EE 432/532 Name____

Exam 1 – Mar. 29, 2017

1. **Localized oxidation of silicon (LOCOS)**
   In a LOCOS process, a portion of a silicon wafer is covered with silicon nitride (the rest of the wafer being bare. The nitride-covered silicon will not oxidize. With the nitride in place the wafer is oxidized using H_2O for 60 minutes at 1100°C. Then the nitride is stripped off (without removing any oxide), and the wafer is oxidized again. The second oxidation also uses H_2O at 1100°C for 60 minutes. Calculate the final thicknesses of the oxide in the two regions. Also, calculate the height of the step that is created at the silicon dioxide surface. (Drawing a couple of sketches will help you visualize what's happening.)

   t_{ox1} = ______________________________.

   t_{ox2} = ______________________________.

   step height = _________________________.

Put your final answers on this sheet and attach any additional sheets behind. You must include your work to get full credit.

EE 432/532 Name____
Exam 1 – Mar. 29, 2017

2. **Shallow p-type diffusion**
In trying to make smaller PMOS transistors, you want to perform a source/drain diffusion that will have lateral diffusion less than 0.15 μm. Design a two-step boron diffusion that will give a high surface concentration (10^{18} cm^{-3}) and lateral diffusion that has the given limit. Calculate the Dt's. The background doping is 10^{15} cm^{-3}. For the solid solubility limit of boron, use $N_S = 10^{20}$ cm^{-3} (independent of temperature.)

$(Dt)_1$ = __________________________. $(Dt)_2$ = __________________________.

Do you see practical difficulties in performing the diffusion? What technology might you use to get around any problems that you see?

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EE 432/532 Name______________________________________

Exam 1 – Mar. 29, 2017

3. **Now try an implant**

In trying to make the p-regions described in problem 2, you decide to switch to ion implantation. You want to form a p-type layer with the peak concentration located at 0.1 μm below the surface. What boron implant energy should you use? What dose should you use to make the lower junction depth be at 0.15 μm? The n-type background doping is 10^{15} cm^{-3}. Ignore any effects of annealing.

E = ________________________________

x_j = ________________________________

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EE 432/532 Name________________________________

Exam 1 – Mar. 29, 2017

k = 1.38 x 10^{-38} J/K = 8.617x10^{-5} eV/K

$$t = \frac{t_{ox}^2}{B} + \frac{t_{ox}}{B/A} - \tau \qquad \tau = \frac{t_{ox,i}^2}{B} + \frac{t_{ox,i}}{B/A}$$

$$t_{ox} = \frac{A}{2}\left[\sqrt{1 + \frac{4B}{A^2}(t+\tau)} - 1\right]$$
$$= \frac{B}{2(B/A)}\left[\sqrt{1 + \frac{4(B/A)^2}{B}(t+\tau)} - 1\right]$$

$$\left(\frac{B}{A}\right)_{wet} = \left(9.70 \times 10^7 \frac{\mu m}{hr}\right)\exp\left(-\frac{2.05eV}{kT}\right) \qquad B_{wet} = \left(386\frac{\mu m^2}{hr}\right)\exp\left(-\frac{0.78eV}{kT}\right)$$

$$\left(\frac{B}{A}\right)_{dry} = \left(3.71 \times 10^6 \frac{\mu m}{hr}\right)\exp\left(-\frac{2.00eV}{kT}\right) \qquad B_{dry} = \left(772\frac{\mu m^2}{hr}\right)\exp\left(-\frac{1.23eV}{kT}\right)$$

Constant-source diffusion: $N(x,t) = N_o erfc\left(\frac{x}{2\sqrt{Dt}}\right)$; $Q = \frac{2N_o\sqrt{Dt}}{\sqrt{\pi}}$

Constant-dose diffusion: $N(x,t) = \frac{Q}{\sqrt{\pi Dt}}\exp\left(-\frac{x^2}{4Dt}\right)$

Two-step diffusion: $N(x,t) = \frac{2N_o}{\pi}\frac{\sqrt{D_1 t_1}}{\sqrt{D_2 t_2}}\exp\left(-\frac{x^2}{4D_2 t_2}\right)$

Diffusion data:

	D_o (cm²/s)	E_A (eV)
Boron	1.0	3.5
Phosphorus	4.70	3.68
Arsenic	9.17	3.99
Antimony	4.58	3.88

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

after an anneal: $N(x) = \frac{Q}{\sqrt{2\pi(\Delta R_P^2 + 2Dt)}}\exp\left[-\frac{(x-R_p)^2}{2(\Delta R_P^2 + 2Dt)}\right]$

