ECE437 VLSI Technology

# Project # 1
# n-Well Resistor Process & Device Simulation

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# 1

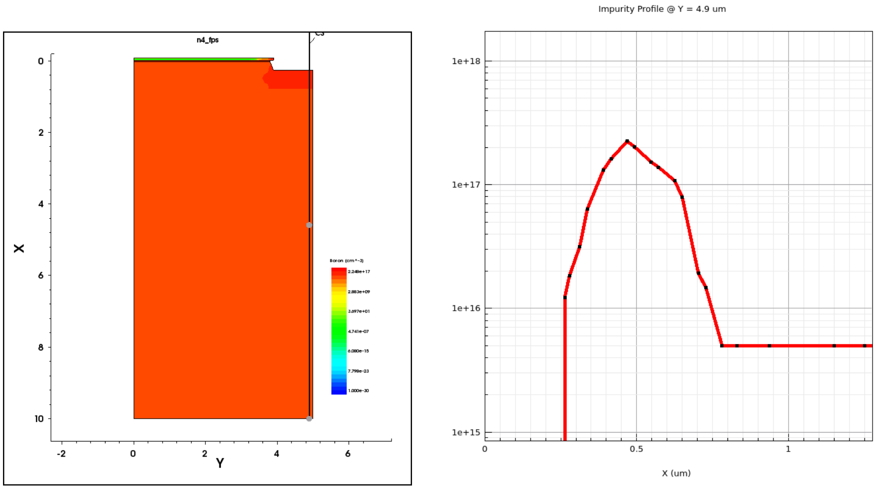


Fig. 1 Impurity profile seen along the cut line at Y=4.9µm in silicon

Figure 1 shows the doping distribution formed after the first step of etching and ion implantation, and the following part is the doping code of the substrate and the ion implantation code at Y=4.9µm. From figure 1, the peak concentration is 2.248e17 cm$^{-3}$ and the depth at which the concentration of the implanted ions is equal to the background concentration is about 0.755 µm.

The initial substrate concentration code is created with a concentration of 5e15 and an initial substrate crystal direction of 100.

// init silicon field= Boron concentration= 5e15 wafer.orient= 100

Injection of boron into the resistor terminal region (P-type doping)

// implant Boron dose=5e12<cm-2> energy=50<keV> tilt=7 rotation=30

Calculations:

$Q$ dosage $5e^{12}$ Boron

Background Concentration $5e^{15}$

$E$ energy : $50\text{ekV}$

Peak Concentration (Fig.1): $2.248e^{17}cm^{-3}$

From slides, $\Delta R_p = 0.062$ µm, $R_p = 0.175$ µm

$$N(x) = g(x)Q(first - orderGaussian)$$
$$= \frac{Q}{\sqrt{2\pi}\Delta R_p} \exp\left[-\frac{1}{2}\left(\frac{x - R_p}{\Delta R_p}\right)^2\right]$$
$$N_{\max} = \frac{Q}{\sqrt{2\pi}\Delta R_p} = 3.217e^{17}cm^{-3}$$
$$N(x) = N_{\max} \exp\left[-\frac{1}{2}\left(\frac{x - R_p}{\Delta R_p}\right)^2\right]$$
$$= 3.217e^{17} \exp\left[-\frac{1}{2}\left(\frac{x - 0.175}{0.062}\right)^2\right]$$

Therefore, the depth x is approx. $0.428$ µm

# 2

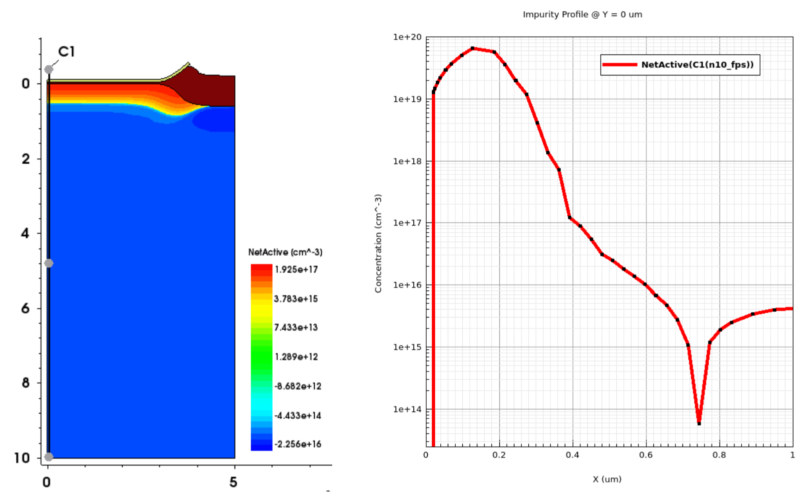


Fig. 2 Impurity profile along Y=0µm

a. Peak concentration in the n-well region of the resistor: 6.5e19 $cm^{-3}$

b. The depth of the p-n junction under the semiconductor surface: 0.745 µm

## 3

| Phosphorus Implant for n-well layer | |
|---|---|
| Dose ($cm^{-2}$) | Energy (KeV) |
| 1.0E13 | 100 |
| 1.0E14 | 100 |
| 1.0E15 | 100 |
| 1.0E16 | 100 |

