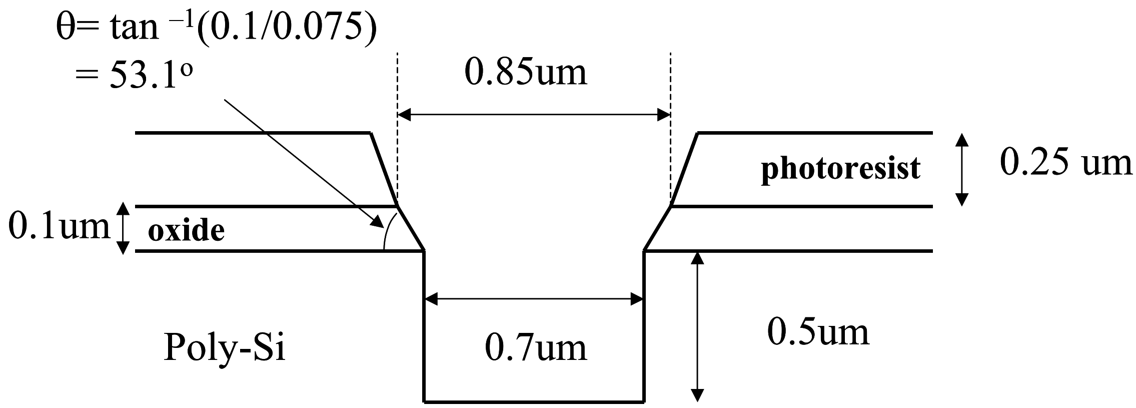
EE143, Fall 2010 **HW#7 Solutions**

Problem 1

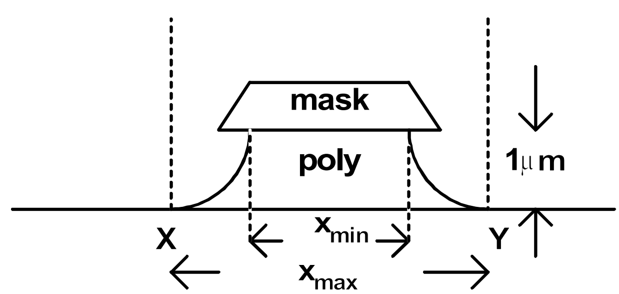
All etchimg rates have only vertical components (completely anisotropic)
Poly etech rate = 0.1 μm /min
Oxide etch rate = 1/5 poly etch rate = 0.02 μm /min
Resist etch rate = 1/ 2 poly etch rate = 0.05 μm /min
Slope of resist before etching $\alpha = \tan^{-1}(0.5/0.15) = 73.3^{o}$

After 5 minutes of etching
(a) Poly-Si will be etched to a depth of 0.1 •5 = 0.5 μm
Photo resist will be etched to a depth of 0.05 •5 = 0.25 μm
Bottom of resist opening will increase by 2 x (0.05 •5 •cot 73.3 ^{o}) = 0.15 μm

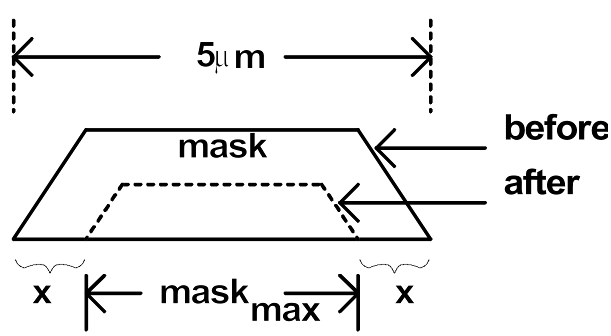


(b) Oxide slope angle $\theta = \tan^{-1}(0.1/0.075) = 53.1^{o}$

Problem 2
i.)The poly etching is completely isotropic and the mask etching is amistropic
Note that the lateral etching rate of poly > lateral removal rate of mask!
(Ii) x_{max} = 5 μm
iii) x_{min} = (5 - 2) μm = 3 μm



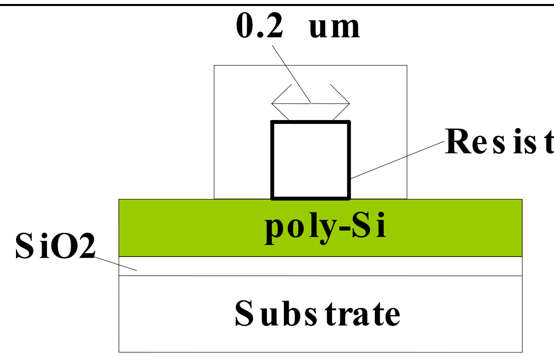
iv) mask etched = 2x = 2 • (0.01 μm/min • $\frac{1\ \mu m}{0.1\ \mu m/min}$
• cot 60° = 2 × 0.058 μm = 0.116 μm
∴ $mask_{max}$= 5 - 0.116 = 4.88 μm
v.) $t_{mask}(max)$ =
$0.5\ \mu m - (\frac{1\ \mu m}{0.1\ \mu m/min}) \times 0.01\ \mu m/min = 0.4\ \mu m$



