VE320 Homework 5

Due Oct. 30, 11:40am

1.

Consider a silicon n^+p junction diode. The critical electric field for breakdown in silicon is approximately $E_{crit} = 4 \times 10^5$ V/cm. Determine the maximum p-type doping concentration such that the breakdown voltage is (*a*) 40 V and (*b*) 20 V.

2.

A silicon p^+n junction has doping concentrations of $N_a = 2 \times 10^{17}$ cm^{-3} and $N_d = 2 \times 10^{15}$ cm^{-3}. The cross-sectional area is 10^{-5} cm^2. Calculate (a) V_{bi} and (b) the junction capacitance at reverse bias V_R (i) $V_R = 1$V, (ii) $V_R = 3$V, and (iii) $V_R = 5$ V. (c) plot $1/C^2$ versus V_R and identify how the slope and intercept at the voltage axis are related to N_d and V_{bi}, repectively.

3.

A one-sided p^+n silicon diode has doping concentrations of $N_a = 5 \times 10^{17}$ cm^{-3} and $N_d = 8 \times 10^{15}$ cm^{-3}. The minority carrier lifetimes are $\tau_{n0} = 10^{-7}$ s and $\tau_{p0} = 8 \times 10^{-8}$ s. The cross-sectional area is $A = 2 \times 10^{-4}$ cm^2. Calculate the (*a*) reverse-biased saturation current, and (*b*) the forward-bias current at (*i*) $V_a = 0.45$ V, (*ii*) $V_a = 0.55$ V, and (*iii*) $V_a = 0.65$ V.

In the following problems, if not stated,
For silicon pn junctions: $Dn=25 cm^2/s$, $Dp=10\ cm^2/s$, $\tau n0=5\times10^{-7} s$, $\tau p0=10^{-7} s$.
For GaAs pn junctions: $Dn=205\ cm^2/s$, $Dp=9.8\ cm^2/s$, $\tau n0=5\times10^{-8} s$, $\tau p0=10^{-8} s$.

4.

Consider an ideal silicon pn junction diode.

(a) What must be the ratio of N_d/N_a so that 90% of the current in the depletion region is due to the flow of electrons?

(b) Repeat part (a) if 80% of the current in the depletion region is due to the flow of holes?

5.

An ideal silicon pn junction at $T = 300K$ is under zero bias. The minority carrier lifetimes are $\tau_{n0} = 10^{-6}s$, and $\tau_{p0} = 10^{-7}s$. The doping concentration in the n region is $N_d = 10^{16}cm^{-3}$.
Plot the ratio of hole current to the total current crossing the space charge region as the p region doping concentration varies over the range $10^{15} \le N_a \le 10^{18}cm^{-3}$. (Use a log scale for the doping concentrations.)

6.

Consider a silicon pn junction diode with an applied reverse-biased voltage of $V_R = 5V$. The doping concentrations are $N_d = N_a = 4 \times 10^{16}cm^{-3}$ and the cross-sectional area is $A = 10^{-4}cm^2$. Assume minority carrier lifetimes of $\tau_0 = \tau_{n0} = \tau_{p0} = 10^{-7}s$. Calculate

(a) the ideal reverse-saturation current,

(b) the reverse-biased generation current,

(c) the ratio of the generation current to ideal saturation current.

7.

Consider a GaAs pn junction diode with a cross-sectional area of $A = 2 \times 10^{-4} cm^2$ and doping concentrations of $N_d = N_a = 7 \times 10^{16} cm^{-3}$. The electron and hole mobility values are $\mu_n = 5500 cm^2/V - s$ and $\mu_p = 220 cm^2/V - s$, respectively, and the lifetime values are $\tau_0 = \tau_{n0} = \tau_{p0} = 2 \times 10^{-8} s$.
Calculate the ideal diode current at a

(a) reverse-biased voltage of $V_R = 3V$
(b) forward-bias voltage of $V_a = 0.6V$
(c) forward-bias voltage of $V_a = 0.8V$
(d) forward-bias voltage of $V_a = 1V$

8.

Consider a GaAs pn diode at $T = 300K$ with $N_d = N_a = 10^{17} cm^{-3}$ and with a cross-sectional area of $A = 5 \times 10^{-3} cm^2$. The minority carrier mobilities are $\mu_n = 3500 cm^2/V - s$ and $\mu_p = 220 cm^2/V - s$. The electron-hole lifetimes are $\tau_0 = \tau_{n0} = \tau_{p0} = 10^{-8} s$.
Plot the diode forward-bias current include including recombination current between diode voltages of $0.1 \le V_D \le 1V$. Compare this plot to that for an ideal diode.