Solutions to Exercise: Depletion Thickness

PF@SuS@UniHD 2016

Constants

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In[78]:= Clear[d, v, F, T, σ, ρ, Nicm3];
         (* Clear variable in case definitions are left over *)

In[79]:= Nicm3 = 1.01 × 10^10
          (* intrinisc carrier density at room temperature in atoms / cm^3 *);
         μe = 1400 (* cm2/Vs *);
         q = 1.6 × 10^-19 (* elementary charge *);
         ϵ0 = 8.854 × 10^-12 (* dielectric constant *);
         ϵSi = 11.9 (* dielectric constant of Si *);
```

1. Calculate Wafer doping

In[84]:= $\text{NDcm3} = \frac{1}{q\,\mu e\ \text{rho}}$ /. rho → 2000

Out[84]= 2.23214×10^{12}

In[85]:= $\text{ND}\mu\text{m3} = \frac{\text{NDcm3}}{\left(10^{4}\right)^{3}}$

Out[85]= 2.23214

2. Built In Voltage

In[86]:= $\text{Vbi}[\text{NA\_}, \text{ND\_}] = 0.0259\ \text{Log}\left[\frac{\text{NA ND}}{\text{Nicm3}^{2}}\right]$;

(* general formula, dopings must be given in $1/\text{cm}^3$ *)

In[87]:= $\text{MyVbi} = \text{Vbi}\left[10^{15}, \text{NDcm3}\right]$

Out[87]= 0.43774

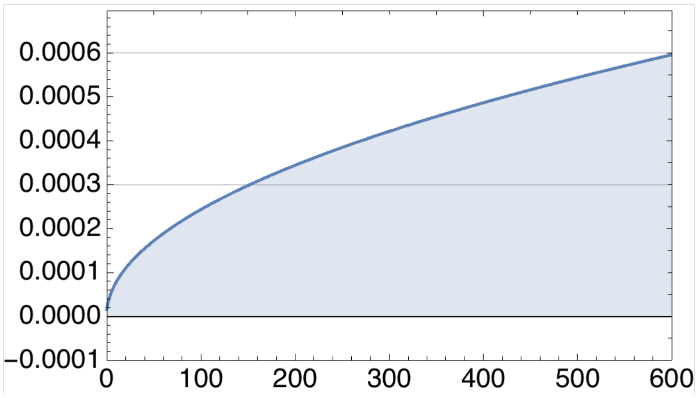
3. Voltage for Depletion

In[99]:=
$$d[NA\_, ND\_, Vbi\_, Vext\_] = \sqrt{\frac{2\,\epsilon_{Si}\,\epsilon_0}{q}\,\frac{NA + ND}{NA\,ND\,10^6}\,Vbi}\,\sqrt{1 - \frac{Vext}{Vbi}};$$
(* NA and ND in cm^{-3}, d is in meter *)

In[100]:= d[NA, ND, Vbi, Vext]

Out[100]=
$$36.2909\,\sqrt{\frac{(NA + ND)\,Vbi}{NA\,ND}}\,\sqrt{1 - \frac{Vext}{Vbi}}$$

In[101]:= Plot[d[10^{15}, NDcm3, MyVbi, -Vext],
{Vext, 0, 600}, GridLines → {{}, {0.3×10^{-3}, 0.6×10^{-3}}}]

Out[101]=


In[102]:= Vdepl = Vext /. NSolve[d[10^{15}, NDcm3, MyVbi, Vext] == 0.3×10^{-3}, Vext] // First

Out[102]= -151.757

4. Field at Junction

In[103]:=
$$\text{Solve}\left[\frac{T\,Emax}{2} == Vdepl\ /.\ T \to 300,\ Emax\right]\ //$$
First (* length unit is μm!, Field is in V/μm *)

Out[103]= {Emax → -1.01171}

In[104]:=
$$\frac{NDcm3\,10^6 \times 300 \times 10^{-6}\,q}{\epsilon_{Si}\,\epsilon_0}$$
(* Directly using Gaus'ss Law *)

Out[104]= 1.0169×10^6

The field is 0 at the Ohmic side just at depletion

5. Field at Overdepletion

Everything increases linearly