VE320 Homework 8

Due: 10/07/2019 10:00 am

For problem 4-9, assume $A^* = 120\ A/K^2\text{-}cm^2$ for silicon and $A^* = 1.12\ A/K^2\text{-}cm^2$ for gallium arsenide Schottky diodes unless otherwise stated.

1.

An npn bipolar transistor is biased in the forward-active mode. (*a*) The collector current is $I_C = 1.2$ mA when biased at $V_{CE} = 2$ V. The Early voltage is $V_A = 120$ V. Determine (*i*) the output resistance r_o, (*ii*) the output conductance g_o, and (*iii*) the collector current when biased at $V_{CE} = 4$ V. (*b*) Repeat part (*a*) if the collector current is $I_C = 0.25$ mA when biased at $V_{CE} = 2$ V and the Early voltage is $V_A = 160$ V.

2.

A uniformly doped silicon npn bipolar transistor at $T = 300$ K has parameters $N_E = 2 \times 10^{18}$ cm^{-3}, $N_B = 2 \times 10^{16}$ cm^{-3}, $N_C = 2 \times 10^{15}$ cm^{-3}, $x_{BO} = 0.85\ \mu$m, and $D_B = 25$ cm^2/s. Assume $x_{BO} \ll L_B$ and let $V_{BE} = 0.650$ V. (*a*) Determine the electron diffusion current density in the base for (*i*) $V_{CB} = 4$ V, (*ii*) $V_{CB} = 8$ V, and (*iii*) $V_{CB} = 12$ V. (*b*) Estimate the Early voltage.

3.

A uniformly doped pnp silicon bipolar transistor has a base doping of $N_B = 10^{16}$ cm^{-3}, a collector doping of $N_C = 10^{15}$ cm^{-3}, a metallurgical base width of $x_{B0} = 0.70\ \mu$m, a base minority carrier diffusion coefficient of $D_B = 10$ cm^2/s, and a B–E cross-sectional area of $A_{BE} = 10^{-4}$ cm^2. The transistor is biased in the forward-active mode with $V_{EB} = 0.625$ V. Neglecting the B–E space charge width and assuming $x_B \ll L_B$, (*a*) determine the change in neutral base width as V_{BC} changes from 1 to 5 V, (*b*) find the corresponding change in collector current, (*c*) estimate the Early voltage, and (*d*) find the output resistance.

4.

(*a*) A Schottky barrier diode formed on n-type silicon has a doping concentration of $N_d = 5 \times 10^{15}$ cm^{-3} and a barrier height of $\phi_{B0} = 0.65$ V. Determine the built-in potential barrier V_{bi}. (*b*) If the doping concentration changes to $N_d = 10^{16}$ cm^{-3}, determine the values of ϕ_{B0} and V_{bi}. Do these values increase, decrease, or remain the same? (*c*) Repeat part (*b*) if the doping concentration is $N_d = 10^{15}$ cm^{-3}.

5.

(*a*) Consider a Schottky diode at $T = 300$ K that is formed with tungsten on n-type silicon. Use Figure 9.5 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*) 10 μA, (*ii*) 100 μA, and (*iii*) 1 mA. (*b*) Repeat part (*a*) for a temperature of $T = 350$ K. (Neglect the barrier lowering effect.)

6.

A pn junction diode and a Schottky diode each have cross-sectional areas of $A = 8 \times 10^{-4}$ cm^2. The reverse saturation current densities at $T = 300$ K for the pn junction diode and Schottky diode are 8×10^{-13} A/cm^2 and 6×10^{-9} A/cm^2, respectively. Determine the required forward-bias voltage in each diode to yields currents of (*a*)150 μA, (*b*) 700 μA, and (*c*) 1.2 mA.

7.

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

8.

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?

9.

A metal–semiconductor junction is formed between a metal with a work function of 4.3 eV and p-type silicon with an electron affinity of 4.0 eV. The acceptor doping concentration in the silicon is $N_a = 5 \times 10^{16}$ 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.