

1. Phosphorus is diffused into a uniformly doped p-type silicon with $N_B = 10^{16}/\text{cm}^3$ at 1150°C . Given that the solid-solubility of phosphorus in silicon at 1150°C is $10^{20}/\text{cm}^3$ and the diffusion coefficient at this temperature is $1 \times 10^{-12} \text{cm}^2/\text{sec}$, (a) calculate the total number of phosphorus atoms per unit area of the silicon surface after a predeposition time of 1 hour. (b) If after this, drive in is carried out for 2 hours at the same temperature, what will be the final junction depth and the surface concentration?

(a) The total amount of phosphorus introduced in silicon per unit area after predeposition is

$$Q(t) = \int_0^{\infty} [N(x, t) - N_B] dx = 2N_o \sqrt{\frac{Dt}{\pi}} \dots\dots(1)$$

$$\text{Therefore } Q = 2 \times 10^{20} \sqrt{\frac{10^{-12} \times 3600}{\pi}} = 6.77 \times 10^{15} / \text{cm}^2$$

(b) Now after drive-in, the surface concentration is given by setting $x = 0$ in the following eqn.

$$N(x, t) = \frac{Q}{\sqrt{\pi Dt}} \exp\left(-\frac{x^2}{4Dt}\right) + N_B \dots\dots(2)$$

So, if the drive-in is carried out for 2 hours at the same temperature, we have

$$N_s = \frac{6.77 \times 10^{15}}{\sqrt{\pi \times 10^{-12} \times 7200}} + 10^{16} = 4.5 \times 10^{19} / \text{cm}^3$$

In order to obtain the junction depth, we note that at the junction, the phosphorus concentration becomes equal to the original background (boron) doping concentration of the sample, i.e. $N(x_j, t) = N_B$. From eqn. 2, we can now write

$$\frac{Q}{\sqrt{\pi Dt}} \exp\left(-\frac{x^2}{4Dt}\right) = N_B \text{ or, } 4.5 \times 10^{19} \exp\left(-\frac{x_j^2}{4 \times 10^{-12} \times 7200}\right) = 10^{16}$$

from which the junction depth is obtained as $x_j = 4.92 \mu\text{m}$.

2. Phosphorus is implanted in a p-type silicon sample with a uniform doping concentration of $10^{16}/\text{cm}^3$. If the beam current density is $2\mu\text{A}/\text{cm}^2$ and the implantation is carried out for ten minutes, calculate the implantation dose. Also find the peak impurity concentration assuming $R_p = 1.1\mu\text{m}$ and $\Delta R_p = 0.3\mu\text{m}$.

Solution: From the following eqn., we obtain the value of the implantation dose as

$$Q_o = \frac{Jt}{q} \dots\dots(1)$$

Where J is the beam current density and t is the implantation time. Therefore

$$Q_o = \frac{2 \times 10^{-6} \times 10 \times 60}{1.6 \times 10^{-19}} = 7.5 \times 10^{15} \text{ cm}^{-2}$$

The peak impurity concentration occurs at $x = R_p$. Substituting this in eqn. (2) given below, we get the peak concentration as

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

$$N_p = \frac{7.5 \times 10^{15}}{0.3 \times 10^{-4} \times \sqrt{2\pi}} = 6.267 \times 10^{20} \text{ cm}^{-3}$$

The surface concentration is obtained by setting $x = 0$ in eqn. (2). Thus

$$N_s = 6.267 \times 10^{20} \exp\left[-\frac{1}{2} \left(\frac{-1.1}{0.3}\right)^2\right] = 1.3747 \times 10^{18} \text{ cm}^{-3}$$
