Design & Simulate 3 Ex1.4

ECE2204 CRN:82929

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Problem 3.4.a.1:

Design

Consider silicon at $T = 300K$ with a diffusion current density of $J_n = 200A/cm^2$. Assume that the electron concentration varies linearly over the distance from $x = 0$ to $x = 7\mu m$ from $n_{lower} = 10^{13}cm^{-3}$ to some unknown upper electron concentration n_{upper}. Assume $D_n = 32cm^2/s$ and that the value of the elementary charge is $e = 1.6 \cdot 10^{-19}C$. Calculate the upper electron concentration n_{upper}.

$$J_n = eD_n \frac{\Delta n}{\Delta x} \implies n_{upper} = \frac{J_n \times \Delta x}{eD_n} + n_{lower} \tag{1}$$

$$n_{upper} = \frac{200A/cm^2 \times 7\mu m}{1.6\times10^{-19}C \times 32cm^2/s} + 10^{13}cm^{-3} = 2.735 \times 10^{16}cm^{-3} \tag{2}$$

The upper electron concentration is $n_{upper} = 2.735 \times 10^{16}cm^{-3}$.

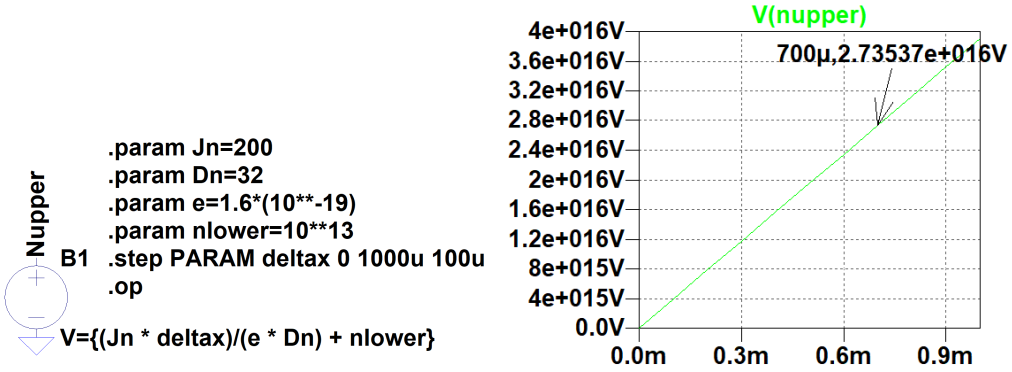
Validation

Mathematica Implementation (accurate with < 1‘% deviation from design result)

```
In[338]:= Jn = 200 A / cm ^ 2;
          Dn = 32  cm ^ 2 / s;
          nlower = 10 ^ {13} cm ^ {-3};
          x0 = 0 m;
          x1 = 7 * 10 ^ {-6} m;
          deltax = x1 - x0;
          nupper = (Jn * deltax)/(ElectronCharge * Dn) + nlower;
          nupperres =  WolframAlpha[ToString[nupper, InputForm], "Result"]
Out[345]= 2.731660×10^16/cm^3
```

$$Err = \frac{|2.735-2.731|}{2.735} = 0.00146 = 0.146\%$$

LTSpice Implementation (equivalent within 4 significant figures)



Problem 3.4.b.1:

Design

The hole concentration in silicon is given by

$$p(x) = 10^3 + 10^{12} e^{\frac{-x}{L_p}} \quad x \geq 0 \tag{3}$$

The value of L_p is $13\mu m$. The hole diffusion coefficient is $D_p = 66 cm^2/s$. Assume the value of the elementary charge is $\mathbb{e} = 1.6 \cdot 10^{-19} C$. Determine the hole diffusion current density at $x = 23\mu m$.

$$\frac{dp}{dx} p(x) = \frac{-10^{12}}{L_p} e^{\frac{-x}{L_p}} \tag{4}$$

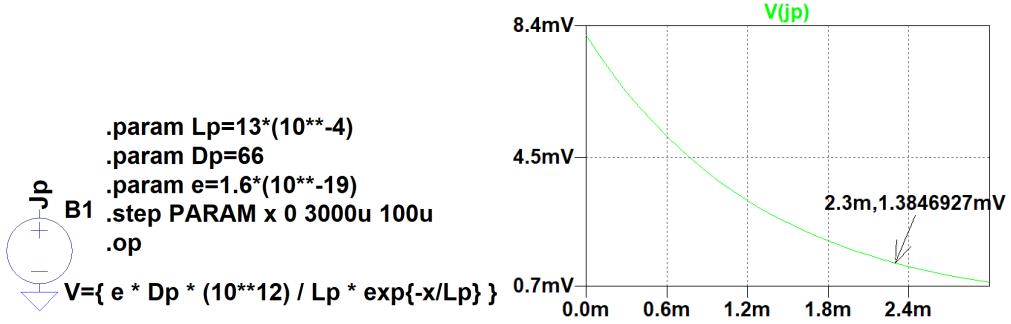
$$J_p = -\mathbb{e} D_p \frac{dp}{dx} \implies J_p = \mathbb{e} D_p \frac{10^{12}}{L_p} e^{\frac{-x}{L_p}} \times cm^{-3} \tag{5}$$

$$J_p = \mathbb{e} \times 66 cm^2/s \times \frac{10^{12}}{13\mu m} e^{\frac{-23\mu m}{13\mu m}} \times cm^{-3} = 1.387 \times 10^{-3} A/cm^2 \tag{6}$$

The hole diffusion current density $J_p = 1.387 \times 10^{-3} A/cm^2$.

Validation

LTSpice Implementation (accurate with $< 1\%$ deviation from design result)



$$Err = \frac{|1.387 - 1.384|}{1.387} = 0.00216 = 0.216\%$$

I have neither given nor received unauthorized assistance on this assignment.