CHE323/384 Chemical Processes for Micro- and Nanofabrication
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Homework #5 Solutions

1. Arsenic is implanted into Si (with a 7° tilt) at an energy of 125keV. The dose is $2\times10^{14}/cm^2$. What is the peak dopant concentration produced?

From Fig. 5.9, the range and standard deviation for 125 keV arsenic are

$$R_P = 0.07\mu m, \quad \Delta R_P = 0.014\mu m$$

The peak concentration is

$$C_P = \frac{Q}{\sqrt{2\pi}\Delta R_P} = \frac{2\times10^{14}}{\sqrt{2\pi}\left(0.014\times10^{-4}\right)} = 5.7\times10^{19} cm^{-3}$$

(In reality, only one significant digit should be used, but I have included two just to help you with ensuring that the problem was worked correctly.)

2. We are designing an implant step which will implant phosphorus ions through 50 nm of SiO_2 into an underlying silicon substrate such that the peak concentration in the substrate is $1\times10^{17} cm^{-3}$ and the concentration at the SiO_2/Si interface is $1\times10^{16} cm^{-3}$. What energy and dose would you use to achieve these conditions? Assume that the stopping power of SiO_2 is the same as that of silicon. Neglect channeling effects.

Using our Gaussian model, the concentration as a function of depth can be related to the peak concentration, C_P:

$$C(z) = C_P \exp\left[-\frac{(z-R_P)^2}{2\Delta R_P^2}\right]$$

At z = 50 nm, C(50 nm) = $1\times10^{16} cm^{-3}$, and C(50 nm)/C_P = 0.1. Taking the log of both sides,

$$\sqrt{2\ln(10)} = \frac{(R_P - 0.05)}{\Delta R_P} = 2.146$$

By trial and error from the graph of the range and sigma for phosphorus (Figure 5.9) we want to find an energy that gives $R_P - 2.15\Delta R_P = 0.05\mu m$.

$$100keV \quad R_P = 0.125, \quad \Delta R_P = 0.035, \quad R_P - 2.15\Delta R_P = 0.048\mu m$$
$$120keV \quad R_P = 0.15, \quad \Delta R_P = 0.040, \quad R_P - 2.15\Delta R_P = 0.064\mu m$$

Interpolating linearly between 100 and 120 keV gives about 103 keV (or just saying 100 keV is good enough, given the significant digits involved)..

At this energy, $\Delta R_P = 0.035\mu m$ and hence we can find the dose from

$$Q = \sqrt{2\pi}\Delta R_P C_P = 8.8 \times 10^{11} cm^{-2}$$

3. We wish to determine the thickness of a mask needed to reduce the peak concentration of that implant in the mask by a factor of 10,000 at the mask/substrate boundary. Provide an equation in terms of the projected range and the straggle of the implant profile in the mask material.

We want to reduce the peak doping N_P in the mask at range R_P by 10,000 at the mask/substrate boundary. We will use the equation which describes the profile of an implant in the mask layer

$$N(z = d) = N_P \exp\left[-\frac{(d - R_P)^2}{2\Delta R_P^{\,2}}\right]$$

When $N(d)/N_P = 10^{-4}$, we have $d = R_P + 4.3\Delta R_P$.

4. Campbell textbook, Chapter 5, problem 2.

No solution provided for this one. You are on your own!