Diode current

A silicon p-n junction diode is doped NA = 2E+15 cm-3 and ND = 2E+17 cm-3. At the temperatoure of operation ni = 1 × 10^10 cm-3. The cross-sectional area of the diode is 10-4 cm2. The diffusion constants and recombination times are: Dn = 20 cm2/s, Dp = 10 cm2/s, τn = 7 × 10-7 s, and τp = 5 × 10-7 s.

What is the reverse saturation current of this diode?

Solution:

At first, we calculate the diffusion length for the holes and the electrons:

$$L_h = \sqrt{D_h \cdot \tau_h}$$

$$L_h = \sqrt{10\frac{cm^2}{s} \cdot 5 \cdot 10^{-7}s} = 2{,}236 \cdot 10^{-3}cm$$

$$L_e = \sqrt{D_e \cdot \tau_e}$$

$$L_e = \sqrt{20\frac{cm^2}{s} \cdot 7 \cdot 10^{-7}s} = 3{,}742 \cdot 10^{-3}cm$$

The current in a pn-diode consist only of diffusion current (all other currents are negligible), so we can calculate the current density with the known formula:

$$J_s = \left(\frac{e \cdot D_e}{L_e} \cdot n_0 + \frac{e \cdot D_h}{L_h} \cdot p_0\right) = \left(\frac{e \cdot D_e}{L_e} \cdot \frac{n_i^2}{N_D} + \frac{e \cdot D_h}{L_h} \cdot \frac{n_i^2}{N_A}\right)$$

$$J_s = \left(\frac{1{,}602 \cdot 10^{-19}As \cdot 20\frac{cm^2}{s}}{3{,}742 \cdot 10^{-3}cm} \cdot \frac{(1 \cdot 10^{10}cm^{-3})^2}{2 \cdot 10^{17}cm^{-3}} + \frac{1{,}602 \cdot 10^{-19}As \cdot 10\frac{cm^2}{s}}{2{,}236 \cdot 10^{-3}cm} \cdot \frac{(1 \cdot 10^{10}cm^{-3})^2}{2 \cdot 10^{15}cm^{-3}}\right)$$

The current density is

$$J_s = 3{,}65 \cdot 10^{-11}\frac{A}{cm^2}.$$

To get the current, we have to multiply the current density with the cross-sectional area.

$$I_s = J_s \cdot A = 3{,}625 \cdot 10^{-11}\frac{A}{cm^2} \cdot 10^{-4}cm^2$$

The reverse saturation current is now

$$I_s = 3{,}625 \cdot 10^{-15}A$$

(For details see: Thuselt: Physik der Halbleiterbauelemente; Page 141)

MatLab-Source for the calculation:

```
%elementary charge
e = 1.60217648*10^-19; % [As]

%doping
N_a = 2*10^15; % [cm^-3]
N_d = 2*10^17; % [cm^-3]
n_i = 1*10^10; % [cm^-3]

% cross-sectional area
A = 10^-4; % [cm^2]

% diffusion constants
D_n = 20; % [cm^2/s]
D_p = 10; % [cm^2/s]
%recombination times
tau_n = 7*10^-7; % [s]
tau_p = 5*10^-7; % [s]

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%Calculating the diffusionlength
L_e = sqrt(D_n*tau_n) % [cm]
L_h = sqrt(D_p*tau_p) % [cm]

%calculating the current-density
J_s = (e*D_n/L_e*(n_i)^2/N_d+e*D_p/L_h*(n_i)^2/N_a) % [A/cm^2]

%calculation the current
I_s = J_s*A % [A]
```