# Working Principle of a Semiconductor Based Solar Cell

## 2.4 Charge carrier excitation

*Week 2*

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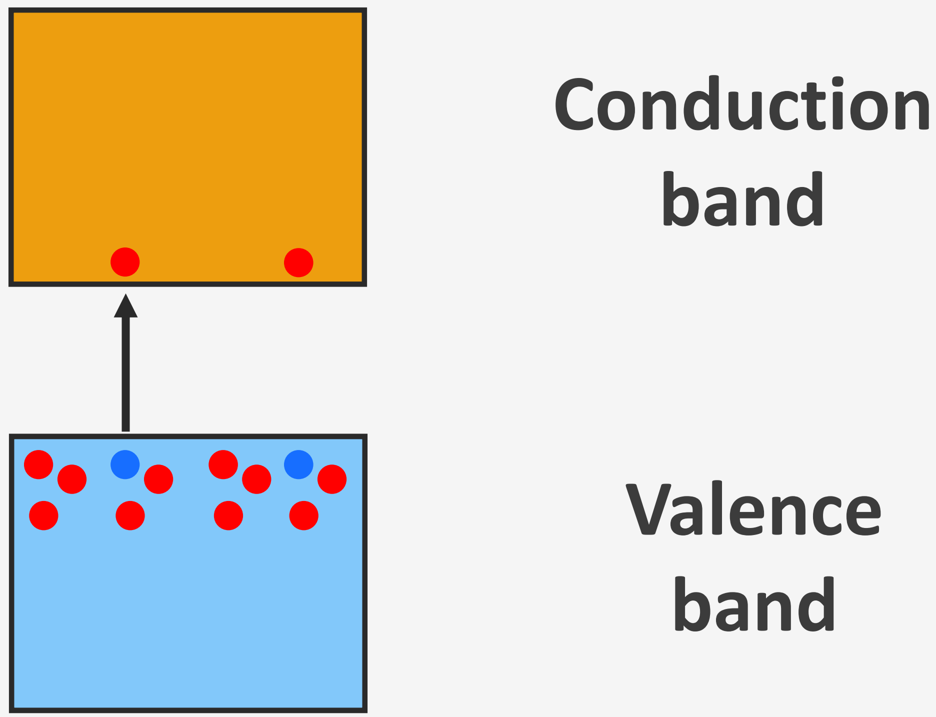
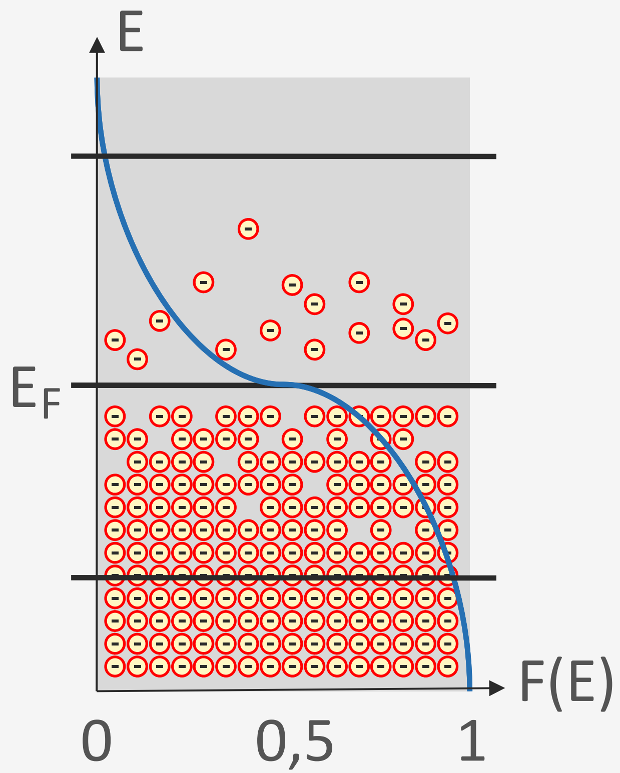
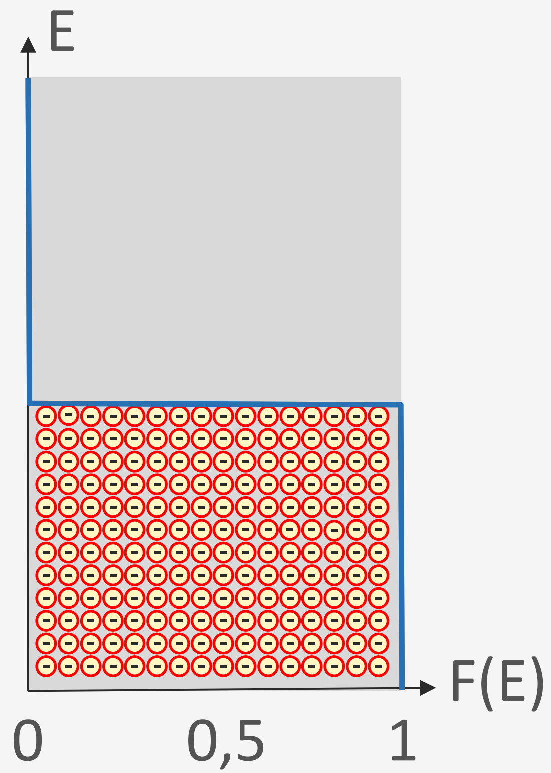

