EE 130 **PN Junction IV Characteristics** Week 5 Notes

Mini-lecture, then quiz (courtesy of Pierret, Prof. Ali Javey, and Prof. Tsu-Jae King), and quiz solutions

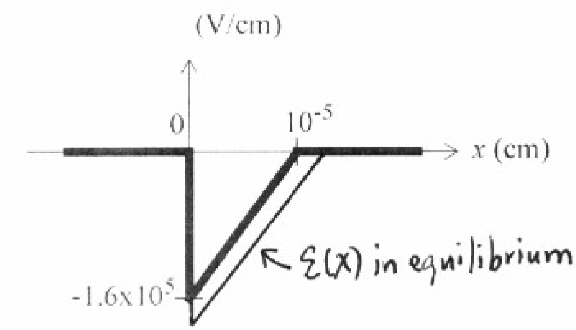
Problem 1

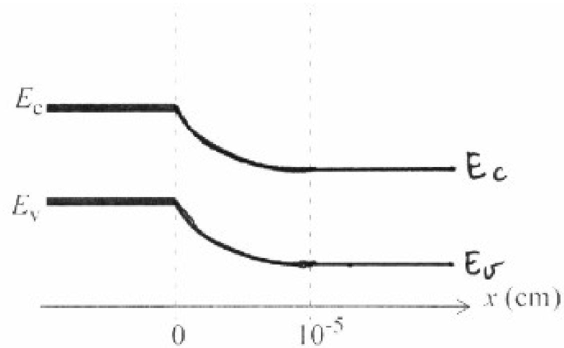
**Physical Constants**

| Description | Symbol | Value |
|---|---|---|
| electronic charge | $q$ | $1.6\times10^{-19}$ C |
| thermal voltage at 300K | $kT/q$ | 0.026 V |
| | $(kT/q)\ln(10)$ | 0.060 V |

**Properties of Silicon at 300K**

| Description | Symbol | Value |
|---|---|---|
| band gap | $E_G$ | 1.12 eV |
| intrinsic carrier density | $n_i$ | $10^{10}$ cm$^{-3}$ |
| permittivity | $\varepsilon_{Si}$ | $1.0\times10^{-12}$ F/cm |




a) Which side is more heavily doped? Explain.

**PN junction with P on left. Depletion region is skewed towards the N side. So, P side is heavier doped.**

b) What is the net dopant concentration on the lighter doped side?

**Using Poisson's Equation, $dE/dx = \rho/\varepsilon_{si} = qN_d/\varepsilon_{si}$ => $N_D = \varepsilon_{si}/q\,(dE/dx)$**
**Find the slope of the E-field from the graph = 1.6E10 V/cm2**
**$N_D = 10^{-12}$ F/cm / 1.6E-19 C * 1.6E10 V/cm2 = $10^{17}$ cm-3**

c) Is the junction forward or reverse biased? Justify.

**$V_{bi} = E_q/2q + kt/q \ln(N_D/n_i) = 0.56V + 0.42V = 0.98V$**
**Find the total voltage drop under left curve. That is $V_{bi} - V_A = 0.5*(1.6\times10^5$ V/cm$)(10^{-5}$ cm$)$ = 0.8V**
**$V_A = 0.98V - 0.8V = 0.18V$**

d) Sketch the equilibrium E-field distribution on the left graph.
e) Complete the energy-band diagram on the right graph.

Problem 2

Indicate how and why the following characteristics of a one-sided Si pn junction maintained at T=300K would change if the dopant concentration on the more lightly doped side were to be increased slightly.

Forward-bias current (I for a given $V_A$)

**Decreases because V_bi increases. Acts like applying reverse bias to the device. Barrier to diffusion is higher. Less diffusion current = less overall current for forward bias.**

Reverse-bias current (I for a given $V_A$)

**Decreases. Mobility goes down b/c of ion scattering. Minority carrier concentration goes down as well. Less overall drift current.**

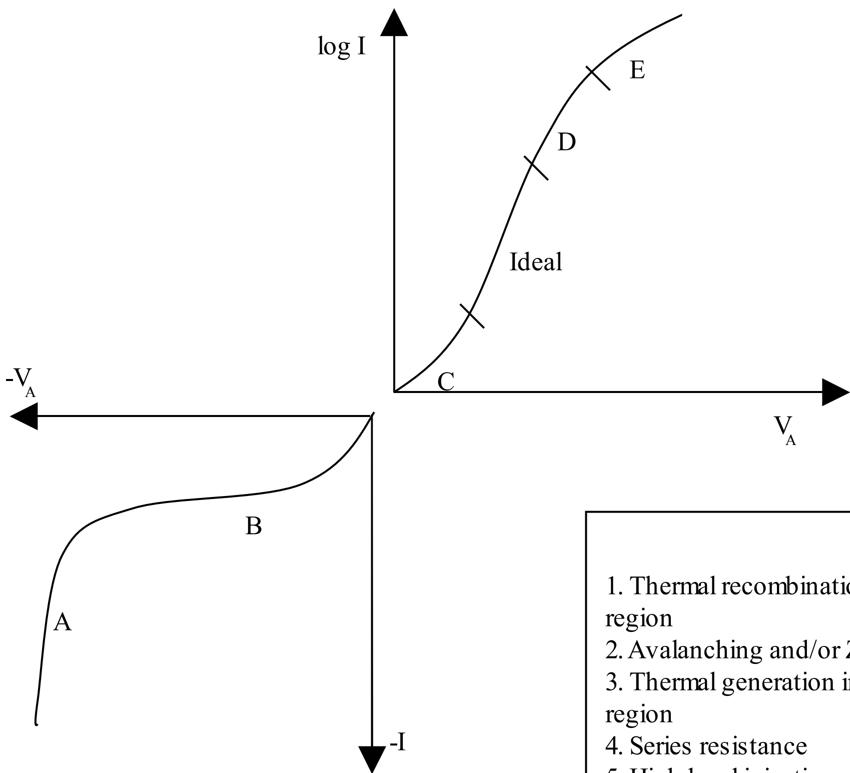
Reverse breakdown voltage ($V_{BR}$)

**Decreases. Much smaller depletion width. Same voltage dropping over it will result in higher e-field. Thus, V_BR is reached much sooner. Also, tunneling is easier to happen for smaller dep width.**

<u>Problem 3</u>

Identify the source of non-idealities (A, B, C, D, and E) in the I-V characteristic of a room temperature Si diode. Notice the forward bias region is on a semi-log plot and the reverse bias region is on a linear scale.

**A2, B3, C1, D5, E4**




1. Thermal recombination in the depletion region
2. Avalanching and/or Zener process
3. Thermal generation in the depletion region
4. Series resistance
5. High level injection