Electronics Devices (19EC31)

Class 5

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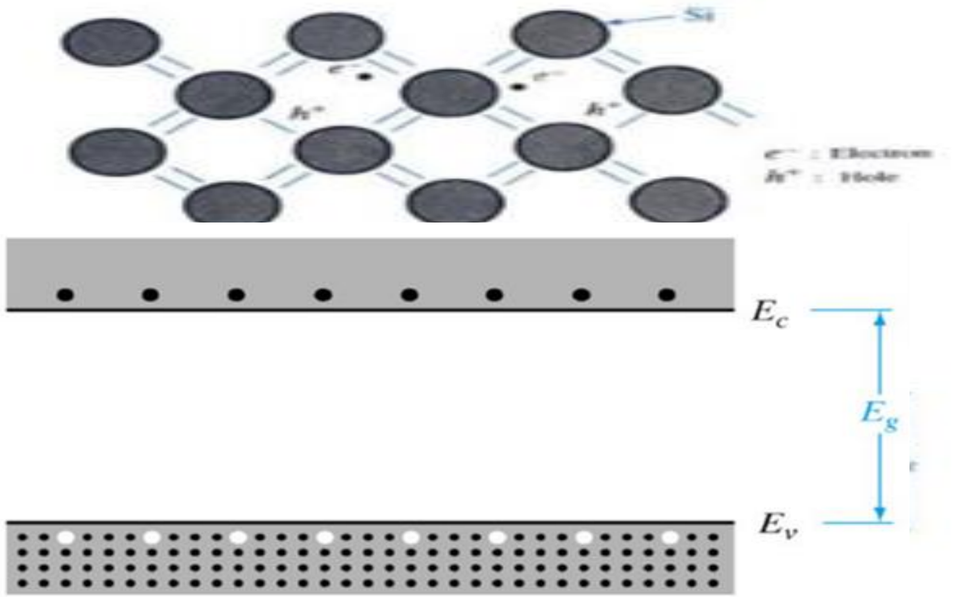
Instrinsic Material

Intrinsic Semiconductor : A perfect semiconductor crystal with no impurities or lattice defects



EHP generation in an *intrinsic* semiconductor

$n \rightarrow$ conduction band electron concentration (electrons per cm³)

$p \rightarrow$ valence band hole concentration

$$n = p = n_i$$

$r_i \rightarrow$ *recombination* rate of EHP; $g_i \rightarrow$ generation rate

$n_0, p_0 \rightarrow$ concentrations at equilibrium; $\alpha_r \rightarrow$ constant

$$r_i = \alpha_r n_0 p_0 = \alpha_r n_i^2 = g_i$$

Extrinisic Material

- Another way to generate carriers in semiconductors is by introducing impurities into the crystal structure (**doping**).
- Doping involves adding column V elements or column III elements when forming the Silicon crystal

Type of dopant	Effect	Dopant atoms
Donors (n-type)	Increases electron concentration in conduction band (n)	Column V elements: P, As, Sb
Acceptors (p-type)	Increases hole concentration in valence band (p)	Column III elements: B, Al, Ga, In

