GSS Simulation Report

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Contents

1 PN-junction

In this section, the results of the simulated pn-junction for different parameters are presented.

The first set of simulations was done for different values of temperature. Silicon was used as the bulk material with the donor and acceptor concentration at 10^{16} cm^{-}3, following a uniform distribution. The results are shown in Table 1.

Temperature [K]	Electron/hole dens. [cm^{-3}]	Junction potential [V]	Space width [μm]
173	10^{16}	0.94	1.8
273	10^{16}	0.77	1.7
373	10^{16}	0.60	1.6

Table 1: Effect of the temperature change on junction potential, charge carrier density and space width.

The theoretical prediction is shown is Table 2. The junction potential was calculated as:

$$\phi = \frac{k_b T}{q} ln(\frac{N_a N_d}{n_i^2}), \tag{1}$$

while the space width was calculated as:

$$\phi = \sqrt{\frac{2\epsilon_0 \epsilon_r}{q}(\frac{1}{N_a} + \frac{1}{N_d})\phi}. \tag{2}$$

In the equations 1 and 2, N_e and N_d are the donor and acceptor concentration while n_i is the intrinsic bulk concentration which was taken from the literature.

Temperature [K]	Electron/hole dens. [cm^{-3}]	Junction potential [V]	Space width [μm]
173	10^{16}	0.97	1.53
273	10^{16}	0.82	1.40
373	10^{16}	0.63	1.25

Table 2: Theoretical prediction: Effect of the temperature change on junction potential, charge carrier density and space width.

Both the theoretical and simulated junction potential and space width decrease with temperature. It can be concluded that the theory and the simulation are in good agreement, though it can be noticed that the theoretical junction potential is around 5% higher while the theoretical space width is around 15% lower for all points.

In the next simulations, the effect of the acceptor/donor ratio was investigated. As previously, silicon was used as the bulk material. The temperature was at 300K. The results are shown in Table 3.

acc/don	Electron dens. [cm^{-3}]	Hole dens. [cm^{-3}]	Junction potential [V]	Space width [μm]
10^{-1}	10^{17}	10^{16}	0.74	1.2
10^{1}	10^{16}	10^{17}	0.77	1.2
10^{2}	10^{16}	10^{18}	0.81	1.1

Table 3: Effect of the acceptor/donor ratio on junction potential and space width.

In the next set of simulations, a difference between the silicon and germanium bulk material was investigated. The temperature was at 300K with the acceptor and donor concentration of 10^{16} following a uniform distribution.

Material	Electron/hole dens. [cm^{-3}]	Junction potential [V]	Space width [μm]
Si	10^{16}	0.7	1.8
Ge	10^{16}	0.3	1.4

Table 4: Effect of the material change on junction potential and space width.

Regarding the acceptor/donor ration, the effect would have been more obvious if one parameter had been kept constant while the other one had been varied. The width for the same acceptor-donor concentration is symmetrical and seemingly higher while it is asymmetrical if the concentration is unequal. The effect of the material is very obvious: Ge has lower junction potential and a narrower width then Si.

