COMPOSANTS SEMI-CONDUCTEURS

II) Solutions S2

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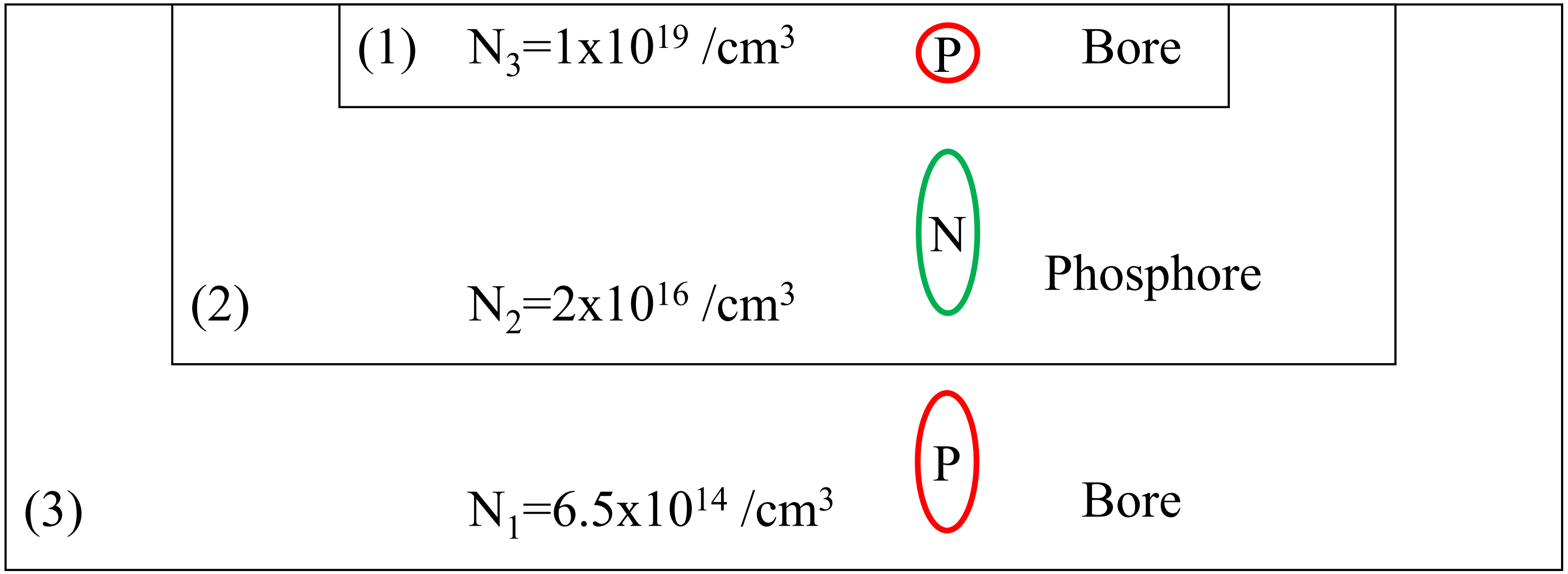
EPFL

Exercice E3.1: profils de dopage



Exercice 3.1: solution

Le bore (III) est un accepteur (dopant p) dans le silicium
Le phosphore (V) est un donneur (dopant n) dans le silicium

3) $p_1 = N_{A1} = 6.5 \times 10^{14}\, cm^{-3}$ $\qquad n_1 = \dfrac{n_i^2}{p_1} = \dfrac{10^{20}}{6.5 \times 10^{14}} \cong 1.5 \times 10^5\, cm^{-3}$

2) $n_2 = N_2 - N_1 = 2 \times 10^{16} - 6.5 \times 10^{14} \cong 2 \times 10^{16}\, cm^{-3}$

$$p_2 = \frac{n_i^2}{n_2} = \frac{10^{20}}{2 \times 10^{16}} = 5 \times 10^3\, cm^{-3}$$

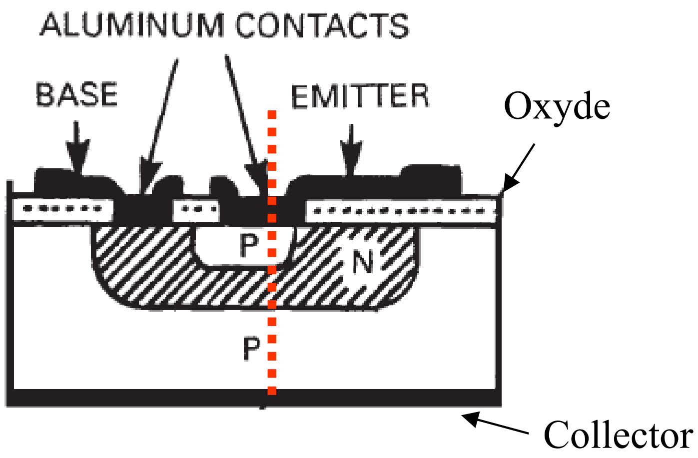
1) $p_3 = N_3 - (N_2 - N_1) \cong N_3 = 1 \times 10^{19}\, cm^{-3}$