Conduction band
Valence band

# Fermi Level

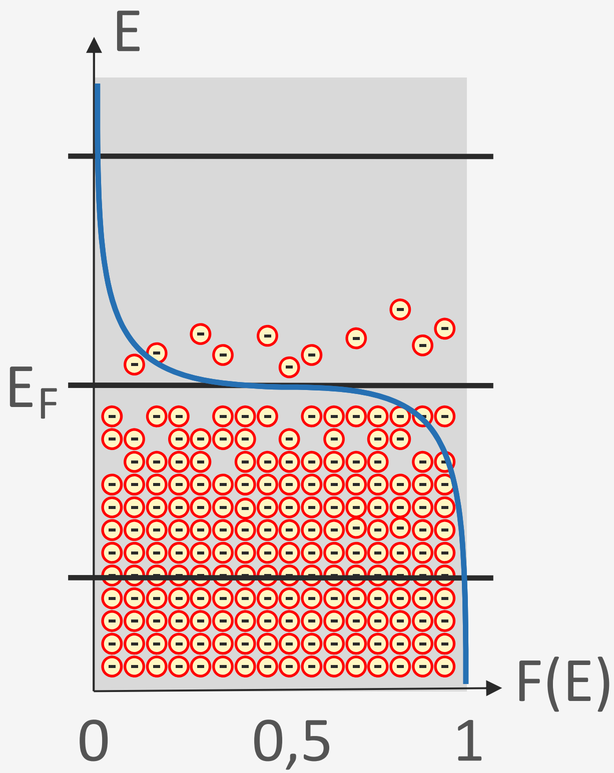


# Fermi level




**T = 0 K**

# Fermi Level



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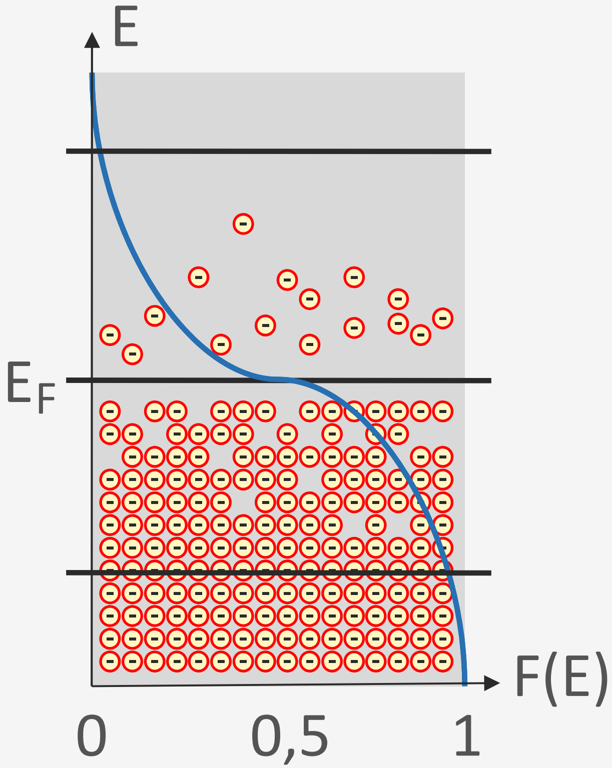

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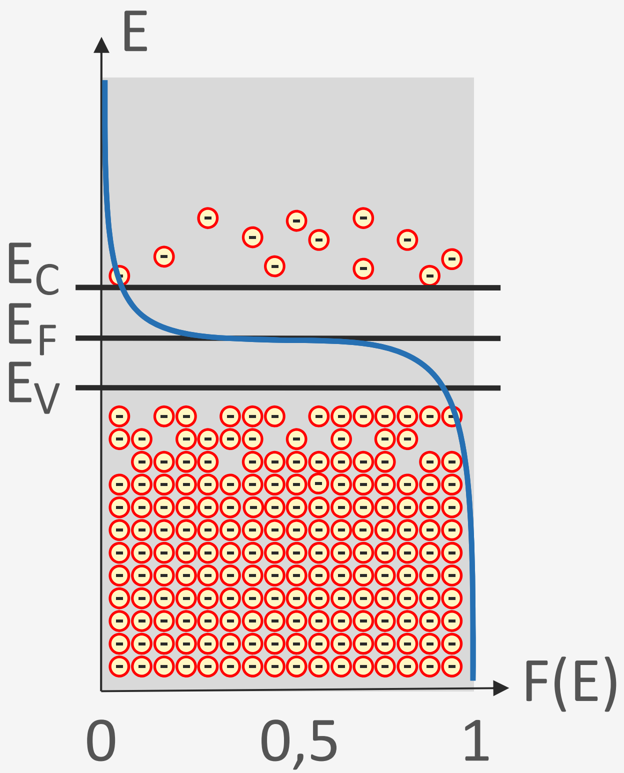