Problem 3
Let R be the nominal etching rate for oxide.
(a) Nominal etching time $t_o = 0.5\ \mu m/R$
Worst-case longest etching time to clear all oxide $t_{long} = (0.5*1.05)\ \mu m / R(0.95) = 0.553\ \mu m / R$
% overetch time = (0.053/0.5) * 100% = 10.6%

(b) Worst-case shortest etching time to clear oxide $t_{short} = (0.5*0.95)\ \mu m / R(1.05) = 0.4523\ \mu m / R$
Between t_{short} and t_{long}, some exposed Si region will be etched which is required to be less than 0.005 μm.
Therefore, R_{Si} (max) = 0.005 μm / [0.553 μm /R - 0.4523 μm /R] = 0.05 R
Or, minimum etch selectivity required between oxide and Si : **$S = (R/R_{Si}) = 20$**

Problem 4

<table>
<tr><th>Process Description</th><th>Cross-section</th></tr>
<tr><td>1) Use isotropic reactive ion etching (e.g. oxygen plasma) to etch photoresist</td><td>
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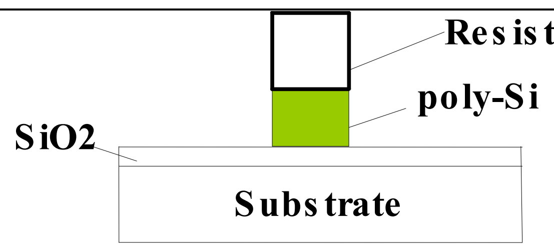
<tr><td>2) Use anisotropic reactive ion etching or ion milling to etch poly-Si</td><td>
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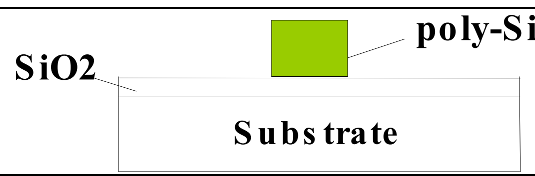
<tr><td>3) Remove photoresist</td><td>
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[Note] This technique is only useful to fabricate isolated devices. It does not improve the packing density of IC devices because of the pitch of inter-device spacing is till limted by lithography.

Problem 5
(i) Let t_o be time required to clear the SiO_2

$$t_o = \frac{x_{SiO_2}}{V_{Ov}}$$

Let t be the time that the foot of resist is eroded to a distance x' from original position (i.e, x=0),

$$t = \frac{x'}{(V_{Rv}\cot\alpha + V_{Rl})}$$

$\therefore$ The vertical thickness of SiO_2 etched at the position x' is :

$$y' = V_{Ov} \times (t_o - t) = V_{Ov} \times \left[\frac{x_{SiO_2}}{V_{Ov}} - \frac{x'}{(V_{Rv}\cot\alpha + V_{Rl})}\right]$$

or y' is linear with x' with constant slope.

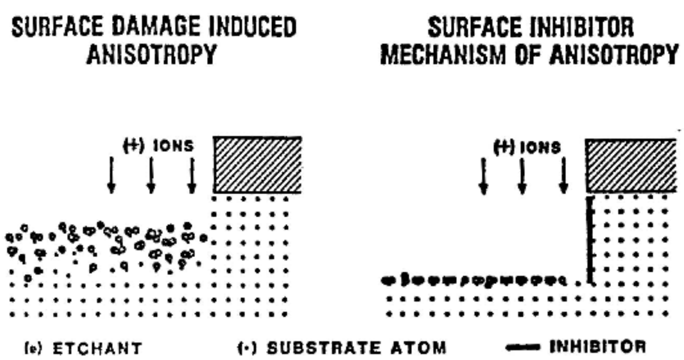
(ii) $$\tan\beta = \frac{V_{Ov}}{(V_{Rv}\cot\alpha + V_{Rl})}$$

$$\tan\beta_{max} = \frac{1.1V_{Ov}}{0.9(V_{Rv}\cot\alpha + V_{Rl})} = \frac{1.1 \times 1000}{0.9(1000\cot 80^\circ + 500)} = 61^\circ$$

$$\tan\beta_{min} = \frac{0.9V_{Ov}}{1.1(V_{Rv}\cot\alpha + V_{Rl})} = \frac{0.9 \times 1000}{1.1(1000\cot 80^\circ + 500)} = 50.4^\circ$$

Problem 6

(a) To increase degree of anisotropy, we can increase the directional ion bombardment by using a larger substrate voltage bias. One can also enhance the polymerization (by chemistry, plasma excitation, etc) to create sidewall coating.



(b) Example: To pattern SiO2 over Si substrates, one can use the CF4+H2 plasma.. The F* radicals generated from CF4 is consumed by the following reaction: F*+H → HF. With a reduced F* concentration, the etching rates of both Si and SiO2 are reduced but with different dependence on added H2 concentration. Hence, the selectivity (**ratio** of SiO2 and Si etching rates) can be controlled by the added H2 concentration.