF_4$

$CF_4 + e^- \rightarrow CF_3 + F + e^-$ Dissociation

$CF_3 + e^- \rightarrow CF_3^+ + 2e^-$ Ionisation

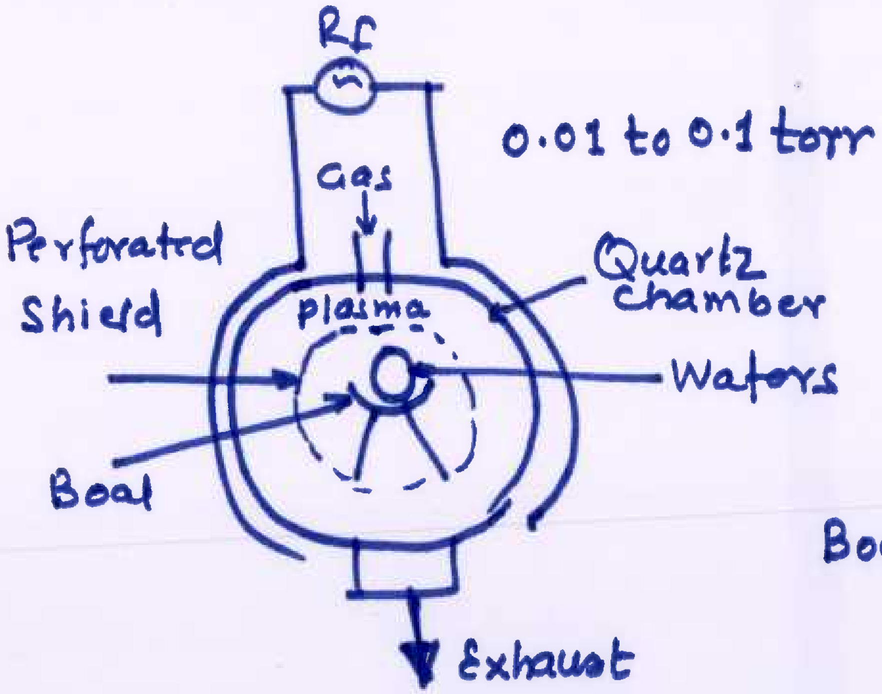
$CF_3^+ + F + e^- \rightarrow CF_4$ Recombination



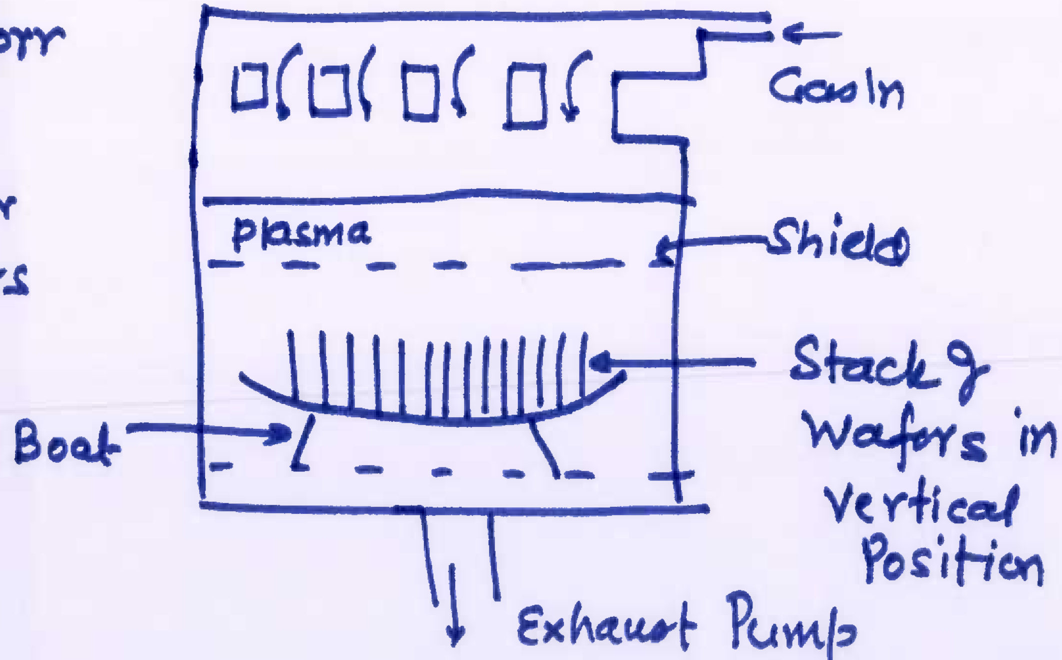
Plasma Etching : (reactive Species of Florine used)

This is Isotropic etching but it is Dry Etching

It is used in Ashing of Resist using Oxygen Plasma



endview



Side view

Etching Models :

(i) Linear Etch Model

(ii) Saturation/Adsorption Model for (RIE)

(i) Assumption: chemical & Ionic components in Plasmaetching, independently act and superimpose each other. Then Etch rate is given by

$$\text{Etch Rate} = \underbrace{\frac{S_c K_f F_c}{N}}_{\text{Chemical}} + \underbrace{\frac{K_i F_i}{N}}_{\text{Ionic}}$$

Here F_c is chemical Flux and F_i is Ionic flux at each Point on Surface

K_f is Rate constant for Ch. Process & K_i is rate constant for Ionic Case.

S_c is sticking Coeff of chemical atoms on Surface $[0 < S_c < 1]$

& Finally N is the density (/cc) of Film material

In this model we say that vertical etching is due to both Chemical & Ionic processes. However etching in lateral direction, one can say that only chemical reaction occures as Ions travel mostly in Vertical direction. For this case we can take $f_i = 0$

(ii) Saturation/Adsorption Model:

In this one assumes that both Chemical & Ionic processes act together. Here assumption is that neutral flux creates sites for etching. It is shown that

$$\text{Etch Rate} = \frac{1}{N} \frac{1}{\left[\frac{1}{K_i F_i} + \frac{1}{S_c F_c}\right]}$$

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