$$n_3 = \frac{n_i^2}{p_3} = \frac{10^{20}}{1 \times 10^{19}} = 10\, cm^{-3}$$

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

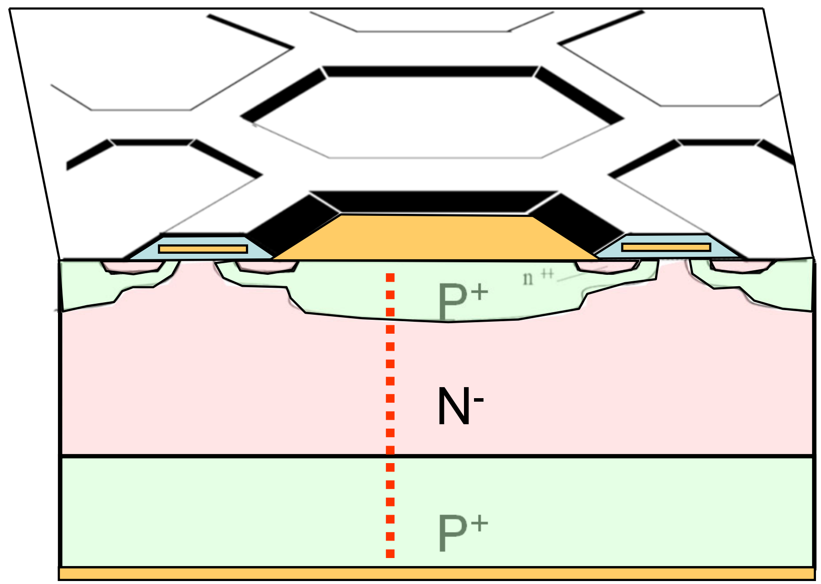
Structures PNP

Transistors bipolaires PNP



http://technology-electronic.blogspot.com/2010/07/bipolar-junction-transistors-bjts.html

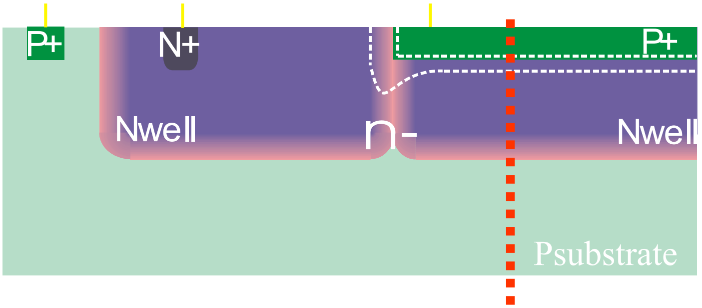
Isolated Gate Bipolar Transistor (IGBT) = Darlington avec un MOSFET et un BJT



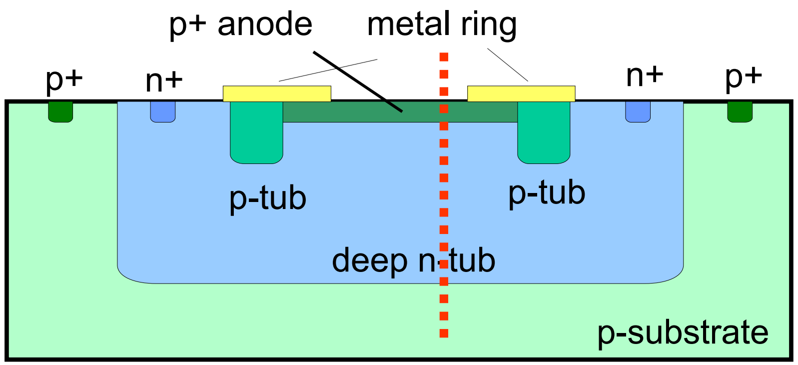
Omar Elmazria: thèse Uni Metz

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Single photon avalanche detector (SPAD)

