VE320 Homework5

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Ex 5.1

(a)

n-side:

$$E_F - E_{Fi} = kT \ln \frac{N_d}{n_i} = 0.0259\,\text{eV} \ln \frac{5 \times 10^{15}\,\text{cm}^{-3}}{1.5 \times 10^{10}\,\text{cm}^{-3}} = 3.294 \times 10^{-1}\,\text{eV}$$

p-side:

$$E_{Fi} - E_F = kT \ln \frac{N_a}{n_i} = 0.0259\,\text{eV} \ln \frac{10^{17}\,\text{cm}^{-3}}{1.5 \times 10^{10}\,\text{cm}^{-3}} = 4.070 \times 10^{-1}\,\text{eV}$$

(b)

$$V_{bi} = 3.294 \times 10^{-1}\,\text{V} + 4.070 \times 10^{-1}\,\text{V} = 7.364 \times 10^{-1}\,\text{V}$$

(c)

$$V_{bi} = \frac{kT}{e} \ln \frac{N_a N_d}{n_i^2} = 0.0259\,\text{V} \ln \frac{10^{17}\,\text{cm}^{-3} \cdot 5 \times 10^{15}\,\text{cm}^{-3}}{(1.5 \times 10^{10}\,\text{cm}^{-3})^2} = 7.363 \times 10^{-1}\,\text{V}$$

It is same as the results in (b).

(d)

$$x_n = \sqrt{\frac{2\epsilon_s V_{bi}}{e} \cdot \frac{N_a}{N_d} \cdot \frac{1}{N_a + N_d}} = 4.261 \times 10^{-5}\,\text{cm}$$

$$x_p = \sqrt{\frac{2\epsilon_s V_{bi}}{e} \cdot \frac{N_d}{N_a} \cdot \frac{1}{N_a + N_d}} = 2.130 \times 10^{-6}\,\text{cm}$$

$$|E_{max}| = \frac{eN_d x_n}{\epsilon_s} = 3.292 \times 10^4\,\text{V/cm}$$

Ex 5.2

(a)

(b)

$$N_d = n_i \exp \frac{E_F - E_{Fi}}{kT} = 1.5 \times 10^{10}\,\text{cm}^{-3} \exp \frac{0.365\,\text{eV}}{0.0259\,\text{eV}} = 1.979 \times 10^{16}\,\text{cm}^{-3}$$

$$N_a = n_i \exp \frac{E_{Fi} - E_F}{kT} = 1.5 \times 10^{10}\,\text{cm}^{-3} \exp \frac{0.330\,\text{eV}}{0.0259\,\text{eV}} = 5.124 \times 10^{15}\,\text{cm}^{-3}$$

(c)

$$V_{bi} = 0.365\,\mathrm{V} + 0.330\,\mathrm{V} = 0.695\,\mathrm{V}$$

Ex 5.3

$$x_n = 0.25(x_n + x_p)$$
$$x_p = 3x_n$$
$$N_d = 3N_a$$

(i)

$$V_{bi} = kT \ln \frac{N_d N_a}{n_i^2} = kT \ln \frac{3N_a^2}{n_i^2}$$
$$N_a = \sqrt{\frac{1}{3} n_i^2 \exp \frac{V_{bi}}{kT}} = 7.766 \times 10^{15}\,\mathrm{cm}^{-3}$$

(ii)

$$N_d = 3N_a = 2.330 \times 10^{16}\,\mathrm{cm}^{-3}$$

(iii)

$$x_n = \sqrt{\frac{2\epsilon_s V_{bi}}{e} \cdot \frac{N_a}{N_d} \cdot \frac{1}{N_a + N_d}} = 9.924 \times 10^{-6}\,\mathrm{cm}$$

