Electrons in solids

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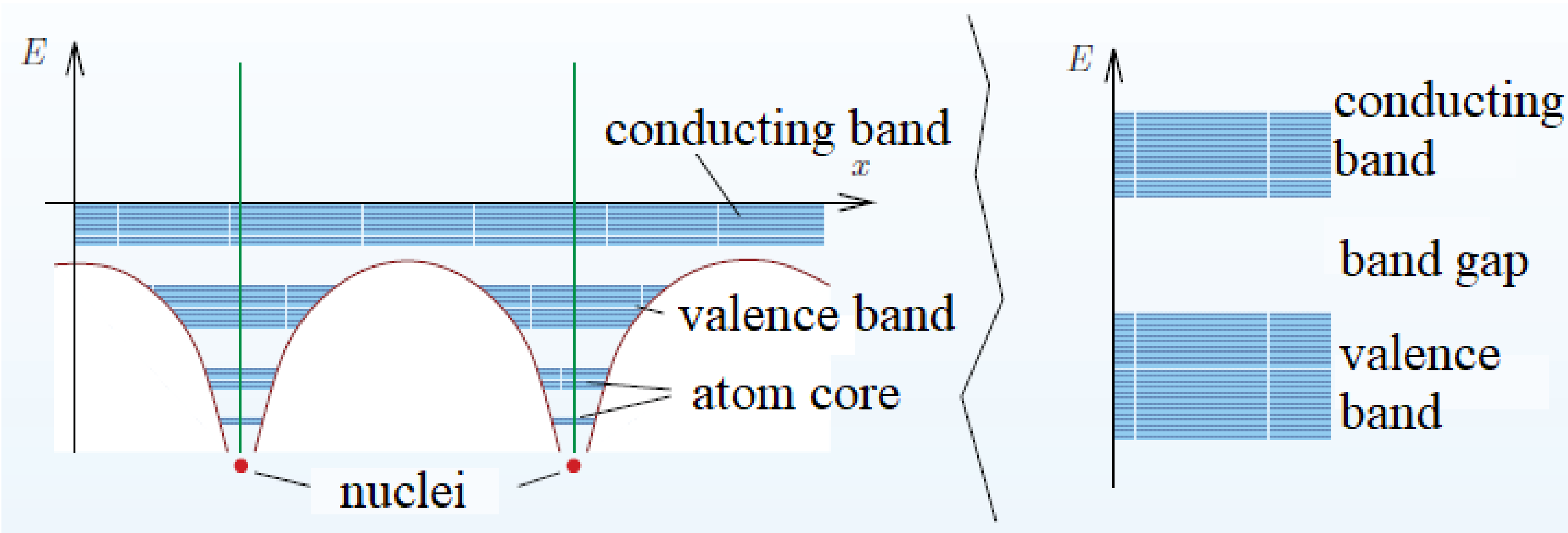
Fizika és Kémia Tanszék

- We have seen that the energy structure of molecules consists of many more possible levels than that of atoms.
- In the case of solids, this phenomenon is even more pronounced.
- Nearby atoms distort each other's electronic structure, thus the original one atomic levels split into many level. Many nearby levels are overlaped and the allowed states are grouped into energy bands. Each band has a different character corresponding to an electronic state:

1. valence band: electrons attached to atoms
2. conducting band: electrons move to any distance within the crystal
3. band gap or energy gap: there can be no electrons here.


E
conducting band
x
valence band
atom core
nuclei
E
conducting band
band gap
valence band

Energy distribution of electrons

The distribution of electrons within the band structure is determined by the energy minimum principle and the Pauli principle.

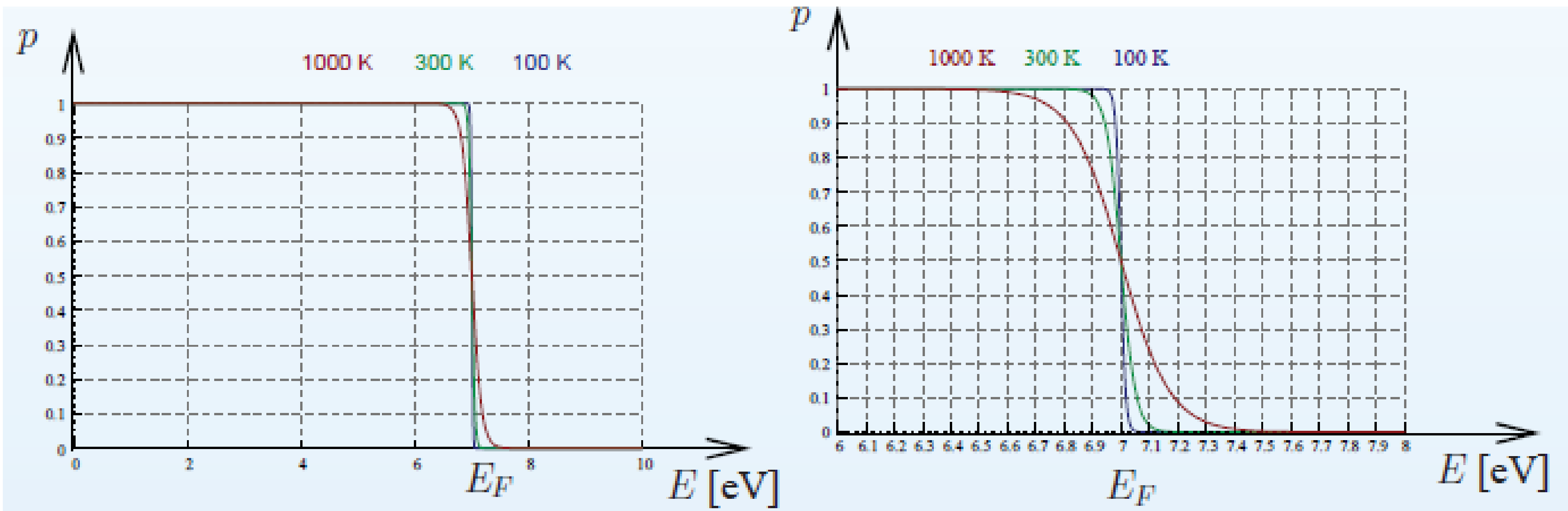
Without termic movement, the electrons are at their lowest possible energy level allowed by the Pauli principle, i.e. up to one level they would occupie all possible states. The name of this level is: Fermi level.

In the case of termic movement, electrons already reach the higher levels. According to statistical physics, at temperature T, the probability that an energy level corresponding to energy E is filled is:

$$p(E) = \frac{1}{e^{\frac{E-E_F}{kT}} + 1}$$

- If $E - E_F << -kT$, then $p(E) \sim 1$.
- If $E = E_F$, then $p(E) = 0.5$.
- If $E - E_F >> kT$, then $p(E) \sim 0$.

Typical value of E_F: 5–10 eV. At room temperature $kT \sim 0.025$ eV.
Example: for E_F = 7eV, at 3 different temperatures:



The change is very sharp at room temperature.

Difference between insulators, semi-conductors and conductors

The conductivity of a material primarily depends on the relative placement of the Fermi level and the bottom of the conduction band.

• insulators: E_F in the middle of the band gap, the width of the band gap is a few eV, so there are very rarely conduction electrons.
• metals: no band gap there, E_F is included in the conduction band, therefore there are many conduction electrons.
• semiconductors: the width of the band gap is approx. 1 eV, E_F is in the middle of band gap,there are only few electrons in the conduction band.