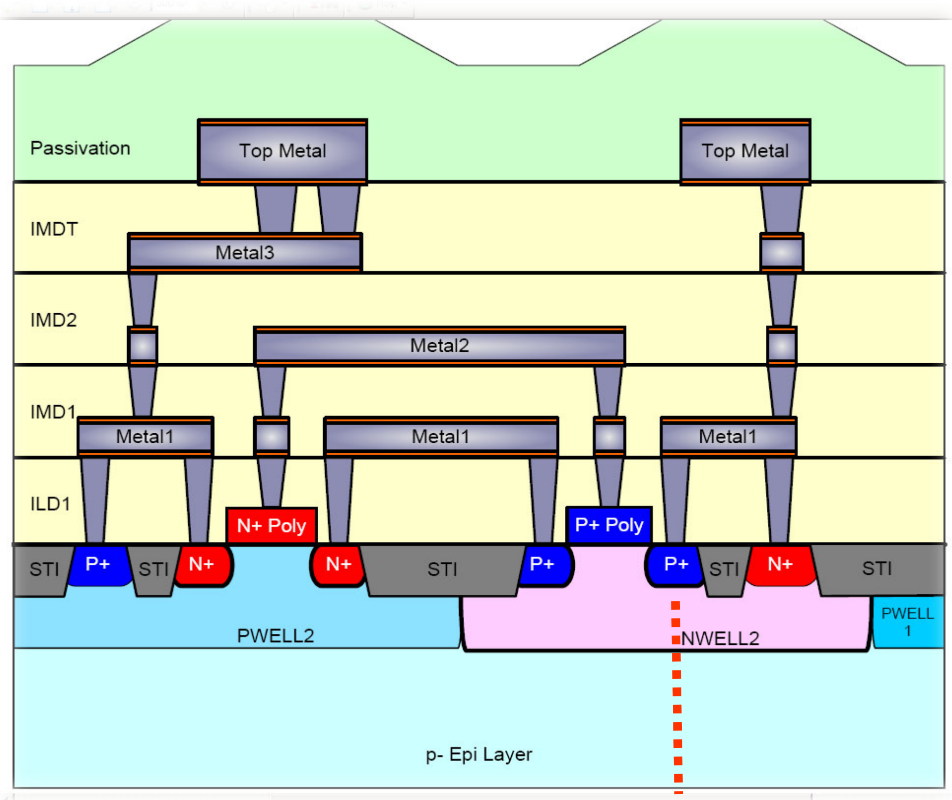


A. Rochas et al., IEEE Transactions Electron Devices, 49 (2002) 387-394.



A. Rochas et al, sent for publication in Review of Scientific Instruments.

Procédé CMOS standard



Approximation des profils de dopage

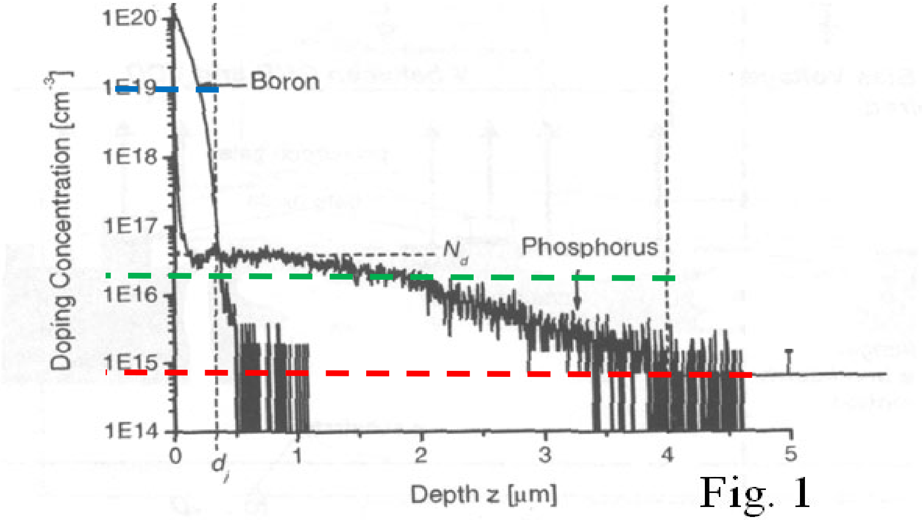


Fig. 1

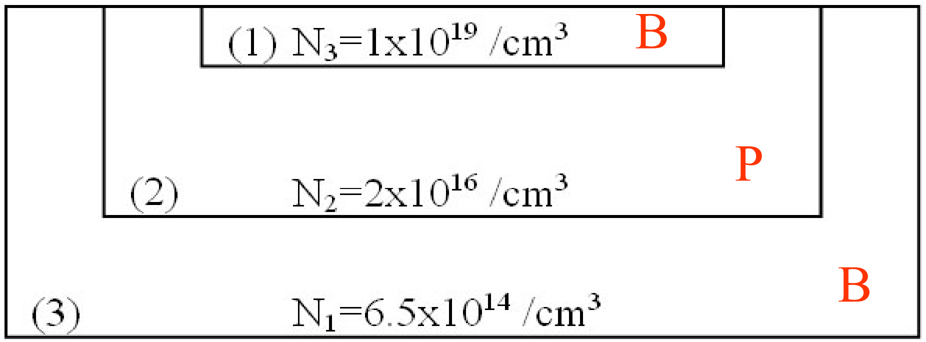
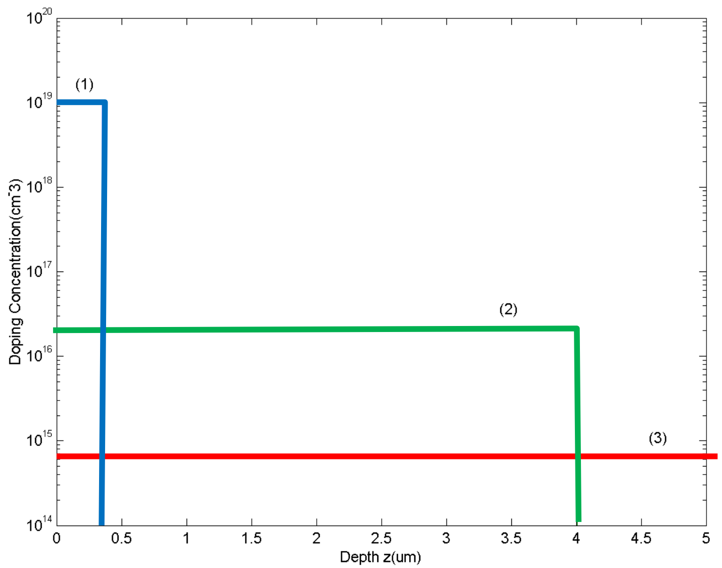


