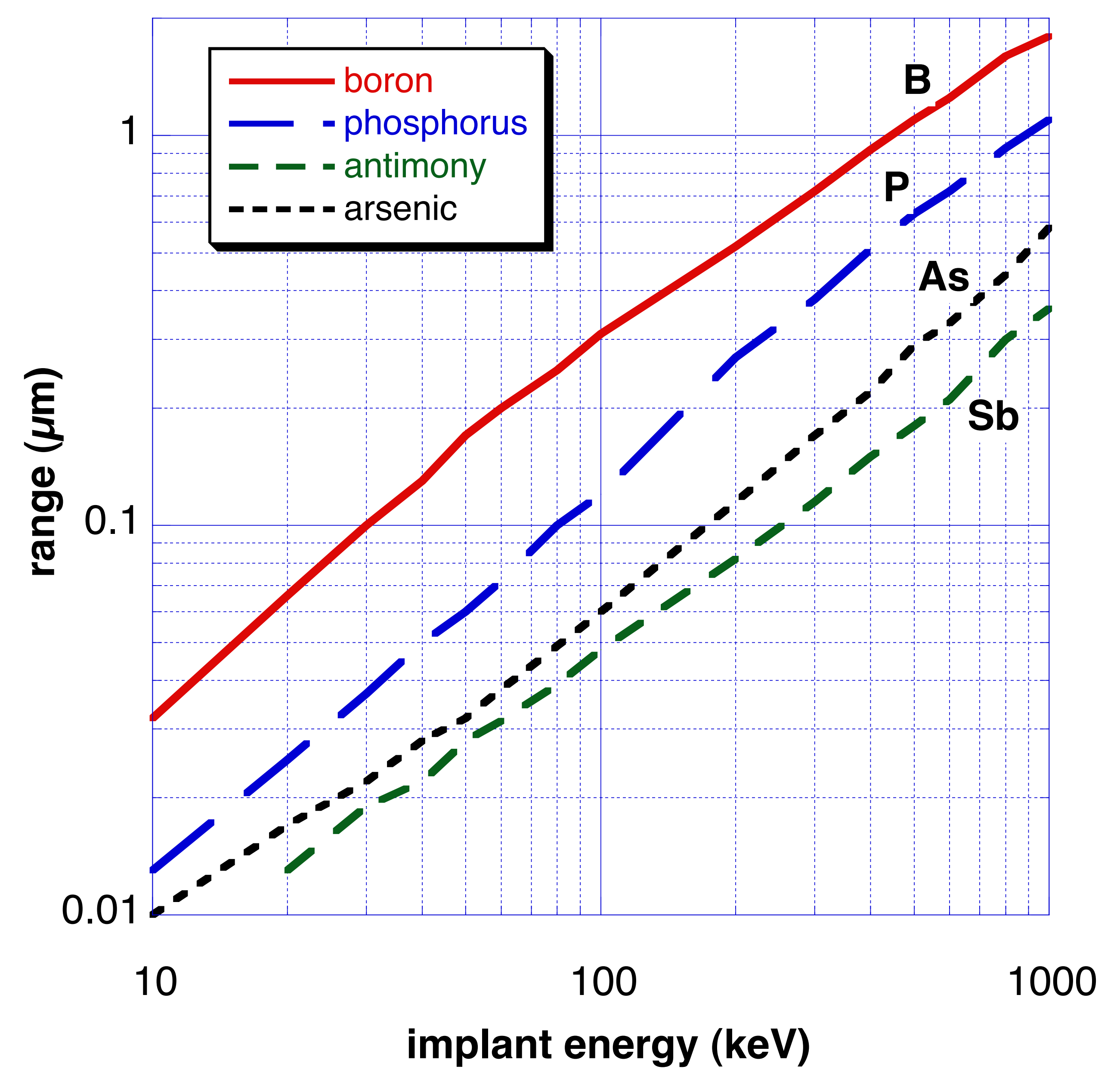
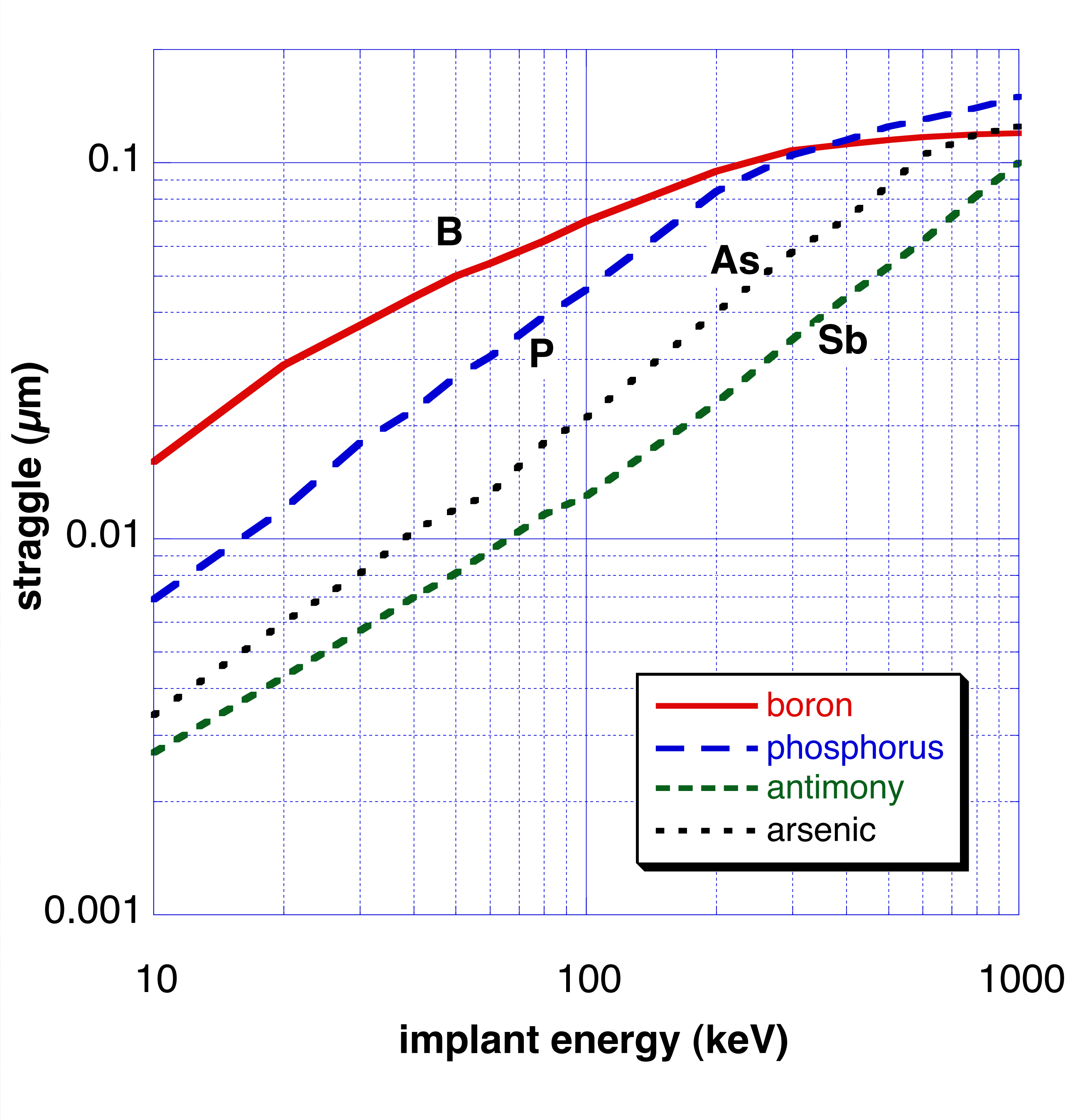
Range and straggle for implants into silicon