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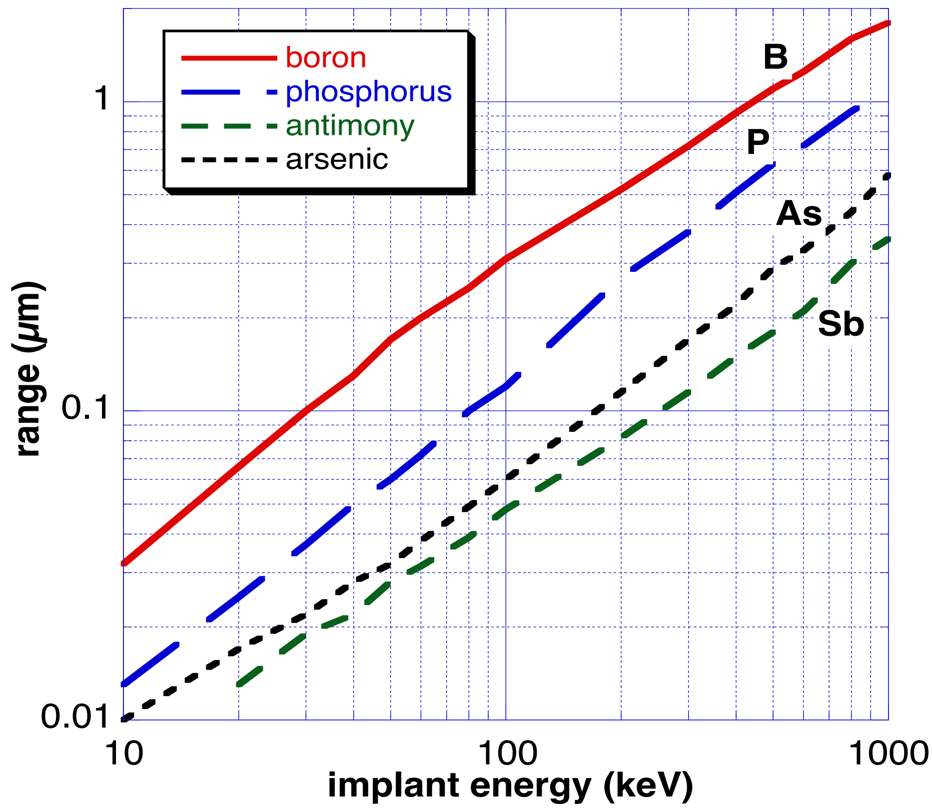
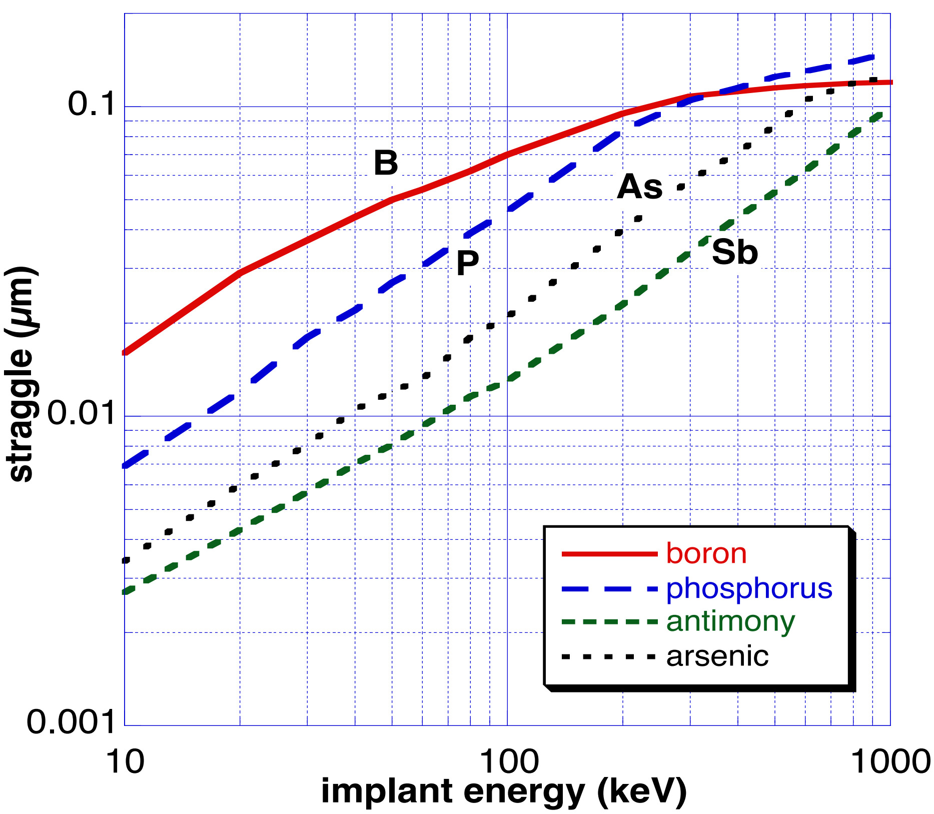
EE 432/532 Name____

Exam 1 – Mar. 29, 2017





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