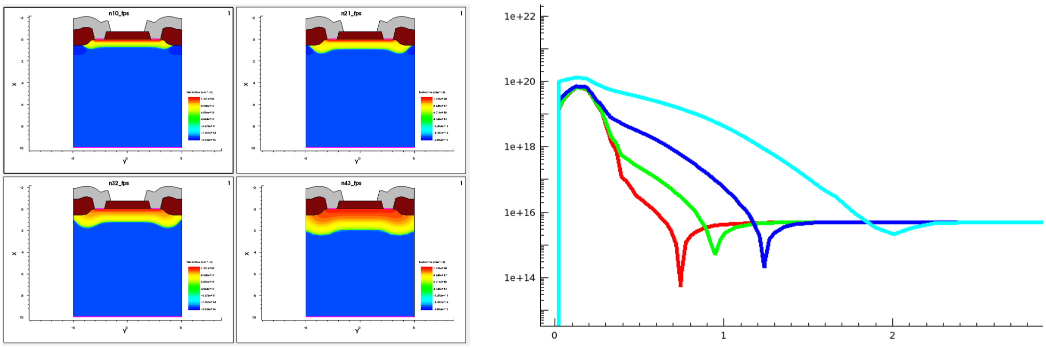


Fig. 3 The device structure diagram and impurity profile along Y=0μm were obtained by changing the injection dose of n well phosphorus

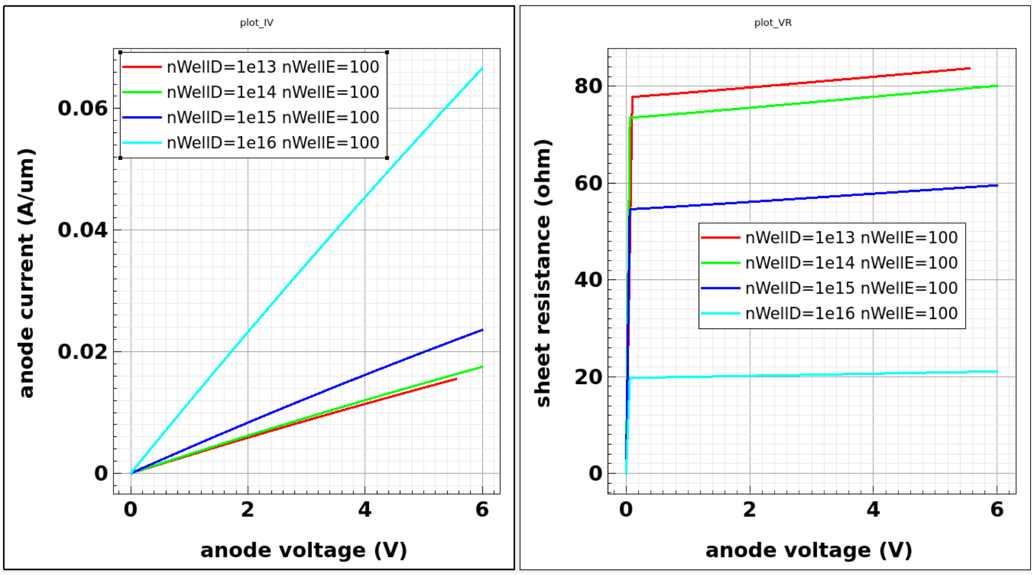


Fig. 4 The I-V curve and sheet resistance curve were obtained by changing the injection dose of N-well phosphorus

Figure 4 shows that larger doping concentration in the n-well region decreases the sheet resistance. As shown in Figure 3, changing the injection of phosphorus will change the depth of n-well push and the concentration distribution of n-well effectively creats a larger cross-sectional area and thus a lower resistance. Additionally, increasing doping concentration will decrease the resistivity of silicon as there are an increased number of charge carriers present.