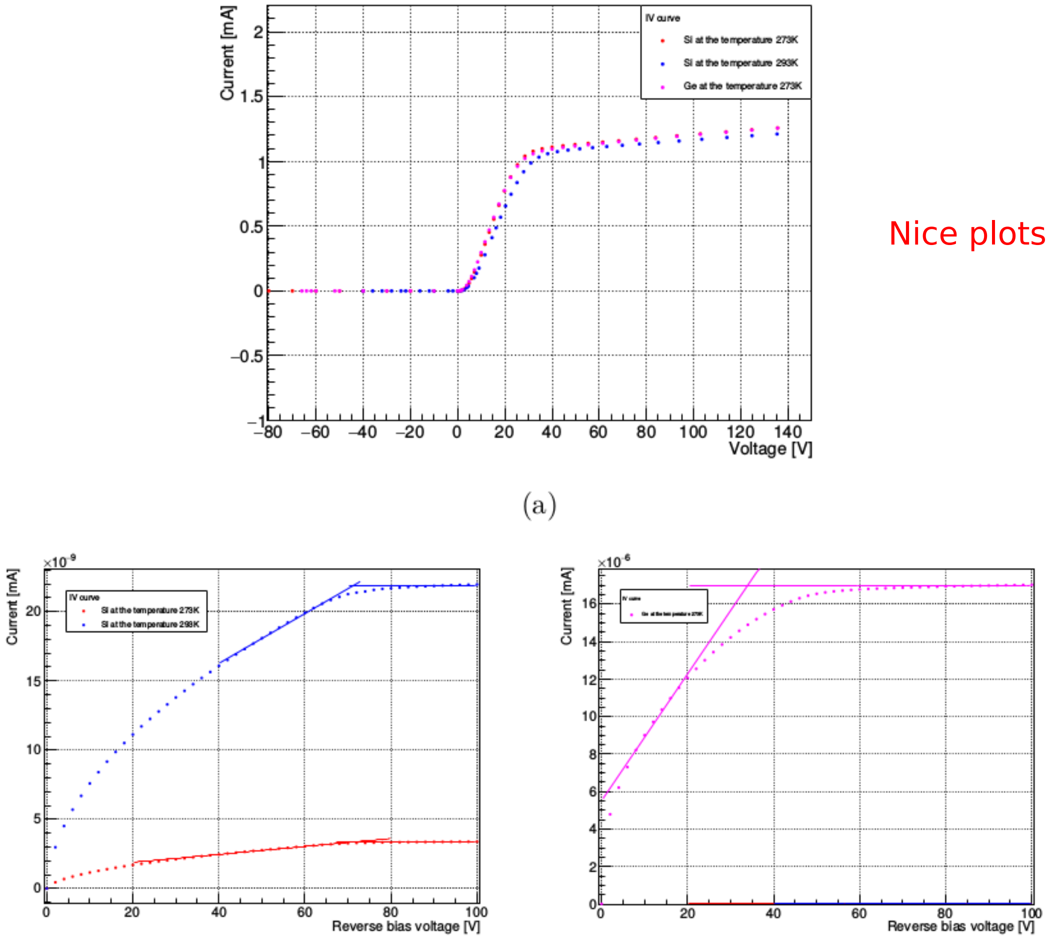
What about the max field in the junction?

The doping concentration is on the high side to really give visible effects.

- **IV Curve**

Next, simulated was a sensor of dimensions 100 $\times 50\mu$m with p-type bulk with concentration of 10^{13} cm^{-3} and 3 μm thick implants at each side, with concentration of 10^{15} cm^{-3}. For Si, the simulation was done for the temperatures of 273K and 293K while for Ge the temperature was at 273K.

The IV-curves for Si and Ge are shown in Figure 1a. The zoomed in IV-curves of the reverse bias voltage only are shown in Figures 1b (Si) and 1c (Ge) in which the reverse bias voltage is drawn as positive. The depletion voltage i.e. the voltage at which the device is fully depleted was calculated as the intersection point of two straight lines fitted to the two regions of the IV-curve.



(a)

(b)

(c)

Nice plots! Nice work!

Figure 1: PN diode: on the top is shown the IV curve for Si at the temperatures of 273K and 293K and Ge at the temperature of 273K (a) below are shown the zoomed in IV curves for the reverse voltage only for (b) Si at the temperatures of 273K and 293K and (c) Ge at the temperature of 273K. The depletion voltage is calculated as the intersection point of the fitted curves.

The depletion voltage for Si and Ge is shown in Table 5.

Material	Temperature [K]	Depletion voltage [V]
Si	273	69
Si	293	71
Ge	273	34

Table 5: The depletion voltage for Si and Ge, at several temperatures.

2 Schottky contact

Next, simulated was a Schottky contact i.e. a metal-semiconducter contact.

The effect of the temperature change on junction potential, charge carrier density and space width is shown in Table 6.

how is your sensor designed?

Temperature [K]	Elec. density [cm^{-3}]	Hole density [cm^{-3}]	Junction pot. [V]	Space width [μm]
273	10^{18}	10^{15}	0.9	3.0
293	10^{18}	10^{15}	1.1	3.0
303	10^{18}	10^{15}	1.2	3.0

back plane contact? bulk?

Table 6: Schottky contact: Effect of the temperature change on junction potential, charge carrier density and space width for Si material.

