Design & Simulate 1 Ex1.2

ECE2204 CRN:82929

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Problem 1.2.a.1:

Design

Consider silicon at $T = 350K$ doped with boron at an unknown concentration. The electron concentration is $n_o = 7.3 \times 10^5 cm^{-3}$. Silicon's bandgap energy is $E_g = 1.1eV$ and Silicon's semiconductor constant is $B = 5.23 \times 10^{15} cm^{-3} K^{\frac{-3}{2}}$. Determine the acceptor concentration N_a.

$$n_i = BT^{\frac{3}{2}} e^{(\frac{-E_g}{2kT})} \tag{1}$$

$$n_i = (5.23 \times 10^{15})(350)^{\frac{3}{2}} e^{\left(\frac{-1.1}{2(86\times10^{-6})(350)}\right)} = 3.97 \times 10^{11} cm^{-3} \tag{2}$$

$$p_o = \frac{n_i^2}{n_o} = \frac{(3.97\times10^{11}cm^{-3})^2}{7.3\times10^5 cm^{-3}} = 2.159 \times 10^{17} cm^{-3} \tag{3}$$

As $p_o \gg n_i$, the acceptor concentration $N_a \approx p_o = 2.159 \times 10^{17} cm^{-3}$.

Validation

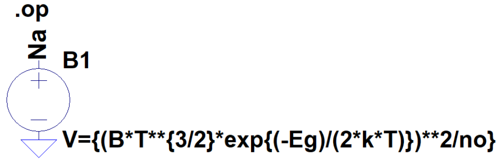
Mathematica Implementation (accurate with < 1% deviation from design result)

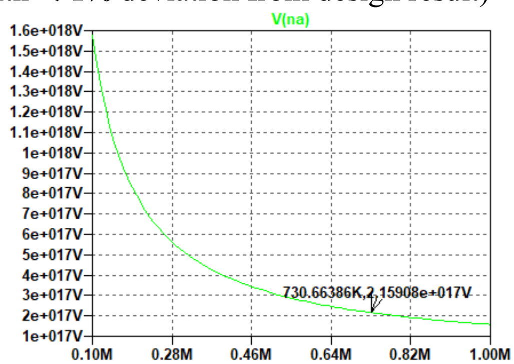
```
In[160]:= no = 7.3 * 10 ^ 5 cm ^ {-3};
          T = 350K;
          Eg = 1.1eV;
          B = 5.23 * 10 ^ {15} cm ^ {-3} K ^ {-3 / 2};
          k = 86 * 10 ^ {-6} eV / K;
          ni = B * T ^ {3 / 2} * e ^ {(-Eg) / (2 * k * T)};
          po = (ni) ^ 2 / no;
          Na = po
```

Out[167]= $\left\{\left\{\frac{2.16101\times10^{17}}{\text{cm}^3}\right\}\right\}$

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

```
.param T=350
.param Eg=1.1
.param B=5.23*(10**15)
.param k=86*(10**-6)
.step PARAM no 100k 1000k 10k
.op
```





Problem 1.2.b.1:

Design

Find the concentration of electrons and holes in a sample of germanium that has a concentration of donor atoms equal to $N_d = 0.4 \times 10^{15} cm^{-3}$. Is the semiconductor n-type or p-type? Germanium's bandgap is $E_g = 0.66eV$ and its semiconductor constant is $B = 1.66 \times 10^{15} cm^{-3} K^{\frac{-3}{2}}$. The temperature is $T = 300K$

$$n_i = (1.66 \times 10^{15})(300)^{\frac{3}{2}} e^{\left(\frac{-0.66}{2(86\times10^{-6})(300)}\right)} = 2.40 \times 10^{13} cm^{-3} \tag{4}$$

As $N_d \gg n_i$, the electron concentration is $n_o \approx N_d = 0.4 \times 10^{15} cm^{-3}$.

$$p_o = \frac{(2.40\times10^{13} cm^{-3})^2}{0.4\times10^{15} cm^{-3}} = 1.44 \times 10^{12} cm^{-3} \tag{5}$$

The hole concentration $p_o = 1.44 \times 10^{12} cm^{-3}$. As the semiconductor has donor atoms, it is n-type.

Validation

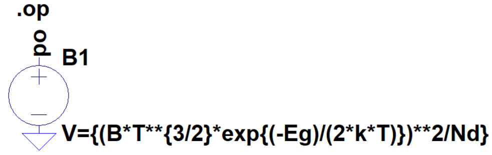
Mathematica Implementation (accurate with < 1% deviation from design result)

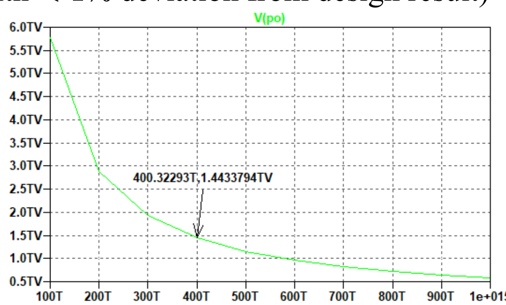
```
In[0]:= Nd = 0.4*10^15 cm^{-3};
T = 300K;
Eg = 0.66eV;
B = 1.66 * 10^{15} cm^{-3}K^{-3/2};
k = 86 * 10^{-6} eV/K;
ni = B*T^{3/2}*e^{(-Eg)/(2*k*T)};
po = (ni)^2 / Nd
```

96]= $\left\{\left\{\frac{1.44431\times10^{12}}{cm^{3}}\right\}\right\}$

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

```
.param T=300
.param Eg=0.66
.param B=1.66*(10**15)
.param k=86*(10**-6)
.step PARAM Nd 100T 1000T 100T
.op
```





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