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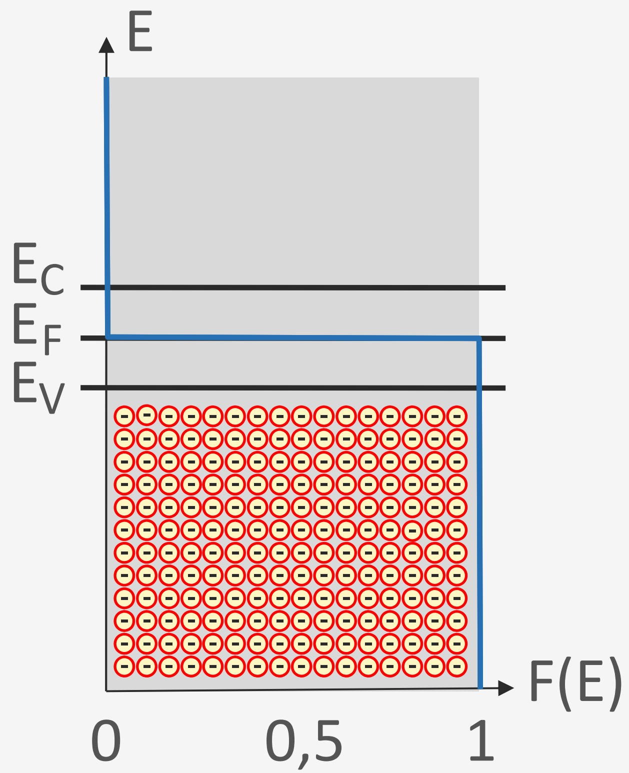
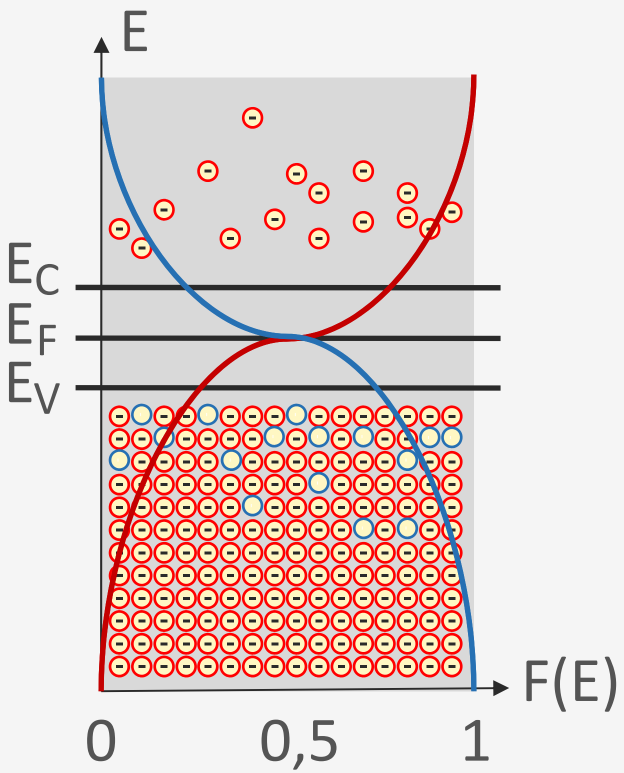
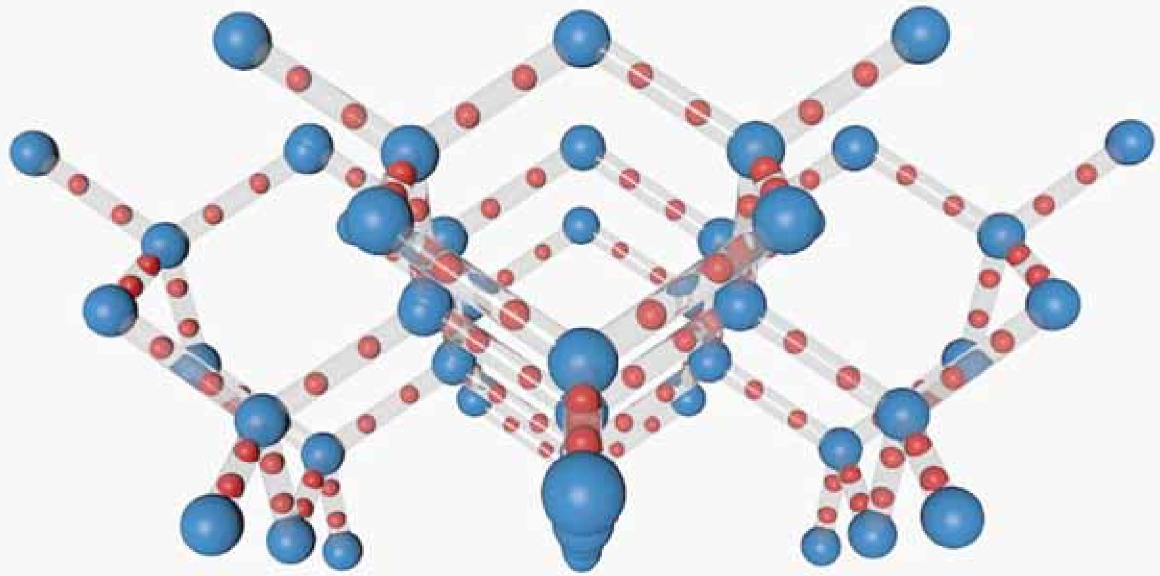


