MIME 262, Lecture #18, March 14, 2012

Group members: Amr Emad Abdel Hamid, Mohamed Abd El Meguid, Mael Illien, Madeleine Incutiyayezu

Last time:

- Oxidation
- Kinetics of oxidation
- Electronic properties

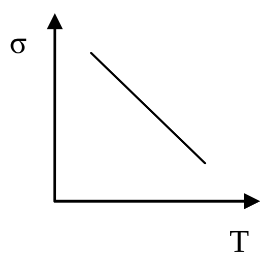
14.2 Intrinsic semiconductors

The electrons that are excited to the conduction band are free to conduct electricity just like the free carriers in a metal. They contribute an electron conductivity,

For metals

$\sigma_e = ne\mu_e$

n is the number of electrons/volume
e is the elementary charge
μ_e is the electron mobility

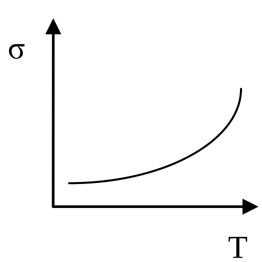


For semiconductors

$\sigma_e = ne\mu_e + ep\mu_p$

p is the number of holes/volume
μ_p is the hole mobility

Electrons have little resistance in a perfect crystal.
As Temperature increases, the electron scattering (which reduces mobility) increases.

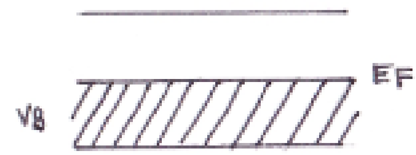


As n and p increase, charge carriers increase

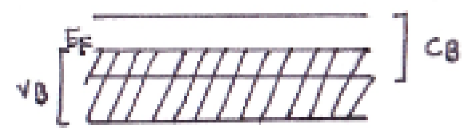
But the mobility still goes down

Mobility monovalent metals vs divalent metals

Monovalent metal



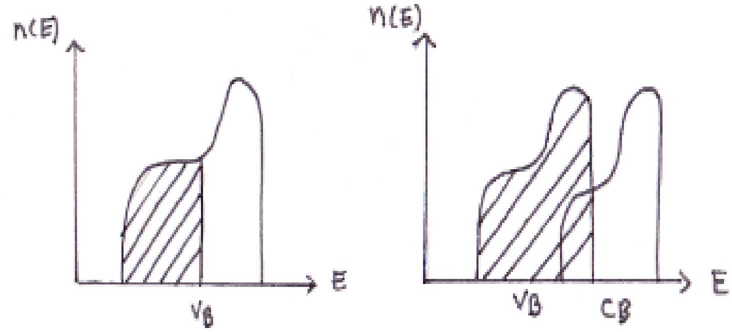
Divalent metal



$\boldsymbol{\sigma_{DM} < \sigma_{MM}}$

Density of states

Monovalent metal Divalent metal

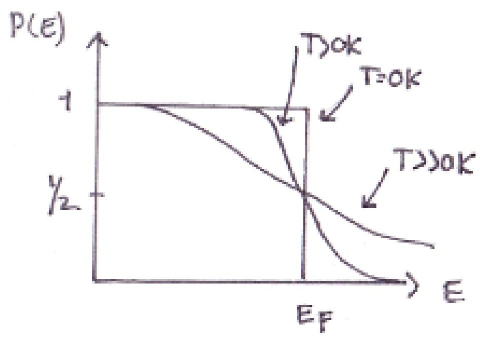


Fermi Energy

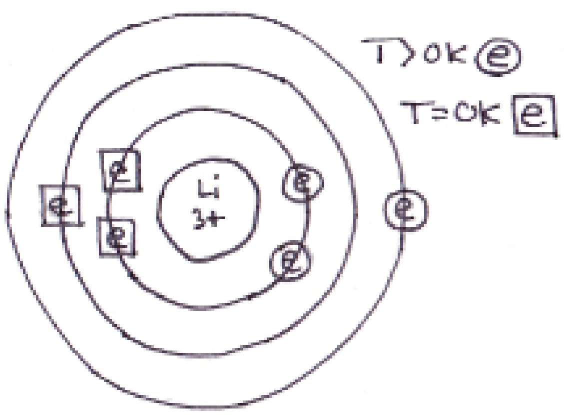
p(E) = F(E) → Fermi function
probability of finding an electron of certain energy

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

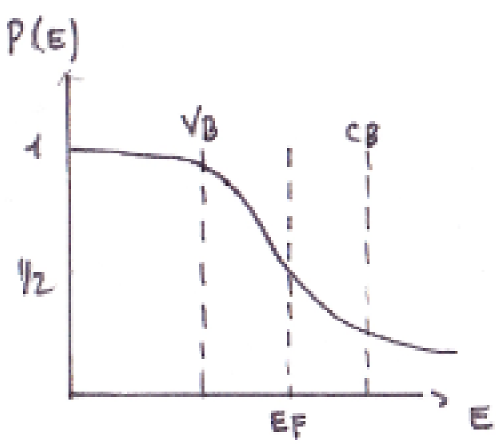
E_F is the Fermi Energy
k is Boltzmann constant
T is temperature (in Kelvin)



Fermi function at different T



Electrons in different E levels (at absolute zero, the electrons are in the lowest state)