(iv)

$$x_p = 3x_n = 2.977 \times 10^{-5}\,\mathrm{cm}$$

(v)

$$|E_{max}| = \frac{eN_d x_n}{\epsilon_s} = 3.573 \times 10^4\,\mathrm{V/cm}$$

Ex 5.4

(a)

left-side:

$$E_F - E_{Fi} = kT \ln \frac{N_d}{n_i} = 0.0259\,\mathrm{eV} \ln \frac{10^{16}\,\mathrm{cm}^{-3}}{1.5 \times 10^{10}\,\mathrm{cm}^{-3}} = 3.473 \times 10^{-1}\,\mathrm{eV}$$

right-side:

$$E_F - E_{Fi} = kT \ln \frac{N_d}{n_i} = 0.0259\,\mathrm{eV} \ln \frac{10^{15}\,\mathrm{cm}^{-3}}{1.5 \times 10^{10}\,\mathrm{cm}^{-3}} = 2.877 \times 10^{-1}\,\mathrm{eV}$$

(b)

$$V_{bi} = 3.473 \times 10^{-1}\,\mathrm{V} - 2.877 \times 10^{-1}\,\mathrm{V} = 5.96 \times 10^{-2}\,\mathrm{V}$$

(c)

Ex 5.5

(a)

$$V_{bi} = \frac{kT}{e} \ln \frac{N_d N_a}{n_i^2} = \frac{kT}{e} \ln \frac{3N_a^2}{n_i^2} = 6.767 \times 10^{-1}\,\mathrm{V}$$

(b)

(i)

$$V_R = 0$$

$$W = \sqrt{\frac{2\epsilon_s(V_{bi} + V_R)}{e} \cdot \frac{N_a + N_d}{N_a N_d}} = 9.482 \times 10^{-5}\,\mathrm{cm}$$

(ii)

$$V_R = 5\,\mathrm{V}$$

$$W = \sqrt{\frac{2\epsilon_s(V_{bi} + V_R)}{e} \cdot \frac{N_a + N_d}{N_a N_d}} = 2.738 \times 10^{-4}\,\mathrm{cm}$$

(c)

(i)

$$V_R = 0$$

$$|E_{max}| = \frac{2(V_{bi} + V_R)}{W} = 1.432 \times 10^4\,\mathrm{V/cm}$$

(ii)

$$V_R = 5\,\mathrm{V}$$

$$|E_{max}| = \frac{2(V_{bi} + V_R)}{W} = 4.147 \times 10^4\,\mathrm{V/cm}$$

Ex 5.6

(a)

$$V_{bi} = kT \ln \frac{N_d N_a}{n_i^2} = kT \ln \frac{80 N_d^2}{n_i^2}$$

$$N_d = \sqrt{\frac{1}{80} n_i^2 \exp \frac{V_{bi}}{kT}} = 2.684 \times 10^{15}\,\mathrm{cm}^{-3}$$

$$N_a = 80 N_d = 2.147 \times 10^{15}\,\mathrm{cm}^{-3}$$

(b)

$$x_n = \sqrt{\frac{2\epsilon_s (V_{bi} + V_R)}{e} \cdot \frac{N_a}{N_d} \cdot \frac{1}{N_a + N_d}} = 2.262 \times 10^{-4}\,\mathrm{cm}$$

$$x_p = \sqrt{\frac{2\epsilon_s (V_{bi} + V_R)}{e} \cdot \frac{N_d}{N_a} \cdot \frac{1}{N_a + N_d}} = 2.827 \times 10^{-6}\,\mathrm{cm}$$

(c)

$$|E_{max}| = \frac{2(V_{bi} + V_R)}{W} = 9.739 \times 10^4\,\mathrm{V/cm}$$

(d)

$$C_j' = \sqrt{\frac{e\epsilon_s N_a N_d}{2(V_{bi} + V_R)(N_a + N_d)}} = 4.522 \times 10^{-9}\,\mathrm{F/cm}^2$$

Ex 5.7

(a)

$$x_p \approx \sqrt{\frac{2\epsilon_s V_R}{e N_a}} = 50\,\mu\mathrm{m}$$

$$V_R \approx 193\,\mathrm{V}$$

(b)

$$x_n = x_p \frac{N_a}{N_d} = 0.5\,\mu\mathrm{m}$$

(c)

$$|E_{max}| \approx \frac{2V_R}{W} = 7.644 \times 10^4\,\mathrm{V/cm}$$