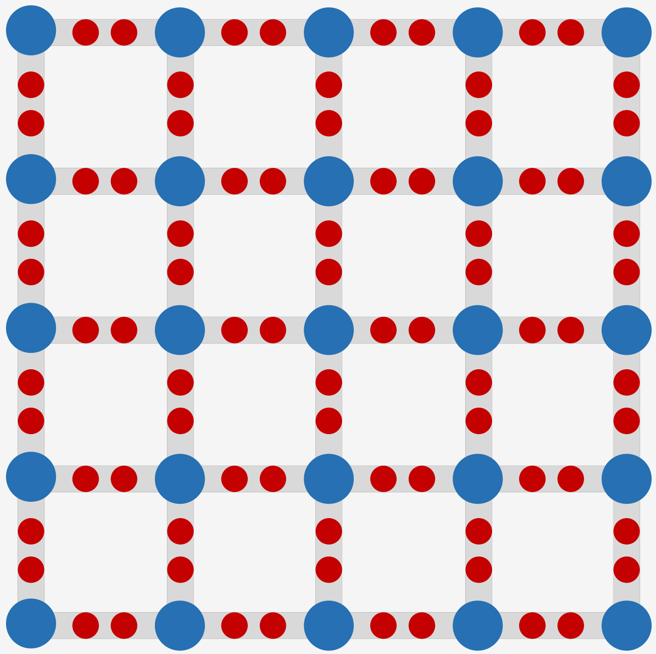

**T = 0 K**

# Fermi Level

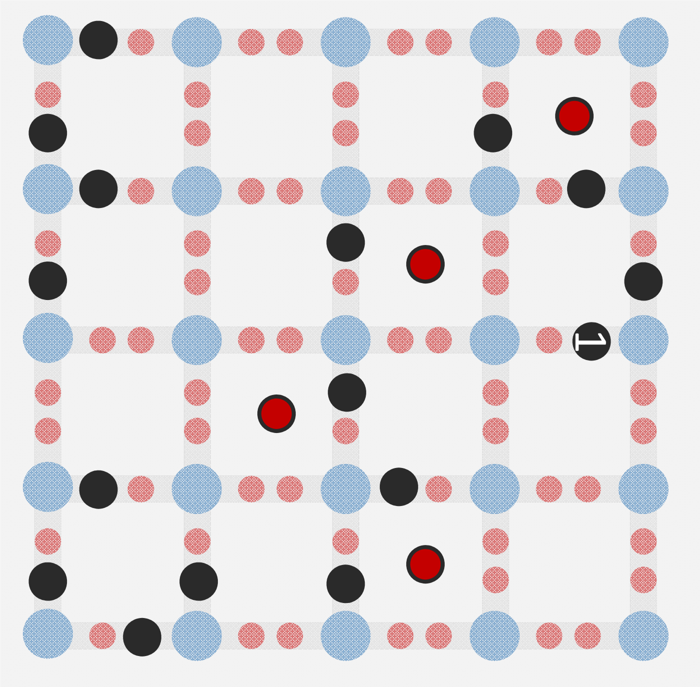




# Silicon Structure representation in 2D



# Silicon Structure

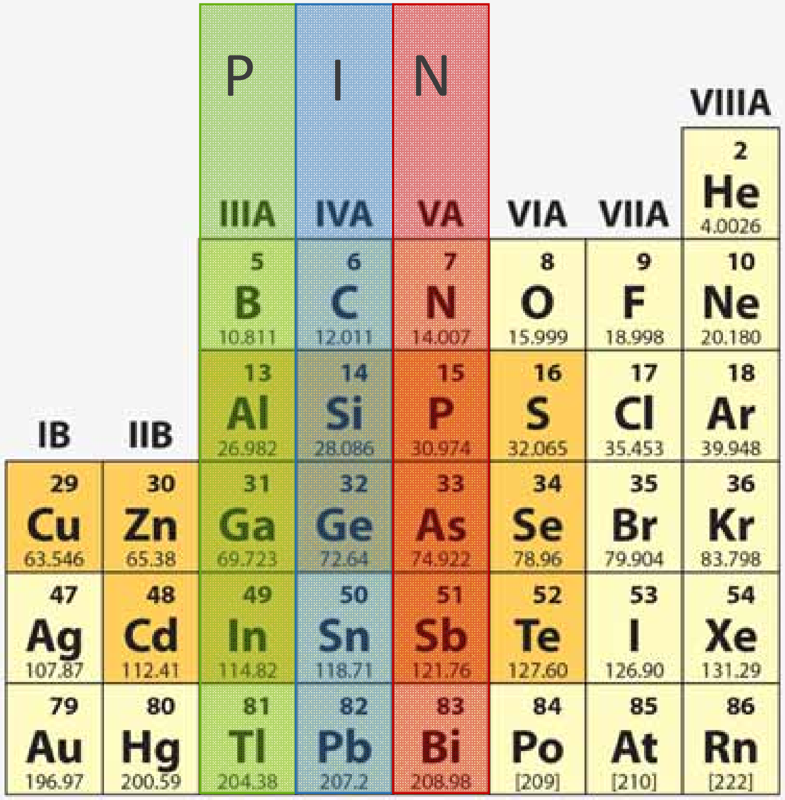


„Free“ electron

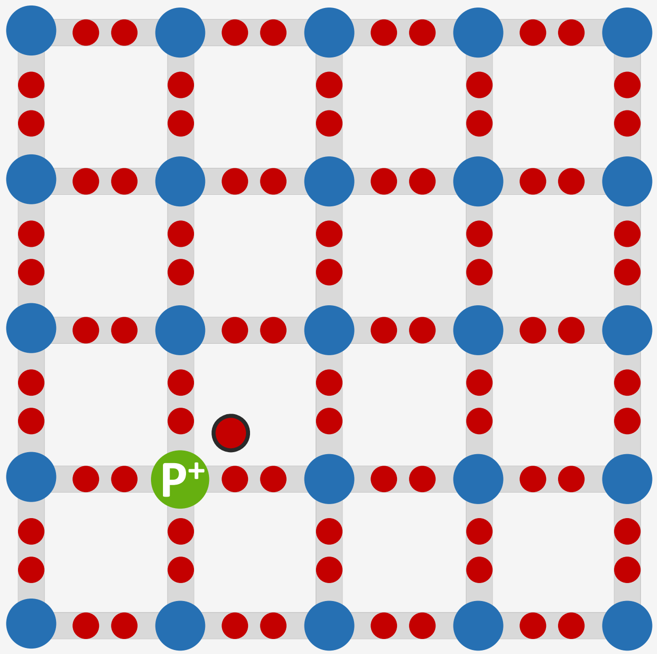
Hole

(bond missing valence electron)