# 4

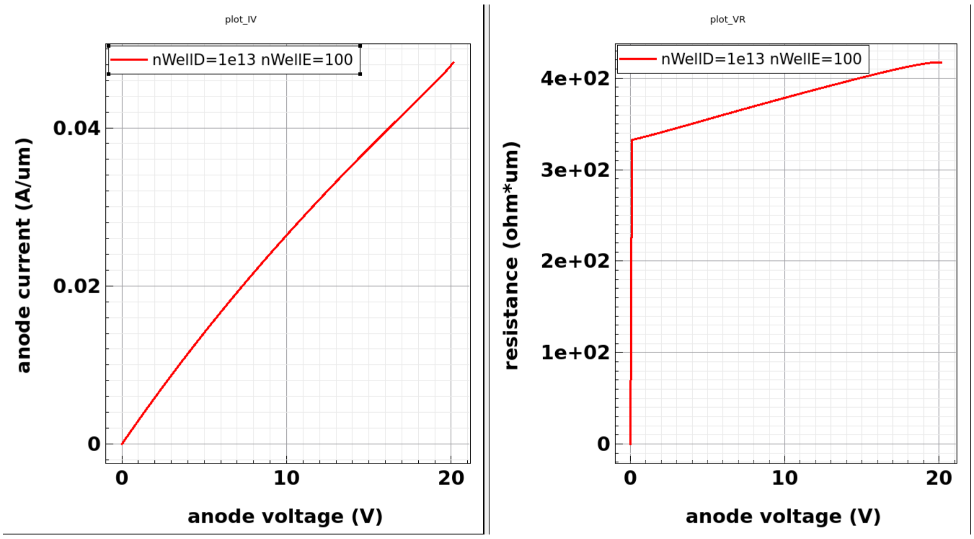


Fig. 5 Resistance curves as the applied voltage increases

As shown in Figure 5, it is observed that the sample resistance increases first and then decreases as the anode voltage increases. The increasing trend is due to the depletion layer width between the n-well and p-substrate (i.e. reversed biased diode). As the voltage increases, the depletion layer extends into the n-well, resulting in a thinner layer, increasing the sheet resistance. However, when the current is increased to a certain extent, the impact ionization rate inside the sample will also increase, eventually leading to an avalanche breakdown effect inside the device, resulting in a decrease in resistance.

# 5

| Phosphorus Implant for n-well layer | |
|---|---|
| Dose ($cm^{-2}$) | Energy (KeV) |
| 1.0E15 | 100 |
| 1.0E15 | 150 |
| 1.0E15 | 200 |

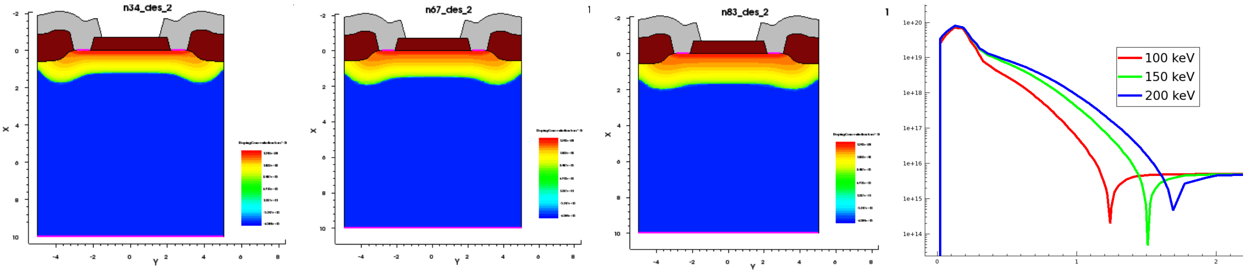


Fig. 6 The device structure diagram and impurity profile along Y=0μm were obtained by changing the n-well phosphorus injection energy

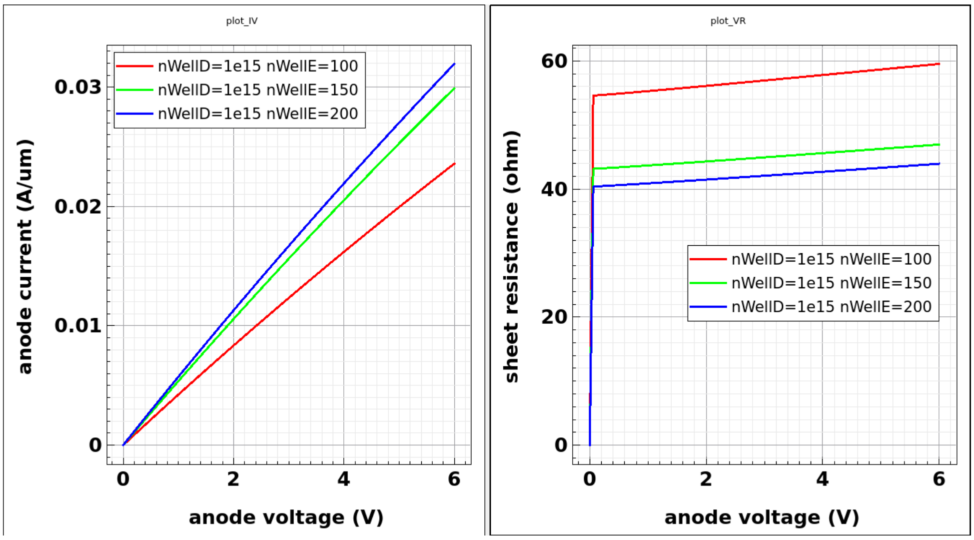


Fig. 7 IV & Resistance curve for changing injection Energy

As shown in Figure 6, changing the injection energy changes the injection depth of the nwell. The deeper the nwell, as shown in Figure 7, the wider the resulting anode and cathode conduction areas of the sample, and ultimately the smaller the resistance of the sample.