Fig. 2



Exercice E2.2: Niveaux de Fermi et température

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

1) *Trouvez le niveau de Fermi d'un silicium dopé avec 10^{16} cm^{-3} atomes de phosphore à 300 K .*

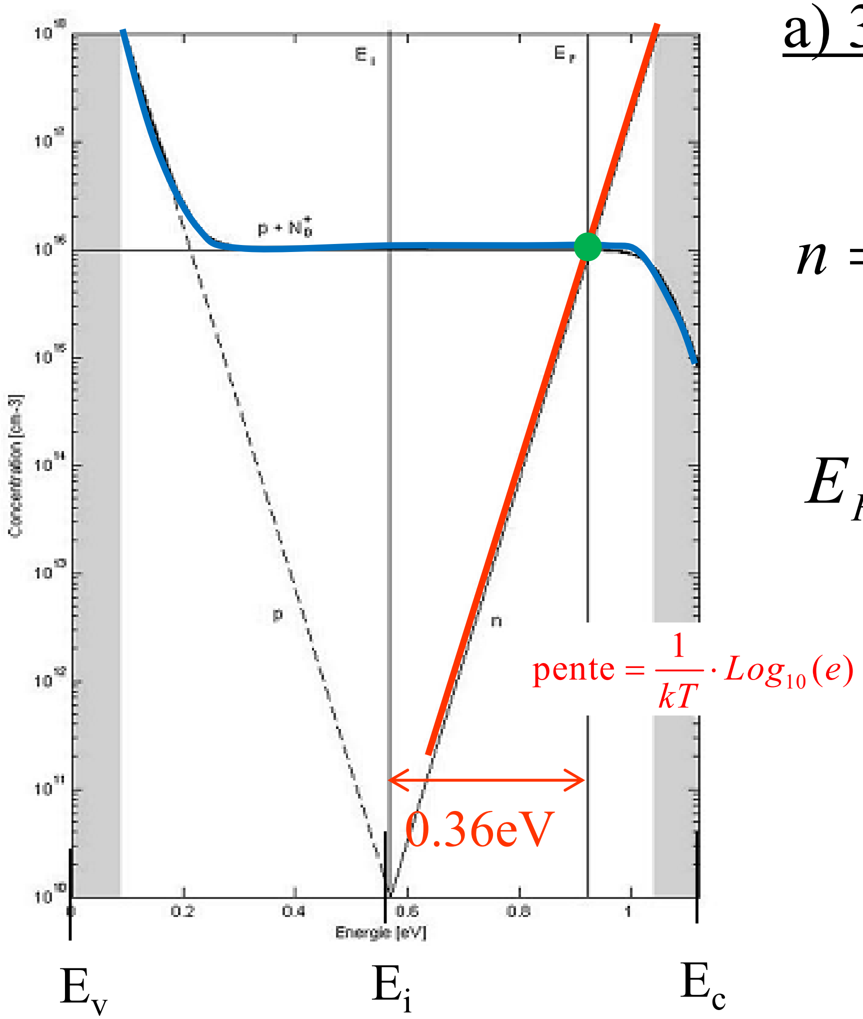
2) *Le même matériau est chauffé à 600 K.*
Calculez la concentration de porteurs intrinsèques à cette température.
Quel est maintenant le niveau de Fermi ?
Supposez le bangap et les masses effectives constants en température .

3) *Si l'échantillon est refroidi à la température de l'azote liquide (77 K), quelle hypothèse faut-il reconsidérer ?*
(Pour information, l'énergie d'ionisation du phosphore est $E_D = E_C$ - 0.045 eV).

