Semiconductor Exercises

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1 Problem 1

The simulation for *pn*-diode was performed using four different sets of parameters, a summary of which is given in table 1

Table 1: Sets of input parameters used for *pn*-diode simulation

No.	Material	T, K	N_d, cm^{-3}	N_a, cm^{-3}
1	Si	300	10^{16}	10^{16}
2	Si	100	10^{16}	10^{16}
3	Si	300	10^{16}	10^{12}
4	Ge	300	10^{16}	10^{16}

The obtained potentials and electric field distributions are shown in fig. 1. The visually estimated width of the depleted region is $W_{\text{sim}} \approx 1.6\text{um}$ for both Germanium and Silicon.

To calculate the depleted width analytically, one first needs to estimate the contact potential, given by

$$\Psi_0 = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right) \approx 0.697\text{V} \tag{1}$$

with $N_a = N_d = 10^{16}\text{cm}^3$, $n_i(T = 300\text{K}) \approx 1.5 \cdot 10^{10}\text{cm}^{-3}$ and $V_T(T = 300\text{K}) \approx 26\text{mV}$. The width of depleted region is then given by

$$W_{\text{a}} = \sqrt{\frac{\varepsilon_R \varepsilon_0 \Psi_0}{q N_d \left(1 + \frac{N_d}{N_a}\right)}} \approx 1.5\text{um} \tag{2}$$

for both Ge and Si?

The IV characteristics for Si *pn*-junction under 280 K and 300 K temperatures and Ge under 300 K temperature is given in fig. 2. The reverse current seems to saturate around 80 V in $T = 300$ K.

The simulation of Schottky diode was performed using four different configurations, see table 2. The main advantage of Schottky diode is that since it is a metal-semiconductor junction, the voltage drop on contact potentials is somewhat lower than that of semiconductor-semiconductor, making them irreplacable in high frequency circuits. However, the breakdown voltage of Schottky diodes are lower ($\sim$ 50V) as compared to *pn*-junctions (up to $\sim$ kV). The leakage currents in Schottky diodes are also considerably larger than ones in *pn*-diode, hence limiting their application.

The IV characteristic of Si Schottky diode is shown in fig. 4. Though the diode was intended to be connected in reverse bias, from the increasing anode current it very much resembles a diode connected in forward bias instead. The current seems to be too large to be a leakage current and there is no saturation region, which is supposed to be below 80 V, as the usual breakdown voltages of Schottky diodes are $\sim$ 50 V. This is likely to be caused by a bug in a simmulation code. It is fine...

Table 2: Sets of input parameters used for Schottky diode simulation

No.	Material	T, K	N_d, cm^{-3}
1	Si	300	10^{15}
2	Si	280	10^{15}
3	Si	300	10^{13}
4	Ge	300	10^{15}

Schottky behave different from pn-junction. You will not get a nice plateau.

A table summarizing simulations is appreciated!

