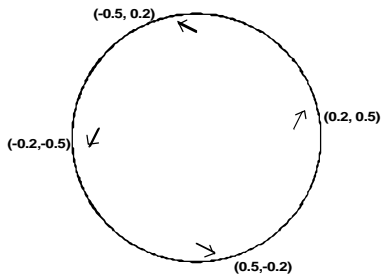


Problem 1

(a) The center only has translational errors: 0.5 μm along x, -0.5 μm along y.

After subtracting the translational error, we have:

	Top	Right	Center	Left	Bottom
x	-0.5	+0.2	0	-0.2	+0.5
y	+0.2	+0.5	0	-0.5	-0.2



The run out error is 0.2 μm

The rotational error is 0.5 μm (counter-clockwise)

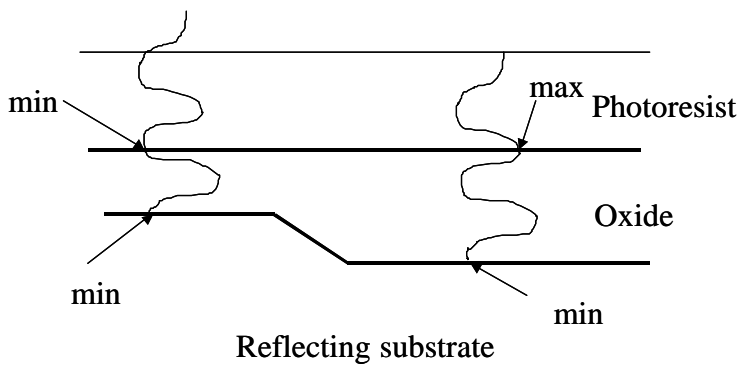
(b) $\text{DOF/R} = \frac{1}{0.8 \text{ NA}} = 2 \rightarrow \text{NA} = 0.62$

(c)

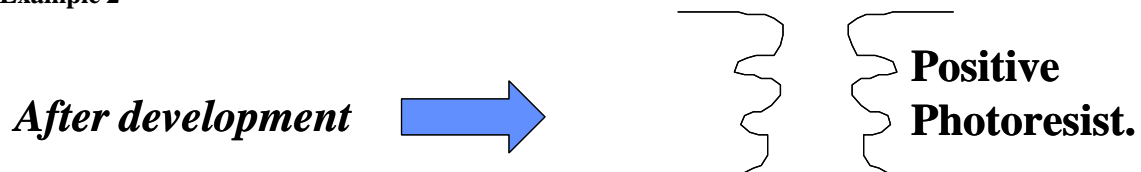
Example 1

Resist openings at the oxide/resist interface will have different sizes on thicker and thinner oxide regions. If the resist is used as the etching mask for oxide, we end up with different oxide feature sizes.

