ECSE-2210 Microelectronics Technology
Class Activity 32 – Solution

1. What is the difference between dry-oxidation and wet-oxidation? For growing gate oxide, which method is used?

Dry Oxidation	Wet Oxidation
Uses pure oxygen for oxidation.	Uses pure water vapor for oxidation.
Results in less oxide charges at the interface, better quality oxide.	More oxide-Si interface charges, poorer quality.
Grows very slowly, good for growing gate oxides.	Faster growth rate, good for growing thick oxides such as field oxides.

2. The charges in the oxide and oxide-silicon interface should be as small as possible in a good MOSFET process. Why?

   We had assumed that the charges in the oxide are zero or negligible in an ideal MOSFET. If this is not zero, we have to make corrections. These charges are not controllable, and hence we cannot predict the final threshold voltage. The MOSFET threshold voltage is given by the equation

   $V_T = -Q_i / C_{ox} + V_{FB} + 2\phi_s$ + other factors where Q_i are the interface charges.

   One important "other factor" mentioned above is the interface charges, which we want to keep to the minimum so that we can optimize the threshold voltage using other factors such as doping. If the interface charges are high, then the threshold voltage of the device may be too high to be useful.

3. Mention approximate temperature range for oxidation, diffusion and ion-implantation processes.

   Oxidation and diffusion are generally carried out at high temperatures (1000 to 1200 °C). The ion implantation is done at room temperature. However, the implantation introduces a lot of damage to the silicon crystal and one has to heat up the wafer to higher temperatures (700 to 900 °C) to remove the damage. This can be part of the next process step.

4. A silicon substrate is implanted with phosphorous (P^+) ions at 100 keV. The dose is 10^{12} ions / cm^{-2}. Assume a range $R_p = 0.14$ µm and straggle $\Delta R_p = 0.06$ µm. The substrate is doped with 10^{16} cm^{-3} of boron. Find the following:

   (a) The depth at which the dopant concentration reaches a maximum.
   This happens at $x = R_p = 0.14$ µm from the surface.

   (b) The dopant density at the maximum.
   To get the dopant density at the maximum, put $x = R_P$ in the equation.

$$N(x) = \frac{\phi}{\sqrt{2\pi}\,\Delta R_p} \exp\left[-\frac{1}{2}\left(\frac{x-R_p}{\Delta R_p}\right)^2\right]$$

$$N(x) = \frac{\phi}{\sqrt{2\pi}\,\Delta R_p}$$

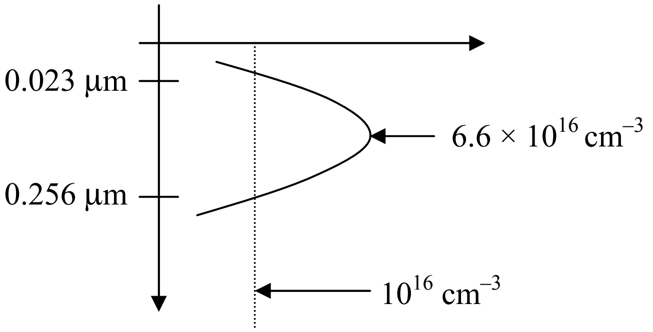
   ➔ $N\,(x = R_P) = 10^{12} / (2\pi)^{0.5} \times 0.06 \times 10^{-4} = 6.6 \times 10^{16}\ cm^{-3}$.

   (c) The p-n junction depth from the surface.
   The junction forms when the doping from the implantation equals the substrate doping, since the implanted species is phosphorous.

   $10^{16}\ cm^{-3} = 6.6 \times 10^{16}\ cm^{-3} \exp\left[-0.5\,(x_j - R_p)^2 / (\Delta R_p)^2\right]$

   $x_j = 0.256$ µm and 0.023 µm

   Note that you get ***two*** junctions in this particular case.



5. Mention a few methods by which one can deposit thin films on to silicon wafers.
   Vacuum evaporation, sputtering, and chemical vapor deposition are some of the methods by which thin films can be deposited.

6. A certain silicon-gate NMOS transistor occupies an area of 25 λ^2 where λ is the minimum lithographic feature size. Find how many MOS transistors can fit on a 5 mm × 5 mm die if (a) $\lambda = 10\ \mu m$ and (b) $\lambda = 1\ \mu m$?
   (a) 10,000
   (b) 1,000,000

7. A simple pn junction diode is shown in cross section in the figure below. Make a possible process flowchart for fabrication of this structure. Include mask steps.
   See class handout on diodes. You will need three masks: One mask for the window for the n-diffusion, one mask for opening contact holes, and one mask for patterning the metal.