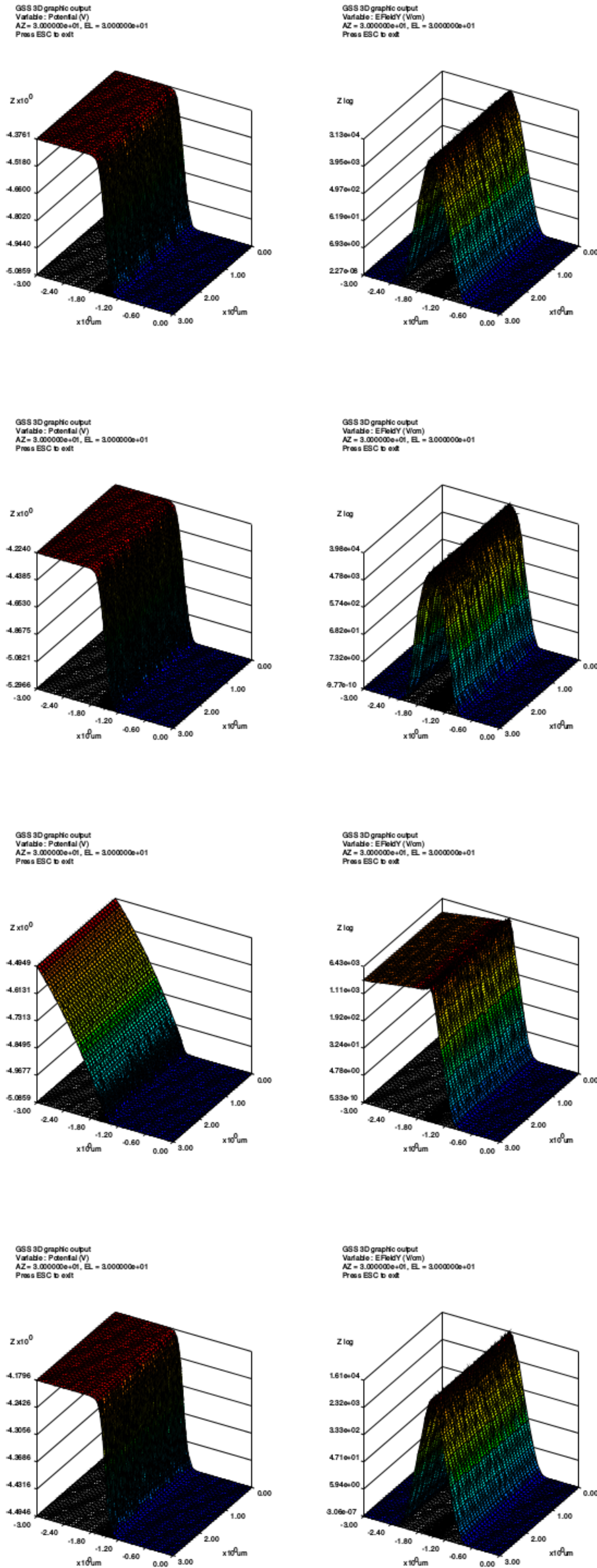

Figure 1: Potential and electric field distribution in simulated *pn*-diode for input parameter sets 1 (top) to 4 (bottom) as given by table 1

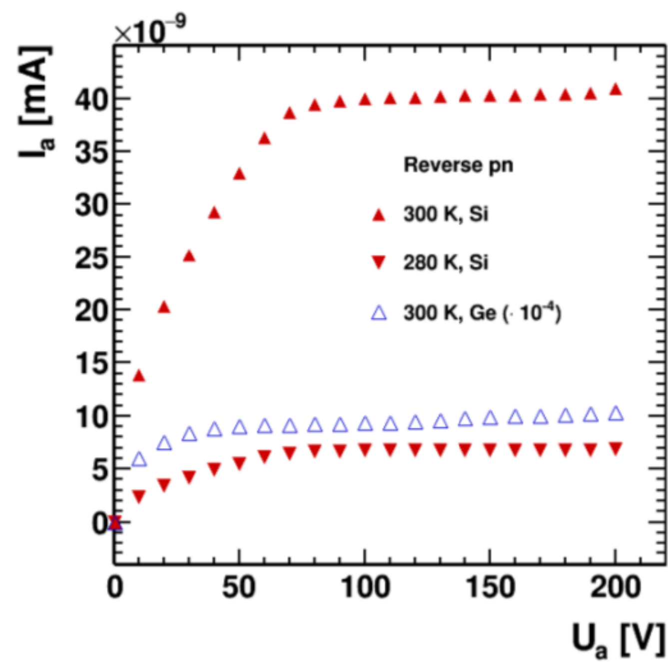

Figure 2: IV characteristics for Si ($T = 280$ K and 300 K) and Ge ($T = 300$ K) *pn*-diodes

Which configuration bulk doping, contact doping.....?