The effect of a change in the acceptor concentration for Si material at the temperature of 273K was also investigated. The results are shown in Table 7.

Acceptor density [cm^{-3}]	Junction potential [V]	Space width [μm]
10^{15}	1.2	3.0
10^{16}	1.3	3.0
10^{17}	1.4	3.0

Table 7: Schottky contact: Effect of the acceptor concentration change on charge carrier density, junction potential and space width for Si material.

The effect of the material is shown in Table 8. The acceptor concentration was 10^{16} while the temperature was 273K.

Material	Acceptor dens. [cm^{-3}]	Junction potential [V]	Space width [μm]
Si	10^{16}	1.3	3.0
Ge	10^{16}	0.3	3.0

Table 8: Schottky contact: Effect of material change on junction potential and space width.

It can be concluded that the space width was constant (full) for the chosen parameters. The junction potential increases with temperature and acceptor density. The space width is the same both for Si and Ge, while the junction potential is significantly lower for Ge. When compared to the pn-junction, junction potential and space width of the Schottky diode are higher.

- **IV Curve**

Next, simulated was a sensor of dimensions 100 $\times 50\mu$m with n-type bulk. The bulk concentration was 10^{13} cm^{-3}. A 3 μm thick acceptor implant with the concentration of 10^{15} cm^{-3} was added to the bottom. The IV curve of the reversed voltage for Ge at the temperature of 273K is plotted in Figure 2. When compared to the PN-junction, one can see that for a same voltage, the current in a Schottky device is lower.

Not a Schottky!

Top metal
n-bulk = donor
Bottom contact (n-type), if you wish to include it in the design.

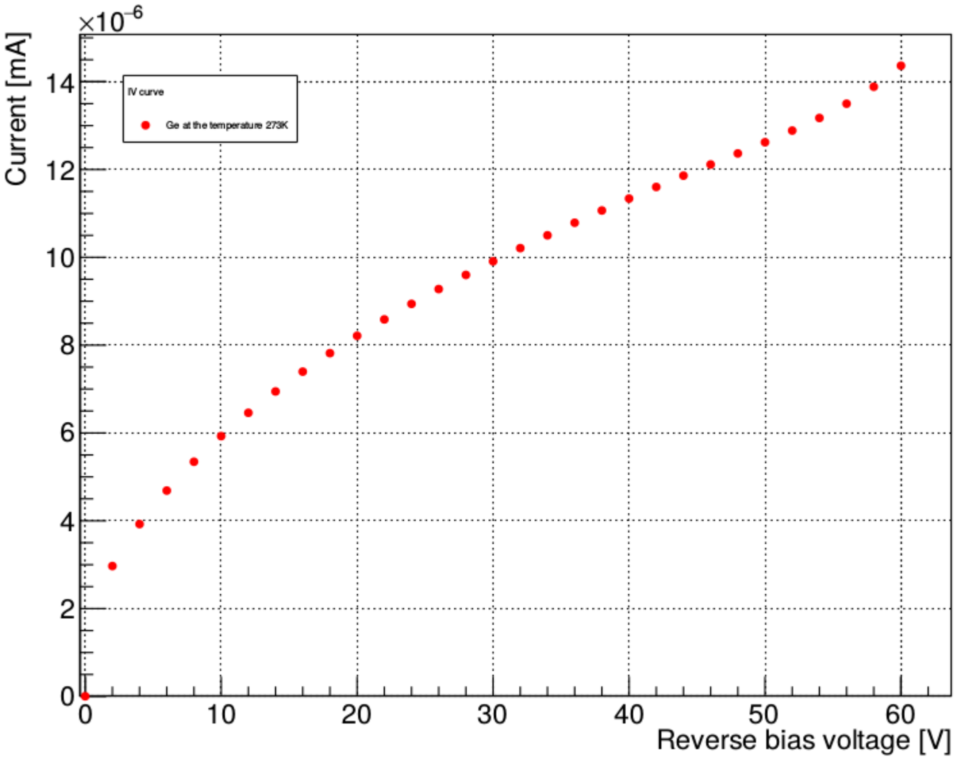


Figure 2: Schottky contact: IV curve for Ge at temperature of 273K.