Ion implant – example 1

A silicon wafer with n-type background doping is subjected to a boron implant. The implant energy is 80 keV and the dose is 10^{14} cm^{-2}. The background doping of the wafer is 2x 10^{16} cm^{-3}. Find the peak concentration and the junction depth of the implanted layer.

First, find the range and straggle for a boron implant at 80 keV. From the graph, $R_P \approx 0.24$ μm and $\Delta R_P \approx 0.063$ μm. Then

$$N_P = \frac{Q}{\sqrt{2\pi}\Delta R_P} = \frac{10^{14}\text{cm}^{-2}}{\sqrt{2\pi}\left(6.3 \times 10^{-6}\text{cm}\right)} = 6.3 \times 10^{18}\text{cm}^{-3}$$

$$x_j = R_P \pm \sqrt{2}\Delta R_P \left[\ln\left(\frac{N_P}{N_B}\right)\right]^{\frac{1}{2}}$$

$$= 0.24\mu\text{m} \pm \sqrt{2}\,(0.063\mu\text{m}) \left[\ln\left(\frac{6.3 \times 10^{18}\text{cm}^{-3}}{2 \times 10^{16}\text{cm}^{-3}}\right)\right]^{\frac{1}{2}}$$

$= -0.026\ \mu$m or $0.45\ \mu$m.

In this case, only the positive value is real

Example 2

You want to do an phosphorus implant into a p-type silicon wafer (background doping of 10^{16} cm^{-3}). You choose to do the implant at 100 keV. What dose would be need to get a junction depth of 0.3 μm? What peak concentration will result?

Again, start by finding the range and straggle for a phosphorus implant at 100 keV. From the graph, $R_P \approx 0.12$ μm and $\Delta R_P \approx 0.045$ μm. Then

$$N_B = N_P \exp\left[-\frac{\left(x_j - R_P\right)^2}{2\Delta R_P^2}\right] \quad \rightarrow \quad N_P = N_B \exp\left[\frac{\left(x_j - R_P\right)^2}{2\Delta R_P^2}\right]$$

$$N_P = \left(10^{16}\text{cm}^{-3}\right)\exp\left[\frac{(0.3\mu\text{m} - 0.12\mu\text{m})^2}{2\,(0.045\mu\text{m})^2}\right] = 3 \times 10^{19}\text{cm}^{-3}$$

$$Q = \sqrt{2\pi}\Delta R_P N_P$$

$$= \sqrt{2\pi}\left(4.5 \times 10^{-6}\text{cm}\right)\left(3.0 \times 10^{10}\text{cm}^{-3}\right) = 3.4 \times 10^{14}\text{cm}^{-2}$$

Example 3

A silicon wafer with n-type background doping of 10^{16} cm^{-3} is subjected to a boron implant. The implant energy is 100 keV and the dose is 10^{16} cm^{-2}. Then the wafer is annealed for 30 minutes at 1000°C. Find the peak concentration and junction depth(s) immediately after implantation and then after annealing.

First, find the range and straggle for a boron implant at 100 keV. From the graph, $R_P \approx 0.3$ μm and $\Delta R_P \approx 0.07$ μm. Before annealing,

$$N_P = \frac{Q}{\sqrt{2\pi}\Delta R_P}$$

$$= \frac{10^{13}\mathrm{cm}^{-2}}{\sqrt{2\pi}\left(7.0 \times 10^{-6}\mathrm{cm}\right)} = 5.7 \times 10^{17}\mathrm{cm}^{-3}$$

$$x_j = R_P \pm \sqrt{2}\Delta R_P \left[\ln\left(\frac{N_P}{N_B}\right)\right]^{\frac{1}{2}}$$

$$= 0.30\mu\mathrm{m} \pm \sqrt{2}\,(0.07\mu\mathrm{m}) \left[\ln\left(\frac{5.7 \times 10^{17}\mathrm{cm}^{-3}}{10^{16}\mathrm{cm}^{-3}}\right)\right]^{\frac{1}{2}}$$

