EECS143,Sp 99 ***N. Cheung***

Midterm Exam #1 Solutions

Problem 1

(a) The observed indicates the growth rate is slower than the Deal-Grove model after 2000 Å of oxide is grown. Even if we take the limit that growth rate is proportional $(\text{time})^{1/2}$, the oxide will be thicker than 4000 **Å** after 4 hours of oxidation. The Si surface layer must have a faster oxide rate than the bulk of the wafer.

***Conjecture 1* :** The processed Si wafer was oxidized first to an oxide thickness of 100 Å and then have the oxide dissolved in HF. **FALSE**
Dopant segregation can enhance oxidation rate but the small oxide growth cannot change the surface layer dopant concentration due to dopant segregation.

Conjecture 2 : The processed Si wafer has a highly doped surface layer (doping > $10^{19}/\text{cm}^3$) which is less than 1000 Å thick. **TRUE**
The Si wafer has a highly doped surface layer ($N > 10^{19}/\text{cm}^3$) which is less than 1000 Å thick (i.e., 0.46×2000 Å $\approx$1000 Å). The underneath substrate is lightly doped. The Si wafer has a highly doped region underneath a lightly doped surface region. Oxidation rate is higher when the doping concentration is higher than $10^{19}/\text{cm}^3$, mainly through the linear term B/A. After this layer of highly doped Si is consumed, the growth rate slows down.

Conjecture 3 : The processed Si wafer has a thin layer of poly-Si layer on top surface. **TRUE**
Initial oxidation of poly-Si is very fast. After poly-Si is all consumed, the oxidation rates slows down.

(b) $$\frac{\text{SiO}_2\text{volume}}{\text{Si volume}} = \frac{5\times10^{22}}{2.3\times10^{22}} = 2.17$$

Volume of sphere $\propto$ radius^3 or $$\frac{\text{radius of SiO}_2}{\text{radius of Si}} = (2.17)^{1/3} = 1.29$$

Therefore , radius of SiO_2 sphere =1.29 μm.

(c) LOCOS Advantages :
(i) Self-aligned channel stop ; (ii) oxide topography more planar than opening an oxide window.
LOCOS Disadvantages: The "bird's beak" region wastes device area.

Problem 2 (a)

Parameter	**Electrical Channel Length L**
Implant Dose ↑	↓
Substrate conc. N_B ↑	↓
Sidewall Angle θ ↑	↑
Gate material changed from poly-Si to Tungsten	↑
Implant ions changed from Phosphorus to Arsenic (same energy)	↑

(b) Restore crystallinity of damage Si caused by ion bombradment
Position implanted dopants into substituitional sites of Si lattice so that the dopants gives "shallow" dnor or acceptor energy levels [i.e. dopant activation]

(c) Tilt the crystal by about 7 degrees with respect to beam incidence direction plus wafer rotation to avoid axial and planar channeling
Pre-amorphise the Si substrate first by Si implanattion, followed by dopant implantation.

Problem 3
(a)
Profile 1 : $C_S \operatorname{erfc} [x_j /2\sqrt{Dt}] = C_S \operatorname{erfc} [0.7/(2 \times 0.1] = C_S \operatorname{erfc} [3.5] = 10^{16}$ /cm^3
Therefore $C_S = 1.3 \times 10^{22}$/cm^3 [26% boron !!!]
Profile 2 : $R_S = 1/ \{ q \mu_p C_S x_j)$ or $C_S = 1/ (q \mu_p x_j R_S) = 3 \times 10^{20}$ / cm^3

The solid solubility of boron in Si is less than 10^{21} /cm^3. Profile 1 is unrealistic. Profile 2 is a better approximation.

[Note: If you use the Irvin Curves for Profile 1 with $R_S x_j$ = 3.5 ohm-um, the extrapolated surface concentration will also be in the 10^{22}/cm^3 range]

(b)

During the initial stage of diffusion, the doped region is intrinsic (n = p) so we won't expect to see any high concentration diffusion effect.

However, Boron diffuses faster than As and the near surface region becomes highly n-doped and the deeper region becomes p-doped. Since the net carrier concentration can still be higher than n_i. We will start to observed high concentration diffusion effects in both regions for longer diffusion times.

Problen 4
(a) Let translational error be (x_t,y_t).
The run in/out errors will contribute $+\delta x$ to A1 and $-\delta x$ to A2
The rotational errors will contribute $+\delta y$ to A1 and $-\delta y$ to A2
Therefore,
$x_1= x_t+\delta x$
$x_2= x_t -\delta x$
$y_1= y_t+\delta y$
$y_2= y_t -\delta y$

Rearranging terms,
$\delta x = \frac{x_1 - x_2}{2}$ (run in/out error) = (0.2-0.4)/2 = - 0.1 um [run-in error]
$\delta y = \frac{y_1 - y_2}{2}$ (rotational error) = (0.2-0.4)/2 = -0.1 um or 2E-6 radians [clockwise]
$x_t = \frac{x_1 + x_2}{2}$ = (0.2+0.4)/2 = 0.3 um
$y_t = \frac{y_1 + y_2}{2}$ = (0.2+0.4)/2 = 0.3 um

(d) $l_m \propto \lambda/NA$. NA reduces by 2X, l_m = 0.5um x 2 = 1um
DOF $\propto \lambda/NA^2$. NA reduces by 2X, DOF = 1um x 4 = 4 um