Exercice 2.2: solution 300K

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

$$n + N_A^- = p + N_D^+$$

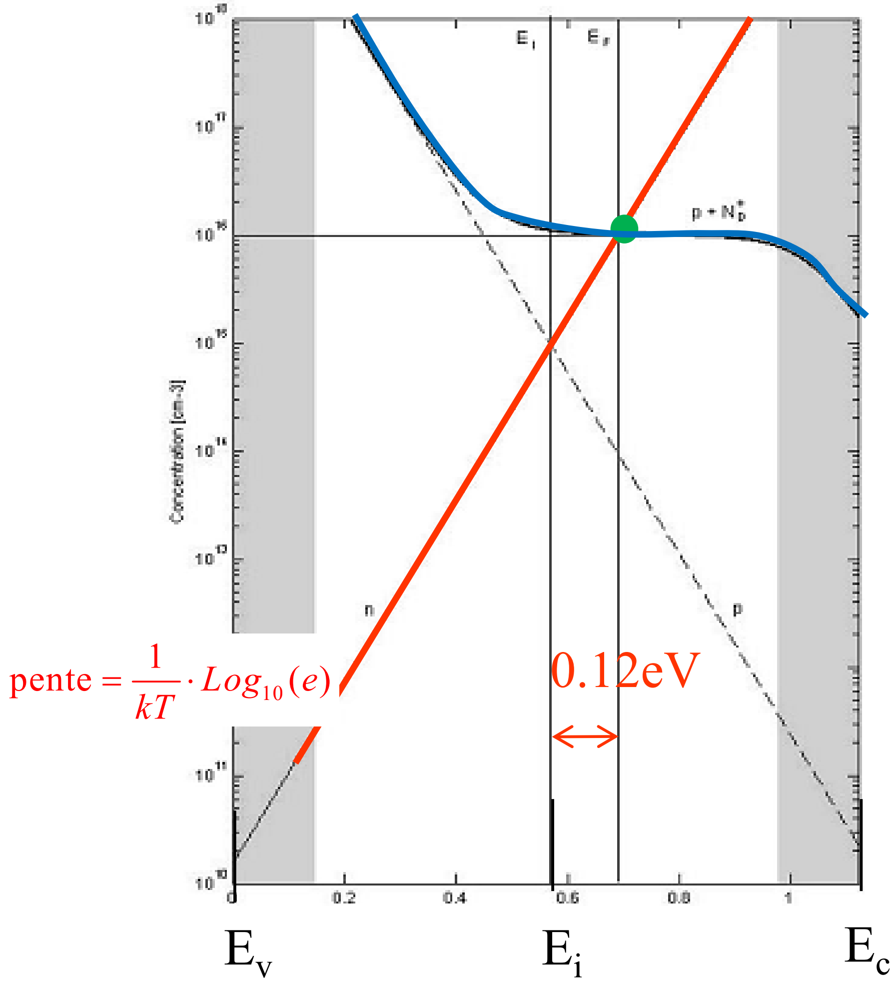


a) 300K

$$n = N_D = n_i \exp\left(\frac{E_F - E_i}{kT}\right)$$

$$E_F - E_i = kT \ln(N_D / n_i) = 0.36eV$$

Exercice 2.2: solution 600K



b) 600K: calcul de n_i

$$N_C = 2\left(\frac{m^*_{dos,n} k_B T}{2\pi\hbar^2}\right)^{3/2} = 7.9\times10^{19}$$