Photon Intensity due to standing wave



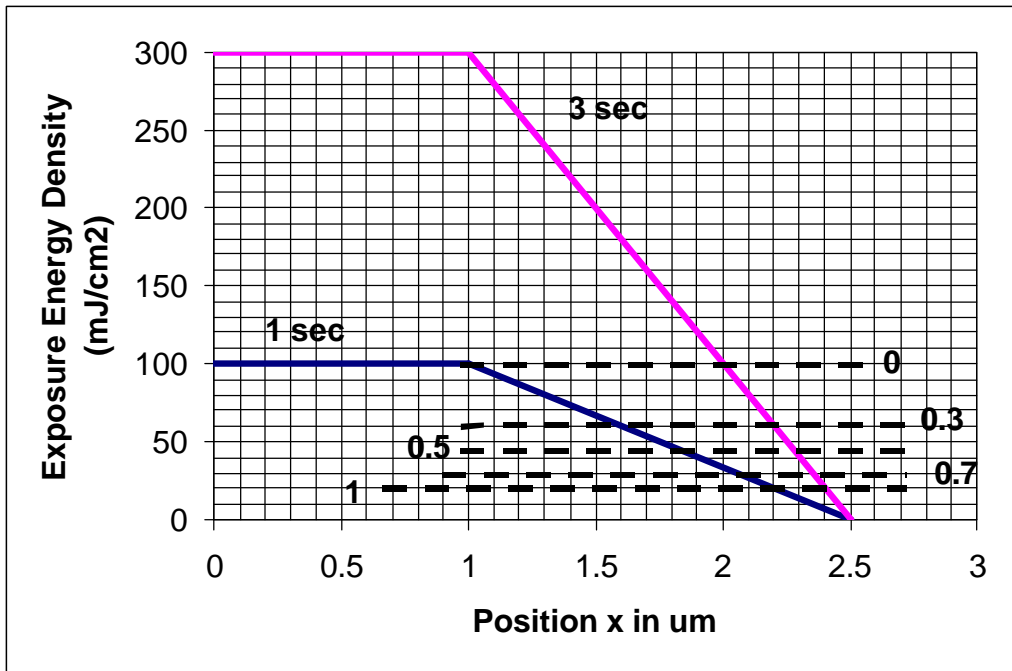
Example 2



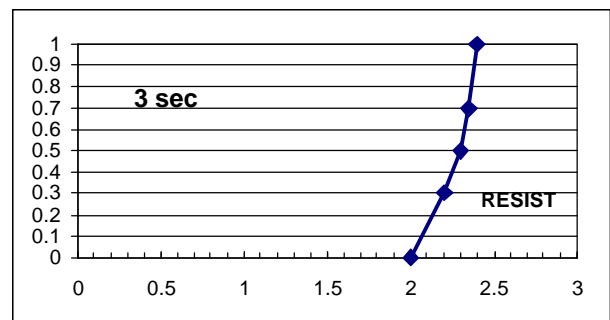
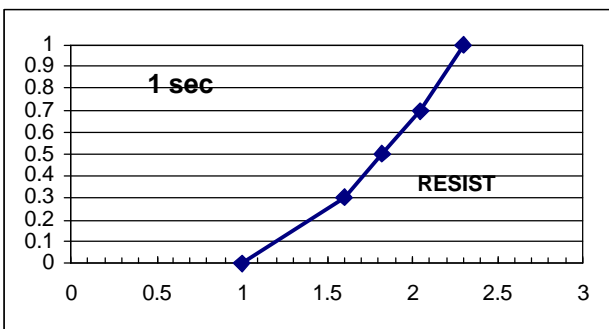
The resist slope angles have large variations if the underlying film has topography variations. For etching recipes which have mask erosion problems, the protective mask with end up with large variation of dimensions during the etching.

(d) (i) contrast $\gamma = 1 / \log_{10} (100/20) = 1.43$

(ii) The exposure energy density versus position are shown below for the 1sec and 3sec exposures. The dashed lines are the normalized remaining resist thickness from the resist contrast curve. Intercepting points show position of that particular remaining thickness.



The resist cross-sections are shown below:



Problem 2

(a) Overetch $\Delta = 7000/4000 = 1.75$

(b)

Uniformity factor $U_{fm} = (1+0.03)(1+1.75) / (1 - 0.05) = 2.98$

$$S_{fm(\min)} = \frac{h_f}{(w/2)} \frac{(1+d)(1+\Delta)}{(1-f_f)} \left[\cot q + \frac{v_{m//}}{v_{m\perp}} \right]$$

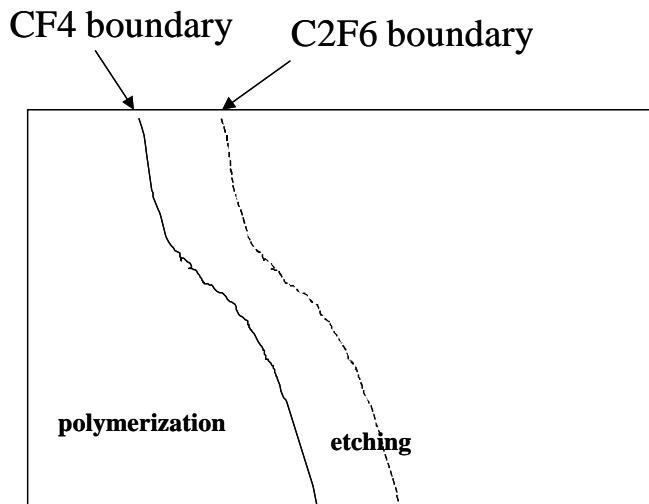
Selectivity with respect to mask $S_{fm} = \frac{4000}{1000/2} [\cot 80^\circ + 0.6] \times 2.98 = 18.5$

(b)

(i) Adding O₂ to CF₄ plasma generates more F* species. The Si+F* reaction by itself is chemical in nature is isotropic. This enhanced etching component will decrease degree of anisotropy.

(ii) Ion bombardment will sputter away the deposited polymer on the surface. Increasing bombardment will reduce polymer accumulation on the surface, giving a higher net etching rate.