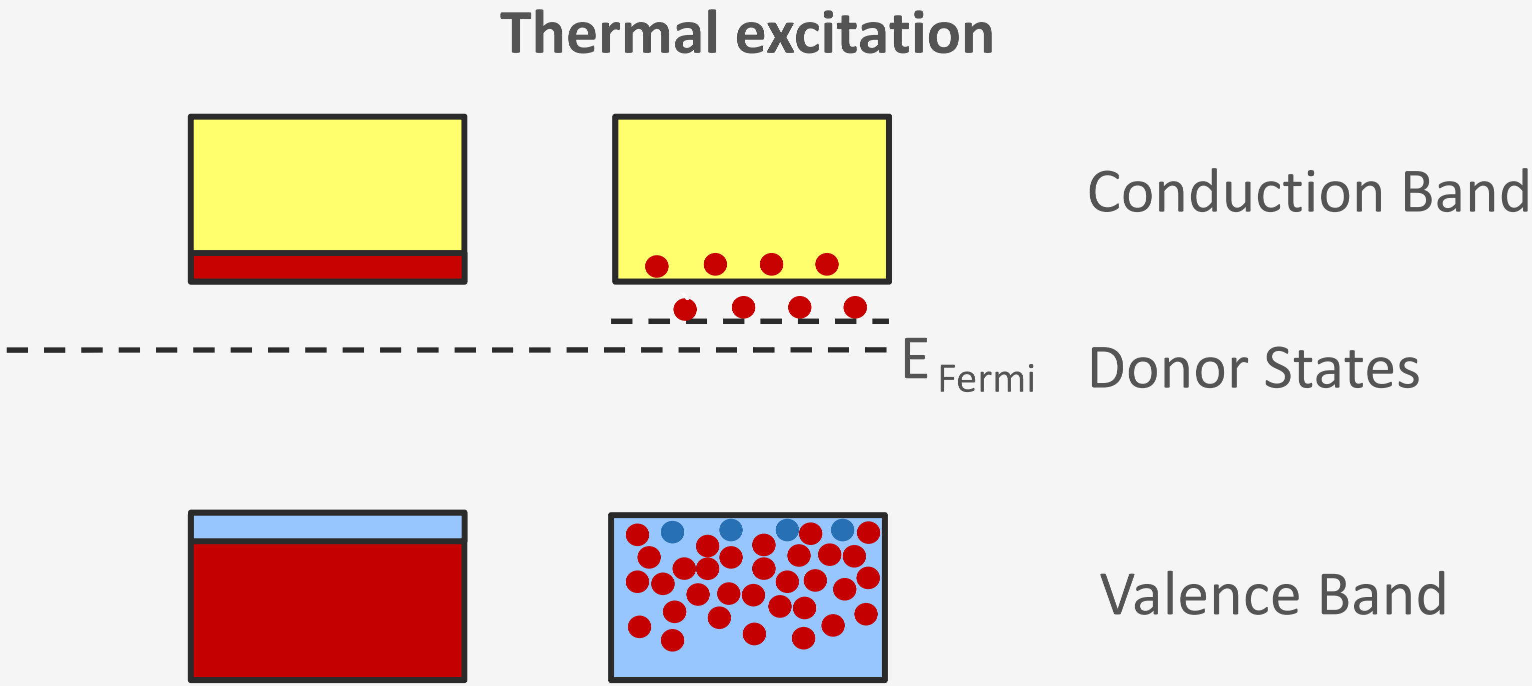
# Semiconductor Materials



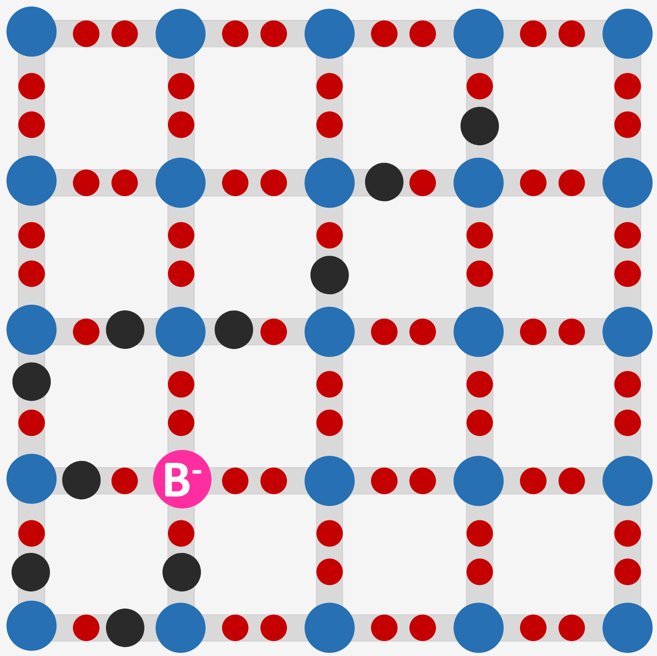