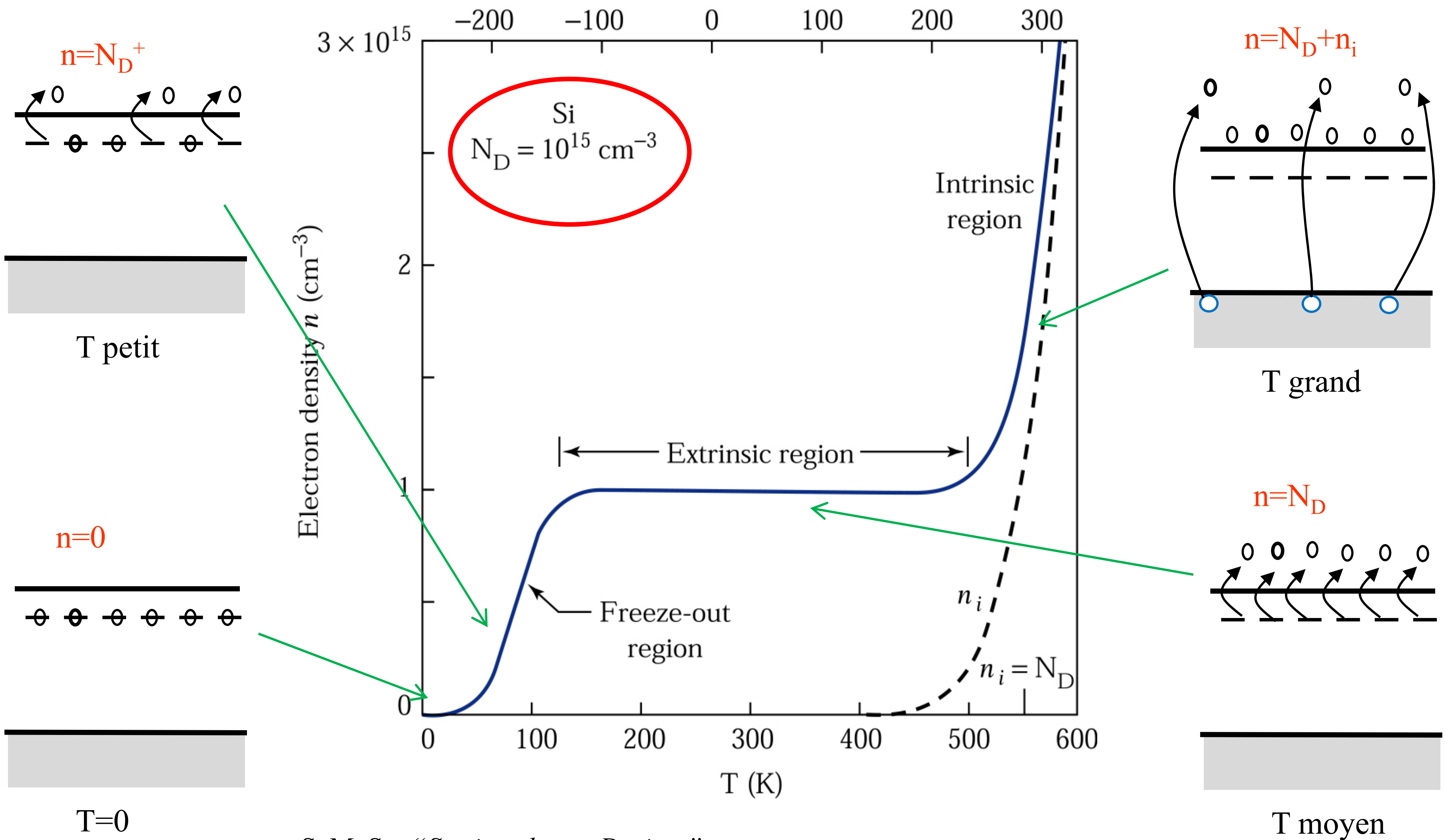
$$N_V = 2\left(\frac{m^*_{dos,p} k_B T}{2\pi\hbar^2}\right)^{3/2} = 2.9\times10^{19}$$

$$n_i = \sqrt{N_C N_V}\exp\left(\frac{-E_g}{2k_B T}\right) = 9.4\times10^{14}$$

Calcul de E_f

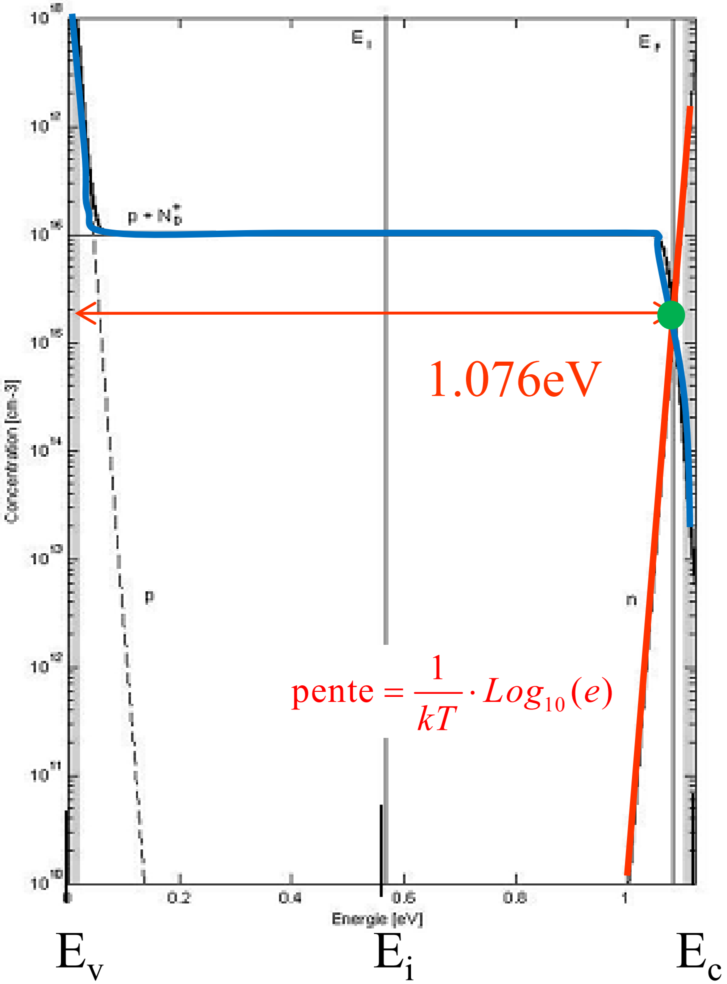
$$E_F - E_i = kT\ln(N_D / n_i) = 0.12eV$$