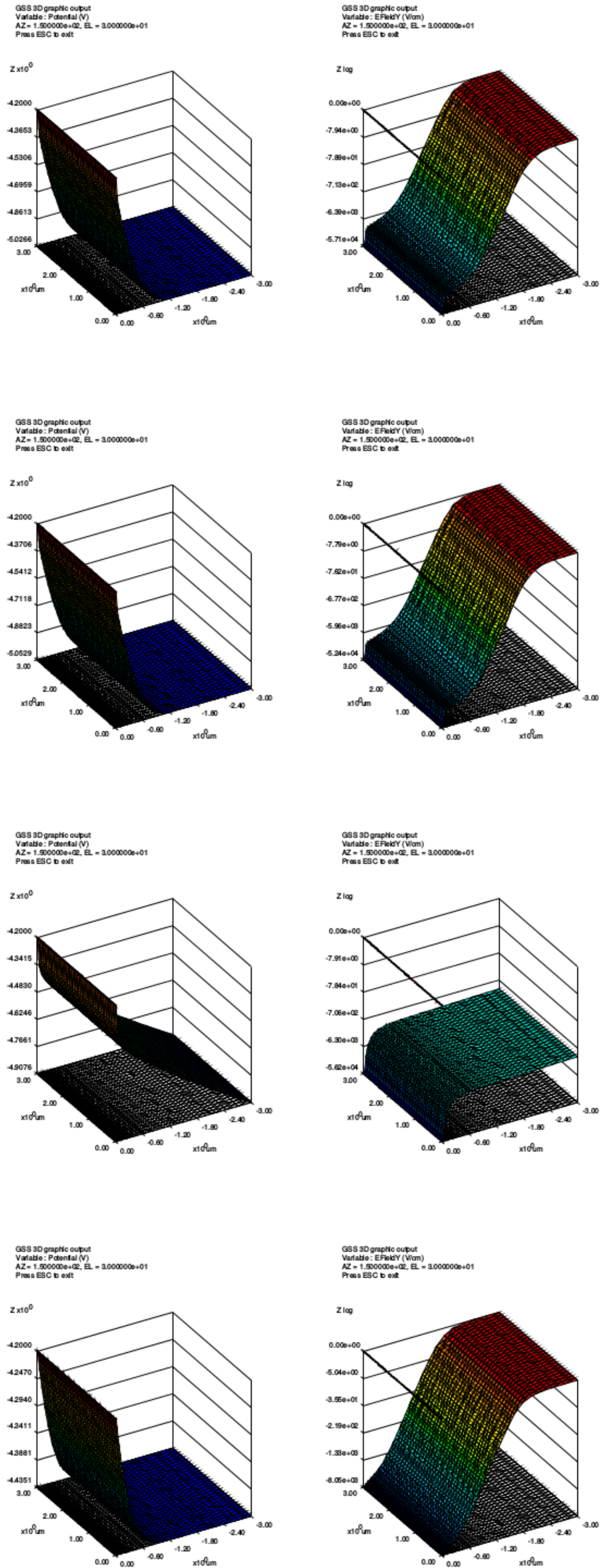

Figure 3: Potential and electric field distribution in simulated Schottky diode for input parameter sets 1 (top) to 4 (bottom) as given by table 2

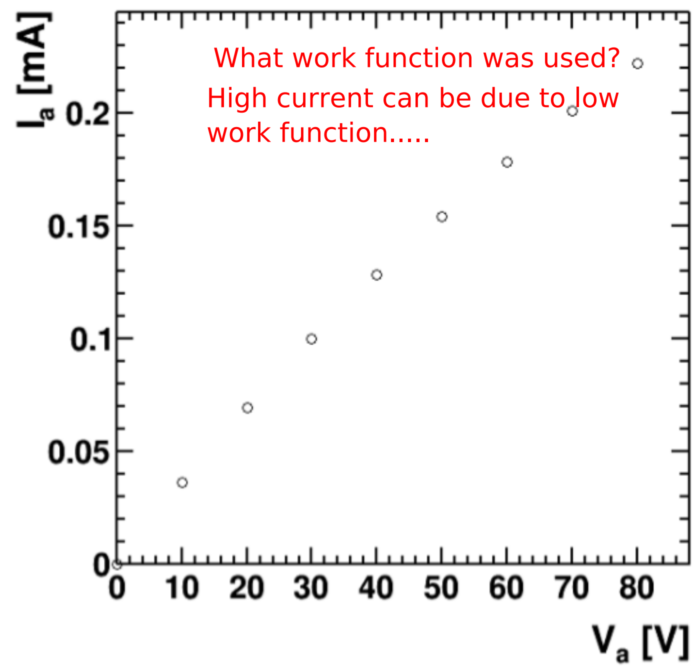

Figure 4: IV characteristic of Si Schottky diode in $T = 300$ K temperature supposedly connected in reverse bias.