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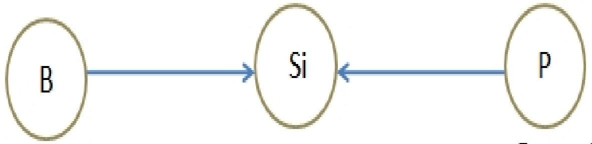
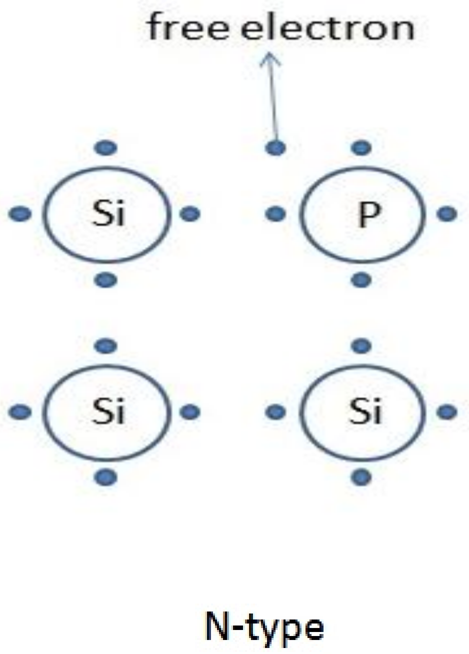
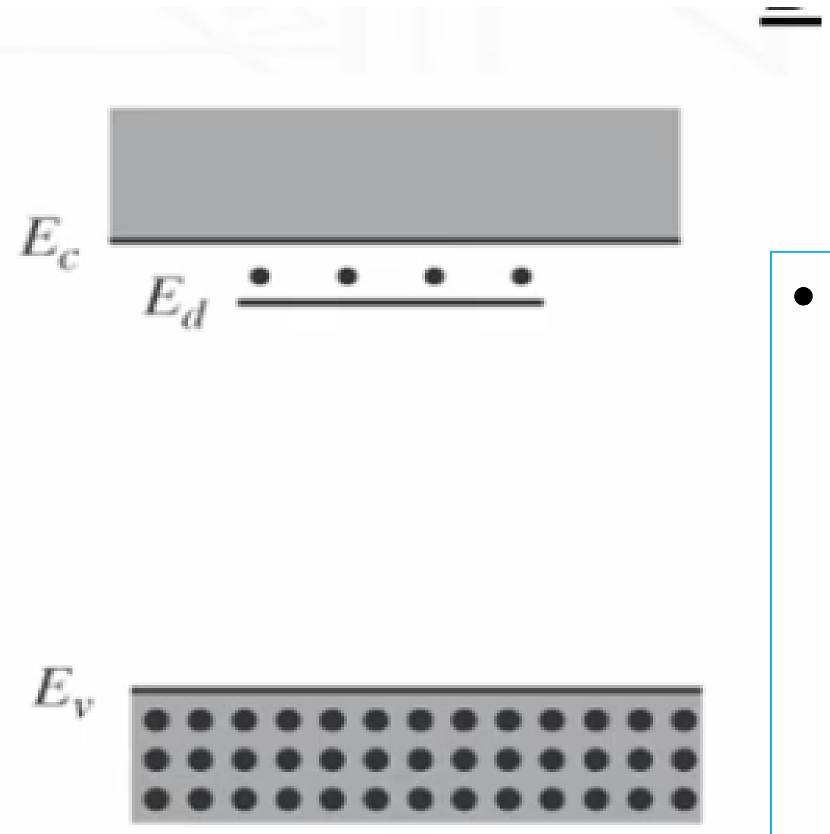