(iii) The F/C ratio is 3 for C₂F₆ and is 4 for CF₄. The plasma will create relatively less F* for etching and more C for polymerization. The etching/polymerization boundary will move towards the right (i.e., polymerization more likely with same RIE conditions when using C₂F₆ plasma).



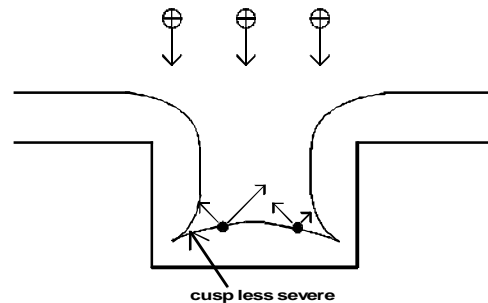
Problem 3

(a)

(i) A higher substrate temperature increases surface diffusion. The deposited atoms can migrate longer distance to smooth out local asperities.

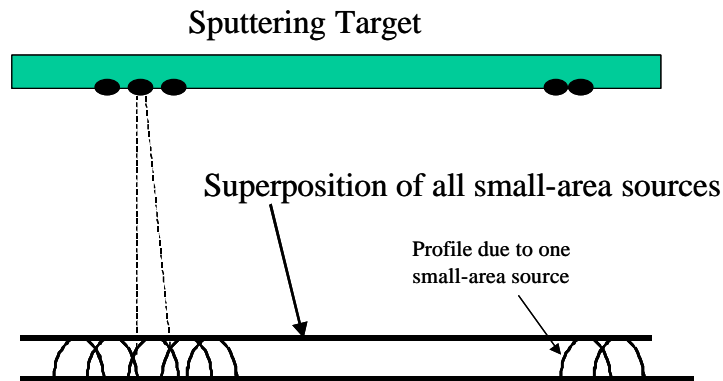
(ii) Deposited film substrate is resputtered. Some redeposited one sidewall \Rightarrow better uniformity along steps.

(iii) If evaporation is used, different components of the alloy will have different vapor pressures. Since the evaporating source is at the same temperature, different component fluxes arriving at the substrate will have a composition very different from that of the evaporation source.



Sputtering of an alloy target can give the same film composition as the target in principle. An alternative is to use different sputtering targets to achieve a particular composition.

- (iv) Area of sputtering target can be made much larger than that of an evaporating source. A larger area can be considered as a superposition of many small-area sources. By adding the flux from all the sources, a large area source will provide better film deposition uniformity.



(b)

(i) With small flow rates, deposition is limited by gas transport, Grove model \Rightarrow .

$$F_1 \equiv D_G \cdot \frac{C_G - C_S}{\delta} \Rightarrow h_G = \frac{D_G}{\delta} \text{ where } D_G = \text{diffusivity}$$

$$\frac{dy}{dt} \propto h_G \propto \frac{1}{\delta} \propto \sqrt{U}$$

(ii) With high flow rates, deposition is limited by surface reaction, $dy/dt \propto k_s$ which is independent of flow rate.

(iii) For small flow rates, deposition rate is limited by gas transport. From Grove model,

$$dy/dt \approx h_G \frac{C_G}{\rho}$$

At a growth rate of $0.1 \mu\text{m}/\text{minute} = 1.67 \times 10^{-7} \text{ cm}/\text{sec}$.

$$h_G = 1.67 \times 10^{-7} \times \frac{5 \times 10^{22}}{4 \times 10^{16}} = 0.208 \text{ cm}/\text{sec}$$

(iv)

(v) Using a higher flow rate with same pressure will supply more reactant gas /unit time into the CVD reactor. Mass depletion due to consumption of reactants will be less severe.

Problem 4

(i) The pockets of SOG are used for partial planarization.

(ii) Because Al is already present when nitride is deposited, the nitride is put down by PECVD which does not have perfect conformal coverage when deposition temperature is relatively low. They form the "keyholes" especially when the gap has higher aspect ratios

(iii) A typical Al alloy composition used for interconnects is Al-2%Si- 2% Cu.

(iv) MoSi_2 acts like a diffusion barrier to minimize Al reaction with substrate Si.

(v) Silicides do not electromigrate. The silicide/Al/silicide sandwich provides a local shunting path in case the Al forms a local void due to electromigration.

(vi) **Approach 1:** Use trench oxide isolation instead of LOCOS. This gives a better planarized surface early on in the process flow.

Approach 2 : Use W-plugs to partially or fully planarize contact holes before interconnect deposition

Approach 3: Fill up contact holes with thick layer deposition. Then use etchback or CMP to planarize back to dielectric surfaces.