3. Exercise	Silicon Sensors & Readout Electronics WS16/17

3.1 Intrinsic Carrier Density

The intrinsic carrier density in silicon at room temperature is $1.01 \times 10^{10}\,\mathrm{cm}^{-3}$ ('latest values'). Low field mobilities of electrons and holes are ≈ 1400 and $\approx 480\ \mathrm{cm}^2/(Vs)$, respectively.

1. How many free electrons / holes are present per cubic micrometer?
2. What would be the current flowing through a (ohmically connected) pixel with an area of $200 \times 200\,\mu\mathrm{m}^2$ in a $300\,\mu$m thick detector when applying 100 V ?
3. How many electrons/holes are that per nanosecond?

3.2 Thickness of Depletion Region

Consider an n-doped wafer of $300\,\mu$m thickness with a bulk resistivity of $2\,\mathrm{k}\Omega\,\mathrm{cm}$. The top surface is p-implanted with 10^{15} atoms per cm^3.

1. What is the wafer doping in atoms per cm^3 and atoms per $\mu\mathrm{m}^3$?
2. What is the build-in voltage?
3. What additional voltage V_{depl} is required to deplete the wafer?
4. What is the field at the pn-junction and at the backside just at depletion?
5. How does the field at the backside increase with extra Over-voltage when the bias voltage is $V_{depl} + V_{over}$?

3.3 Linear Depletion

For constant doping densitiy, the depletion region in a diode grows with the square root of the (reverse) bias voltage. In this exercise you should find a (non-constant) doping profile such that the thickness of the depletion region T grows *linearly* with the applied voltage, i.e. such that $T[V] = k \cdot V$.

1. We assume that the junction is at $x = 0$. To the left, we have 'infinite' p-doping.
2. To the right, we assume a n-doping density following a power law
$$n(x) = Ax^{\alpha}.$$
3. Assume that the depletion region extends to $T > 0$, i.e. that the donors are depleted and a space charge corresponding to donor density exists.
4. Calculate $E(x)$ from Gauß's law (by integrating over space charge).
5. From $E(x)$, calculate $V(x)$, and in particular $V(T)$.
6. Now find $T(V)$.
7. What exponent α is required for $T \propto V$?
8. Verify also that for $T \propto \sqrt{V}$, you find constant doping.