# n-Doping



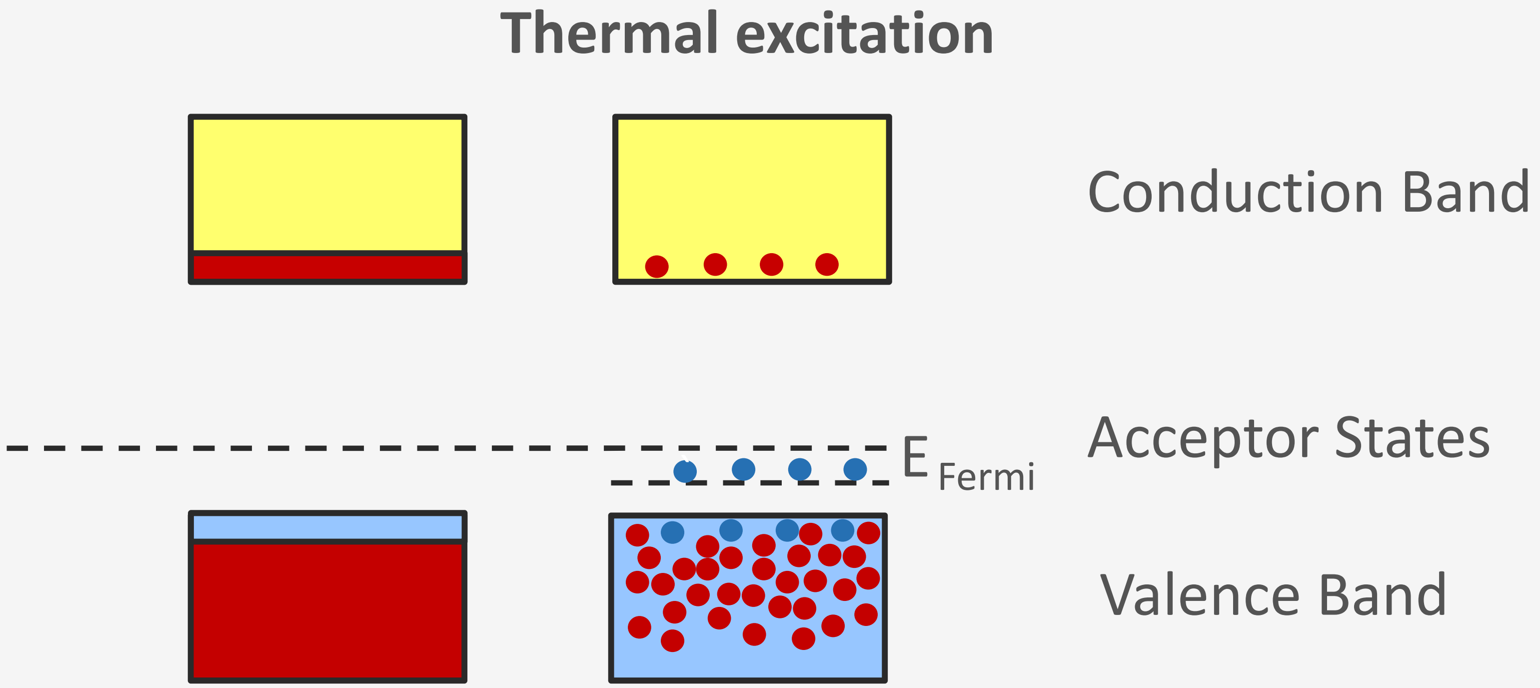
# Energy band diagram of n-doped Silicon