Concentration et température



S. M. Sze "*Semiconductor Devices*"

Exercice 2.2: solution 77K



c) 77K: calcul de n_i

$$N_C = 2\left(\frac{m^*_{dos,n} k_B T}{2\pi\hbar^2}\right)^{3/2} = 3.66\times10^{18} \quad \left[cm^{-3}\right]$$

$$N_V = 2\left(\frac{m^*_{dos,p} k_B T}{2\pi\hbar^2}\right)^{3/2} = 1.33\times10^{18} \quad \left[cm^{-3}\right]$$

$$n_i = \sqrt{N_C N_V}\exp\left(\frac{-E_g}{2k_B T}\right) = 4.8\times10^{-19} \quad \left[cm^{-3}\right]$$

Condition de neutralité: $n = N_D^+$

Exercice 2.2: solution 77K

Condition de neutralité: $n=N_D^+$

$$n = n_i \exp\left(\frac{E_F - E_i}{k_B T}\right) = N_D^+ = N_D\left(1 - \frac{1}{1 + \frac{1}{2}\exp\left(\left(E_D - E_F\right)/k_B T\right)}\right)$$

$$E_F = 1.076 \ eV$$

avec $2E_i = E_g = E_c = 1.12 \ eV$

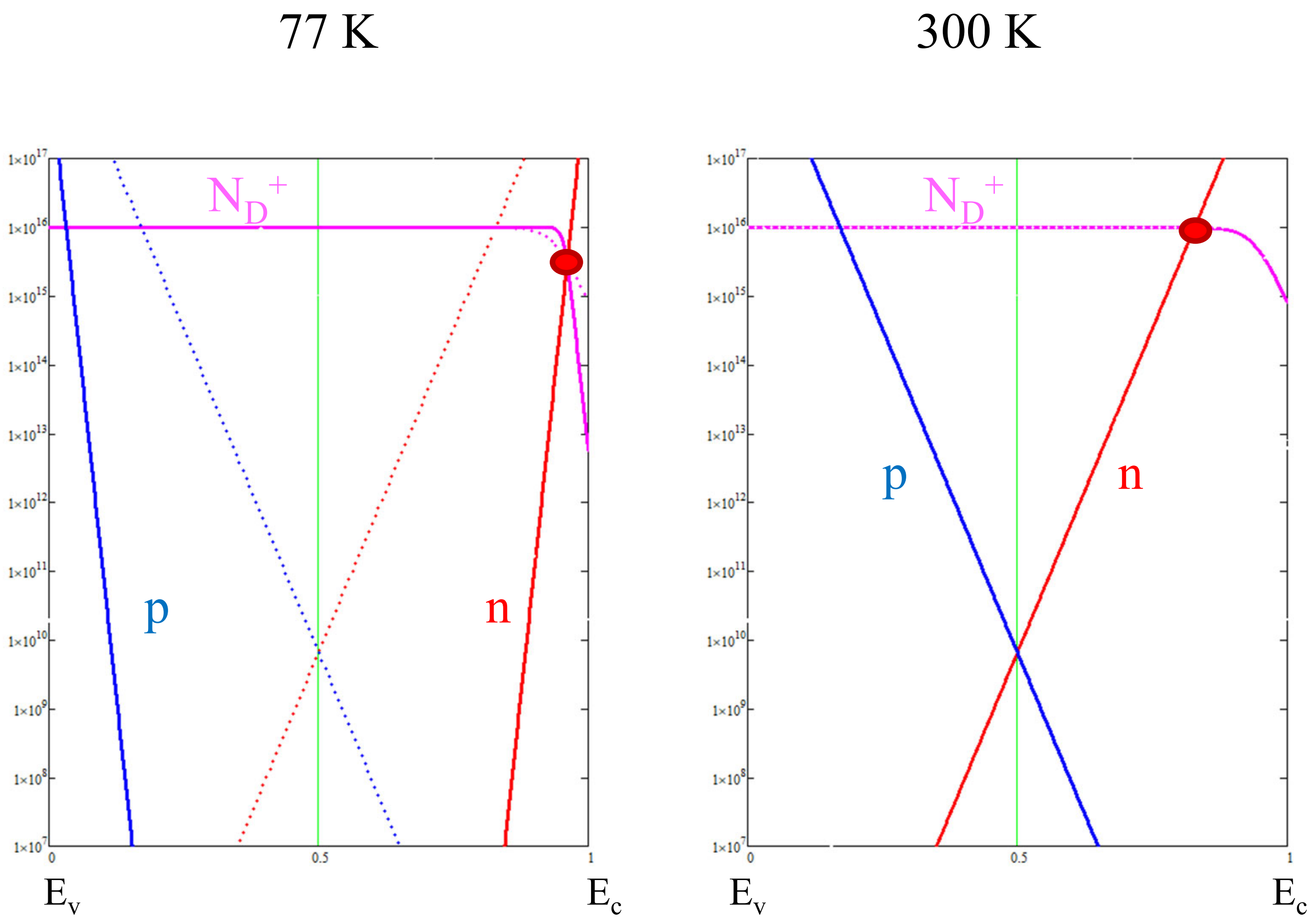
$$E_C - E_F = 44 \ meV$$

$$E_C - E_D = 45 \ meV$$

$$N_D^+ = 3\times 10^{15} \ cm^{-3}$$

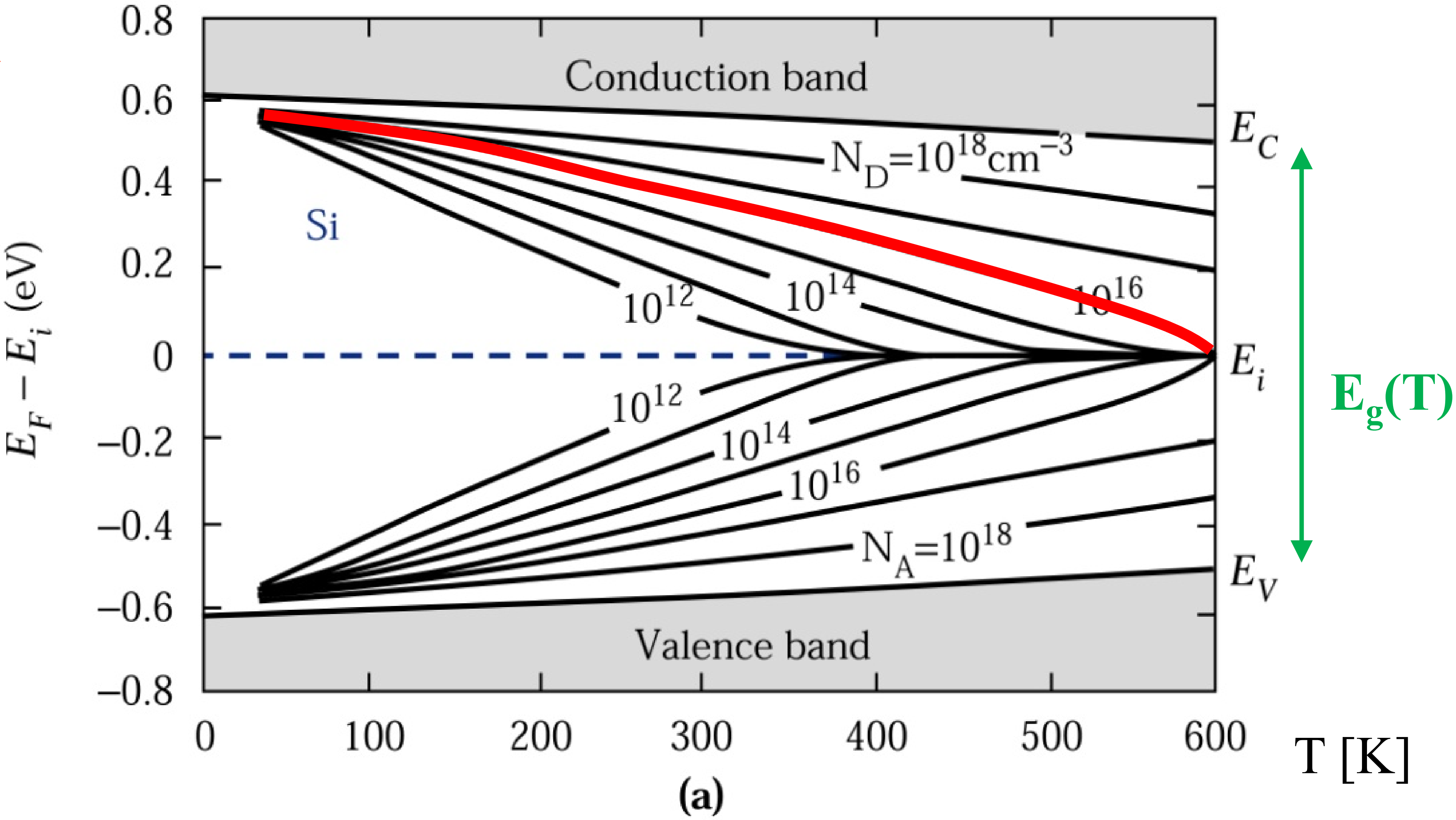
$$\frac{N_D^+}{N_D} = 30\%$$

Résumé du comportement en température



Niveau de Fermi

Silicium



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