$$= +0.1\ \mu\mathrm{m}\ \text{or}\ 0.5\ \mu\mathrm{m}.$$

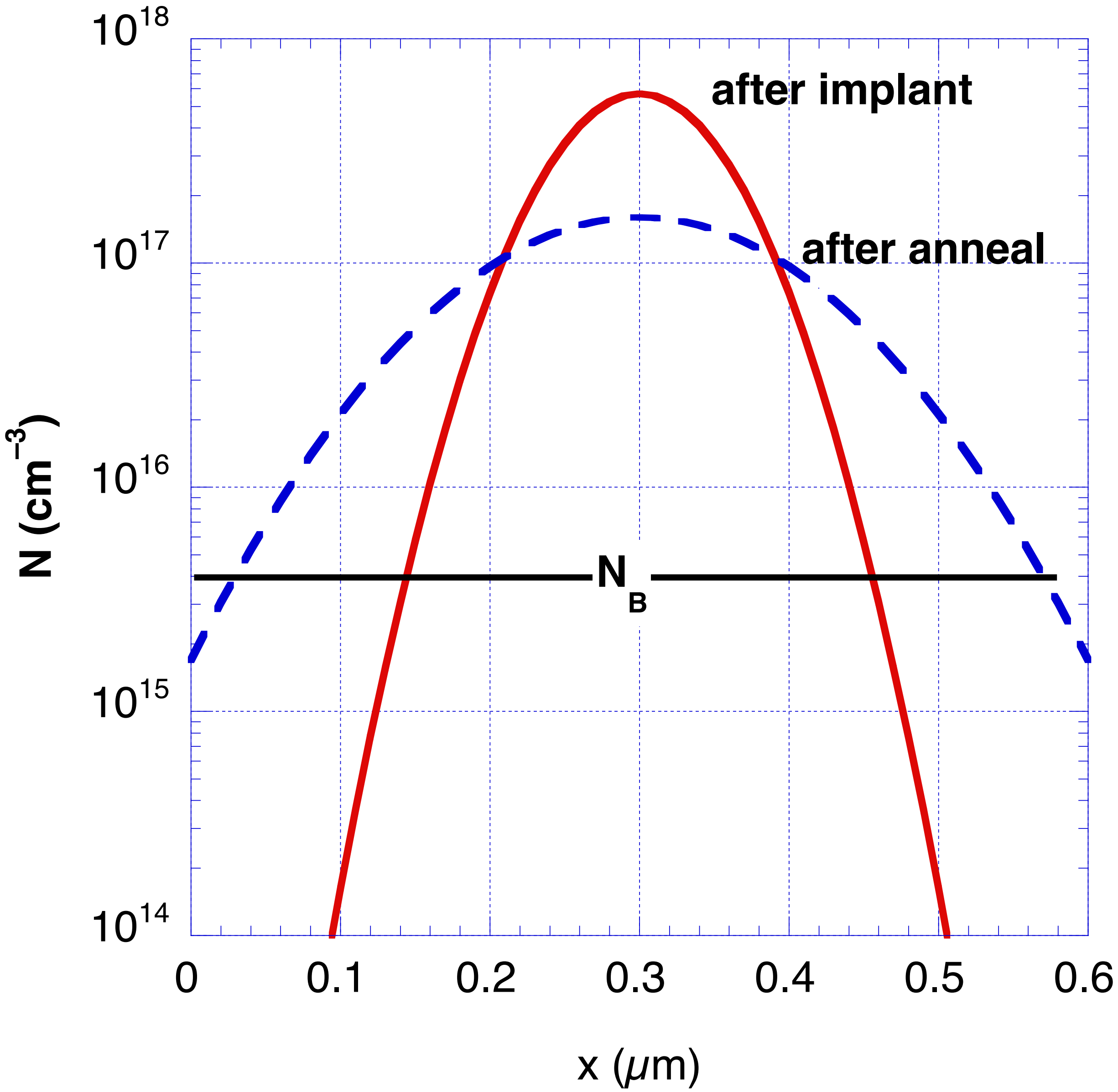
For the heat treatment,

$Dt = 2.5\text{x}10^{-11}\ \text{cm}^2$

$$N_P = \frac{Q}{2\sqrt{\pi\left[\frac{(\Delta R_P)^2}{2} + Dt\right]}}$$

$$= \frac{10^{13}\text{cm}^{-2}}{2\sqrt{\pi\left[\frac{\left(7\times10^{-6}\text{cm}\right)^2}{2} + \left(2.5\times10^{-11}\text{cm}^2\right)\right]}}$$

$= 4.7\text{x}10^{-17}\ \text{cm}^{-3}$



$$x_j = R_P \pm \sqrt{4\left[\frac{(\Delta R_P)^2}{2} + Dt\right]\ln\left(\frac{N_P}{N_B}\right)}$$

$$= 3\times10^{-5}\text{cm} \pm \sqrt{4\left[\frac{\left(7\times10^{-6}\text{cm}\right)^2}{2} + \left(2.5\times10^{-11}\text{cm}^2\right)\right]\ln\left(\frac{4\times10^{17}\text{cm}^{-3}}{10^{16}\text{cm}^{-3}}\right)}$$

$= +0.03\ \mu\text{m}$ or $0.57\ \mu\text{m}$.