# p-Doping



# Energy band diagram of p-doped Silicon



## Typical Concentrations:

$$\frac{\text{Majority Carriers}}{\text{Minority Carriers}} = \frac{10^{16}\ \text{cm}^{-3}}{10^{4}\ \text{cm}^{-3}}$$

**Si density in c-Si is $5 \times 10^{22}$ cm$^{-3}$**

# Law of Mass Action

$n$ = electron carrier concentration
$p$ = hole carrier concentration

} $n \cdot p = 1{,}21\text{X}10^{20}\ \text{cm}^{-6}$

**Intrinsic material** $n = p = n_{intrinsic} = 1{,}1\text{X}10^{10}\text{cm}^{-3}$

Doping: *At Room Temperature:* $n_0\, p_0 = (n_{intrinsic})^2$

**n-type doping**

$$n_0 = N_D$$

$$p_0 = \frac{(n_{intrinsic})^2}{n_0}$$

**p-type doping**

$$p_0 = N_A$$

$$n_0 = \frac{(n_{intrinsic})^2}{p_0}$$

# Example

n-type doping

$$n_0 = N_D$$

$$p_0 = \frac{(n_{intrinsic})^2}{n_0}$$

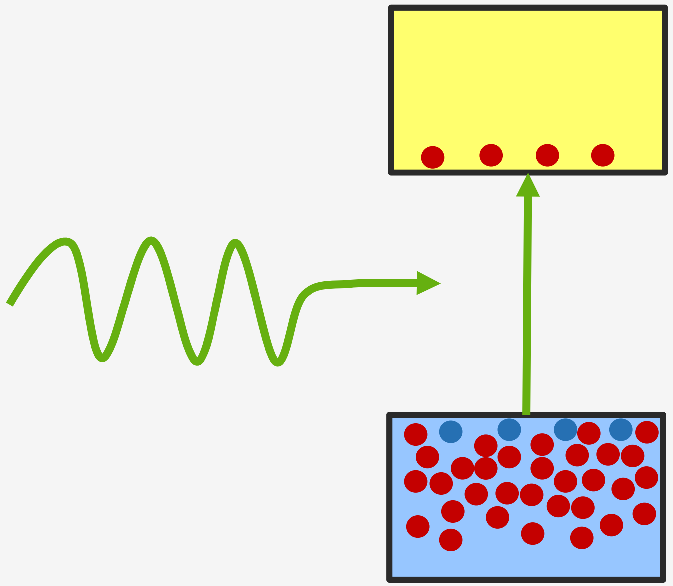
n-type doping example

$$n_0 = N_D = 10^{16}\ cm^{-3}$$

$$p_0 = \frac{1{,}21X10^{20}}{10^{16}} = 1{,}21X10^{4}\ cm^{-3}$$

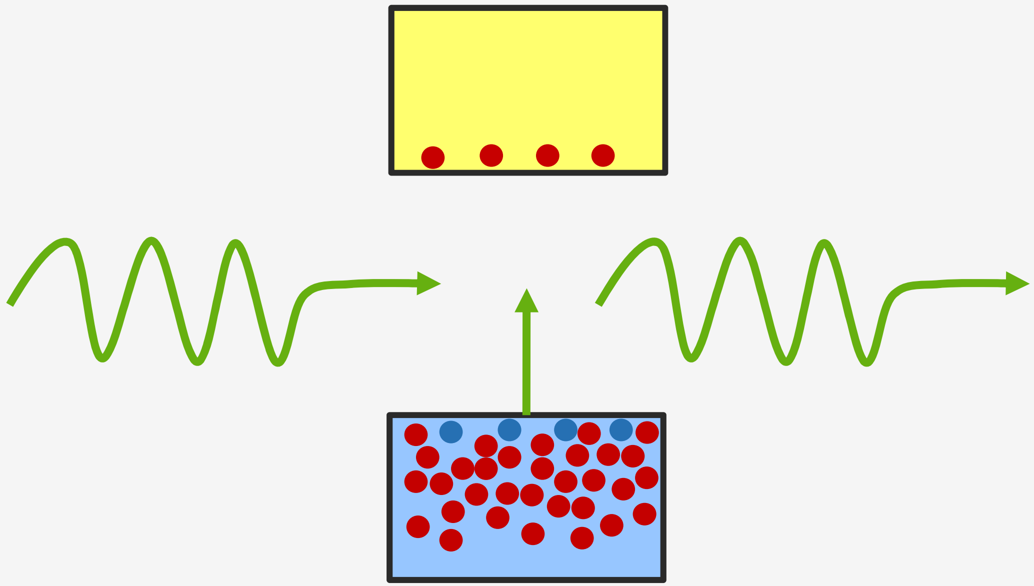
# Light Absorption *scenario 1*

$E_{ph} = E_G$:



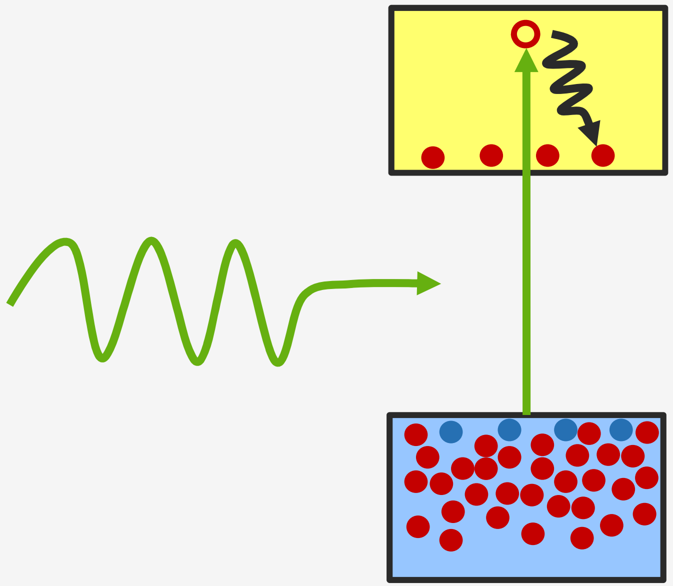
# Light Absorption *scenario 2*

$E_{ph} < E_G$:



## Light Absorption *scenario 3*

$E_{ph} > E_G$:



## Light Absorbtion in doped material

**before** light absorption:

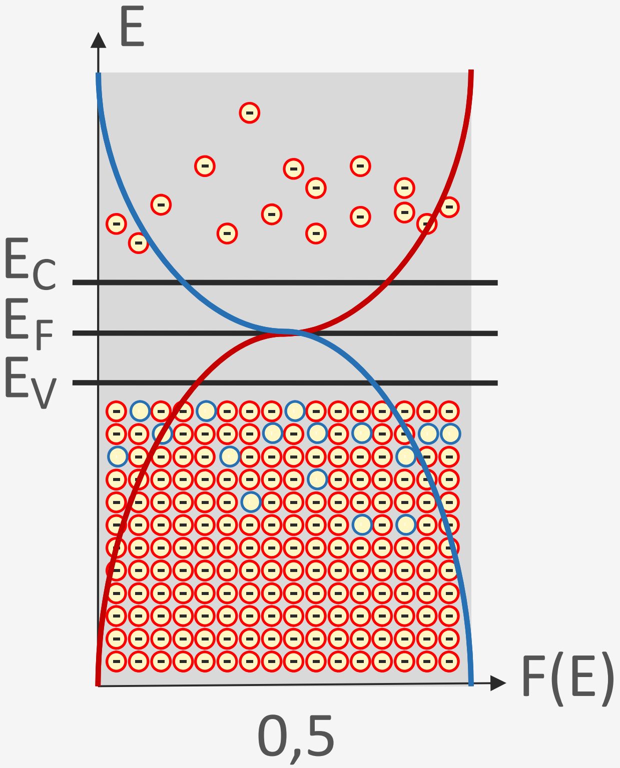
$$\frac{\text{Majority Carriers}}{\text{Minority Carriers}} = \frac{10^{16}\ \text{cm}^{-3}}{10^{4}\ \text{cm}^{-3}}$$

## Light Absorbtion in doped material

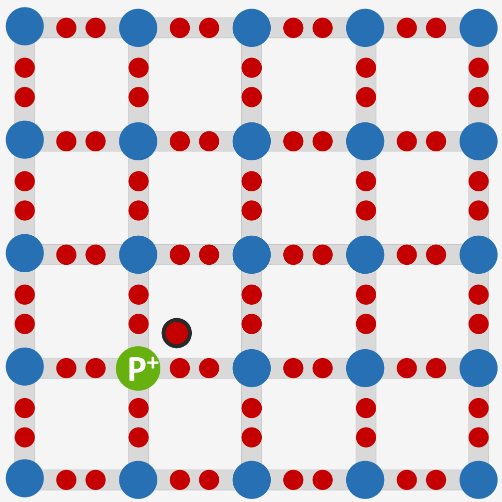
*$10^{11}$ now electron-hole pairs*:

$$\frac{\text{Majority Carriers}}{\text{Minority Carriers}} = \frac{10^{16} + \cancel{10^{11}} \text{ cm}^{-3}}{\cancel{10^{4}} + 10^{11} \text{ cm}^{-3}}$$

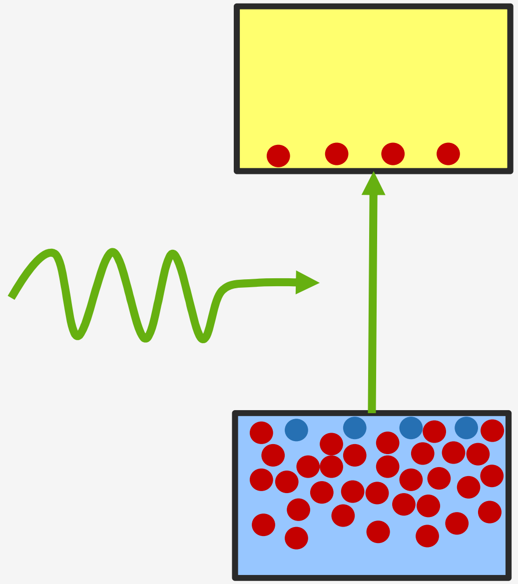
## Temperature




## Doping




## Light



# Thank you for your attention!

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