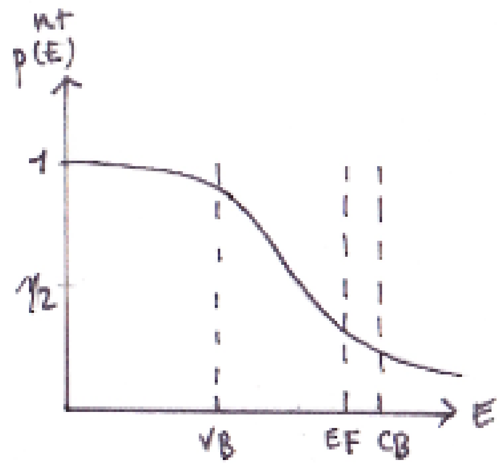
For an intrinsic semiconductor, the Fermi energy is halfway between the VB and VC

Boltzmann Approximation

p(E) ≈ $e^{-(E-E_F)/kT}$

n = n_e = N_{eo} $e^{-(E-E_F)/kT}$

p = n_n = N_{no} $e^{-(E-E_F)/kT}$



For a highly doped species, the Fermi energy is closer to the conduction band CB

np = $n_e n_n$ = constant (at a given T)

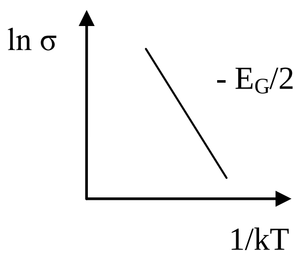
Intrinsic number of carriers:

$n_i = N_o\, e^{E_q/2KT}$

While the electron mobility μ_e decreases with T just as it does in the case of a metal, this decrease is over whelmed by the exponential increase in the density of charge carriers. An approximation of the conductivity of an intrinsic semi conductor can be written

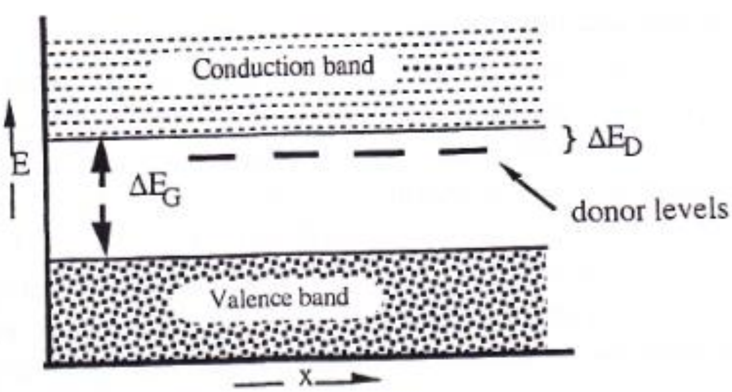
$\sigma \approx \sigma_i\, e^{E_q/2KT}$

σ_i is a constant. It follows that a plot of logarithm of σ against 1/kT yields a straight line with a negative slope $E_G/2$ as shown below

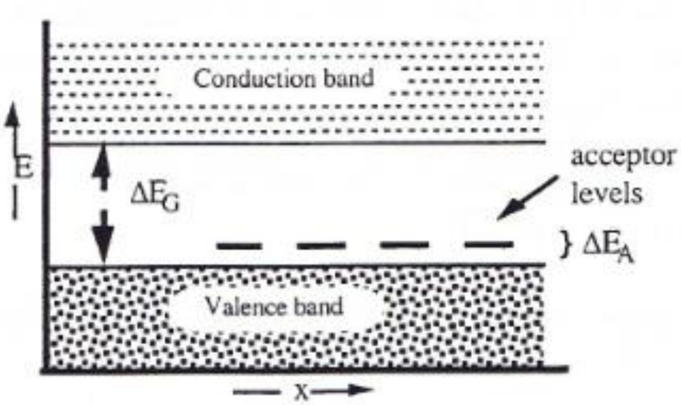


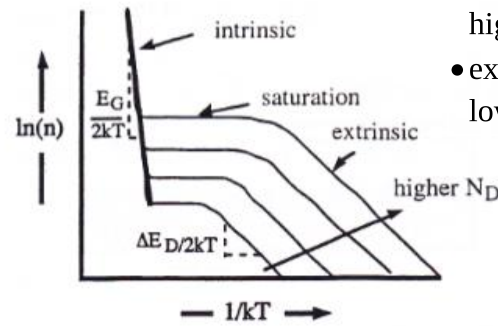
14.3 Extrinsic semiconductors

An Extrinsic semiconductor is a semiconductor whose charge carriers are primarily due to ionization of defects in the crystal lattice. If extrinsic carriers are electrons in the conduction band the defect called donors and the extrinsic semiconductor is said to be n-type.



If the extrinsic carriers are holes in the valence band the defects are acceptors and the semi conductor is p- type





- intrinsic behaviour at high temperatures
- extrinsic behaviour at low temperature

14.4 The N-P Junction

Semiconductors have different electronic characteristics derived from the behavior of the energy bands near the junction. On e half is doped to become n-type and the other half is doped to become p-type. Before the two regions are separated they have the same band structure and the same Fermi level at the mid-point. Once doped, the Fermi energy is higher in the center for n-type, lower in the center for p-type