VE320 Homework Seven

Due: 2021/7/12 23:59

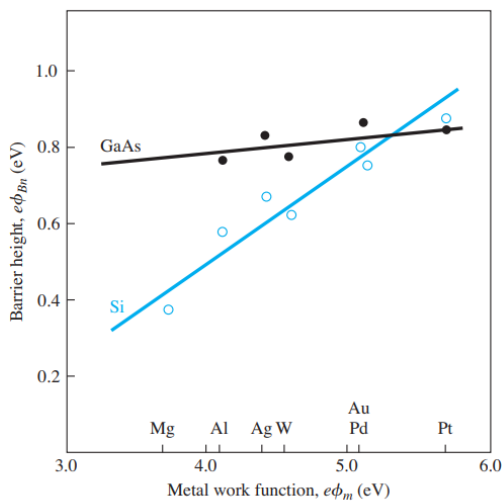
In the following problems, if not stated,
For silicon pn junctions: $D_n = 25\text{cm}^2/\text{s}, D_p = 10\text{cm}^2/\text{s}, \tau_{n0} = 5\times10^{-7}\text{s}, \tau_{p0} = 10^{-7}\text{s}$
For GaAs pn junctions: $D_n = 205\text{cm}^2/\text{s}, D_p = 9.8\text{cm}^2/\text{s}, \tau_{n0} = 5\times10^{-8}\text{s},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

1. An ideal silicon pn junction at $T = 300$ K is under forward 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.)

2. Consider a silicon pn junction diode with an applied reverse-biased voltage of $V_R =$ 5V. The doping concentrations are $N_a = N_d = 4\times10^{16}$ 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 the (a) ideal reverse-saturation current, (b) reverse-biased generation current, and (c) the ratio of the generation current to ideal saturation current.

3. Consider a GaAs pn junction diode with a cross-sectional area of $A = 2\times10^{-4}$ cm^2 and doping concentrations of $N_a = N_d = 7\times10^{16}$ 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 $\tau_0 = \tau_{n0} = \tau_{p0} = 2\times10^{-8}$ s.
(a) Calculate the ideal diode current at a (i) reverse-biased voltage of $V_R = 3$ V, (ii) forward-bias voltage of $V_a = 0.6$ V,(iii) forward-bias voltage of $V_a = 0.8$ V, and (iv) forward-bias voltage of $V_a = 1.0$ V
(b) (i) Calculate the generation current at $V_R = 3$ V. Assuming the recombination current extrapolated to $V_a = 0$ is $I_{ro} = 6\times10^{-14}$ A, determine the generation current at (ii) $V_a =$ 0.6 V, (iii) $V_a = 0.8$ V, and (iv) $V_a = 1.0$ V

4. (a) Consider a Schottky diode at $T = 300$ K that is formed with tungsten on n-type silicon. Use the figure below to determine the barrier height. Assume a doping concentration of $N_d =$ 10^{16} cm^{-3} and assume a cross-sectional area $A = 10^{-4}$ cm^2. Determine the forward-bias voltage required to induce a current of (i) 10μA, (ii)100μA, and (iii) 1 mA.
(b) Repeat part (a) for a temperature of $T = 350$ K. (Neglect the barrier lowering effect.)



5. (a) The contact resistance of an ohmic contact is $R_c = 5 \times 10^{-5} \Omega \cdot \mathrm{cm}^2$. The cross-sectional area of the junction is $10^{-5}\ \mathrm{cm}^2$. Determine the voltage across the junction if the current is (i) $I = 1$ mA and $(ii)\ I = 100\mu$A.
(b) Repeat part (a) if the cross-sectional area is $10^{-6}\ \mathrm{cm}^2$.

6. A metal, with a work function $\phi_m = 4.2$ V, is deposited on an n-type silicon semiconductor with $\chi_s = 4.0$ V and $E_g = 1.12$eV. Assume no interface states exist at the junction. Let $T = 300$ K.
(a) **Sketch** the energy-band diagram for zero bias for the case when no space charge region exists at the junction.
(b) Determine N_d so that the condition in part (a) is satisfied.
(c) What is the potential barrier height seen by electrons in the metal moving into the semiconductor?

7. A metal-semiconductor junction is formed between a metal with a work function of 4.3eV and p-type silicon with an electron affinity of 4.0eV. The acceptor doping concentration in the silicon is $N_a = 5 \times 10^{16}\ \mathrm{cm}^{-3}$. Assume $T = 300$ K.
(a) **Sketch** the thermal equilibrium energy-band diagram.
(b) Determine the height of the Schottky barrier.
(c) **Sketch** the energy-band diagram with an applied reverse-biased voltage of $V_R = 3$ V.
(d) **Sketch** the energy-band diagram with an applied forward-bias voltage of $V_a = 0.25$ V