Extrinisic Material – N-type Semiconductor

N type Semiconductor

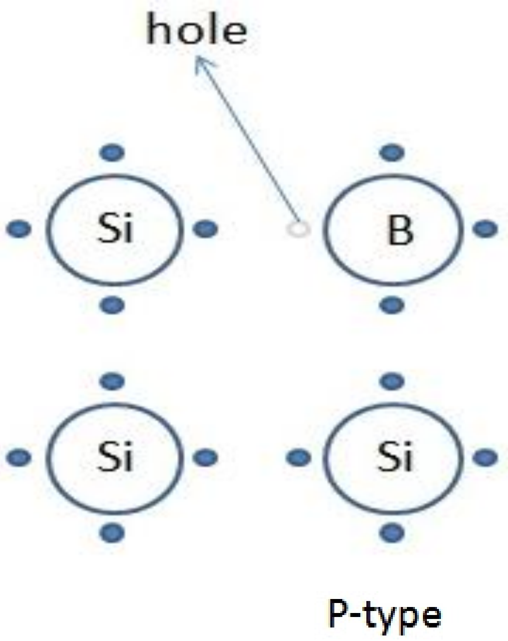


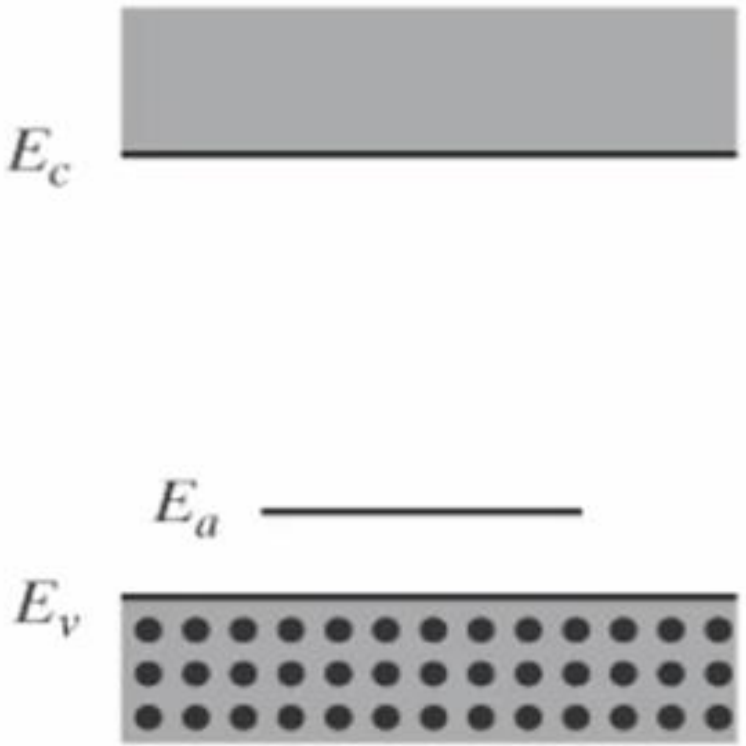


- E_d = donor energy level,
  Donor Elements--
  P-Phosphorous
  As – Aresenic
  Sb - Antimony

Extrinisic Material – P-type Semiconductor

P type Semiconductor



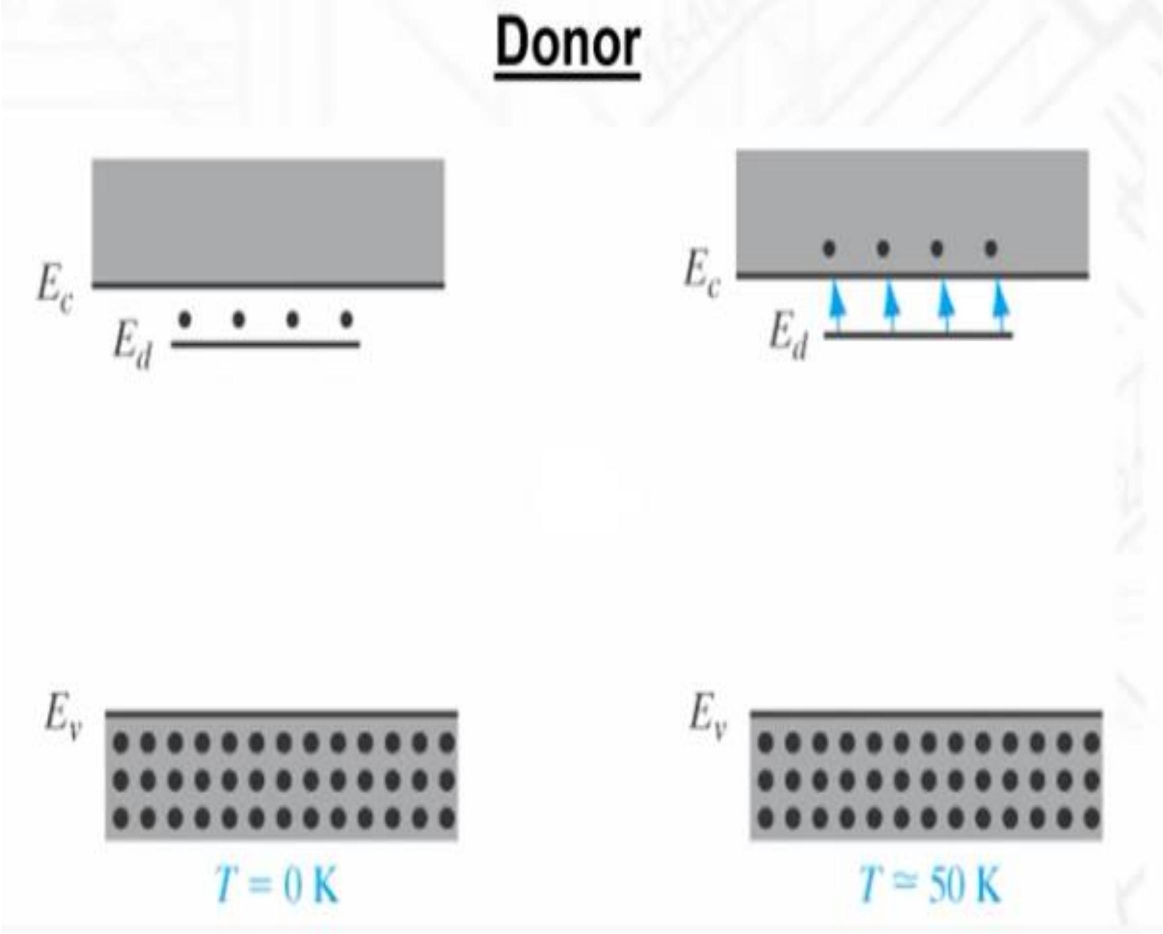


- Acceptor Elements -- B –Boron
  Al – Aluminuim
  In – Indium
- E_a = Acceptor Energy level,

Extrinisic Material

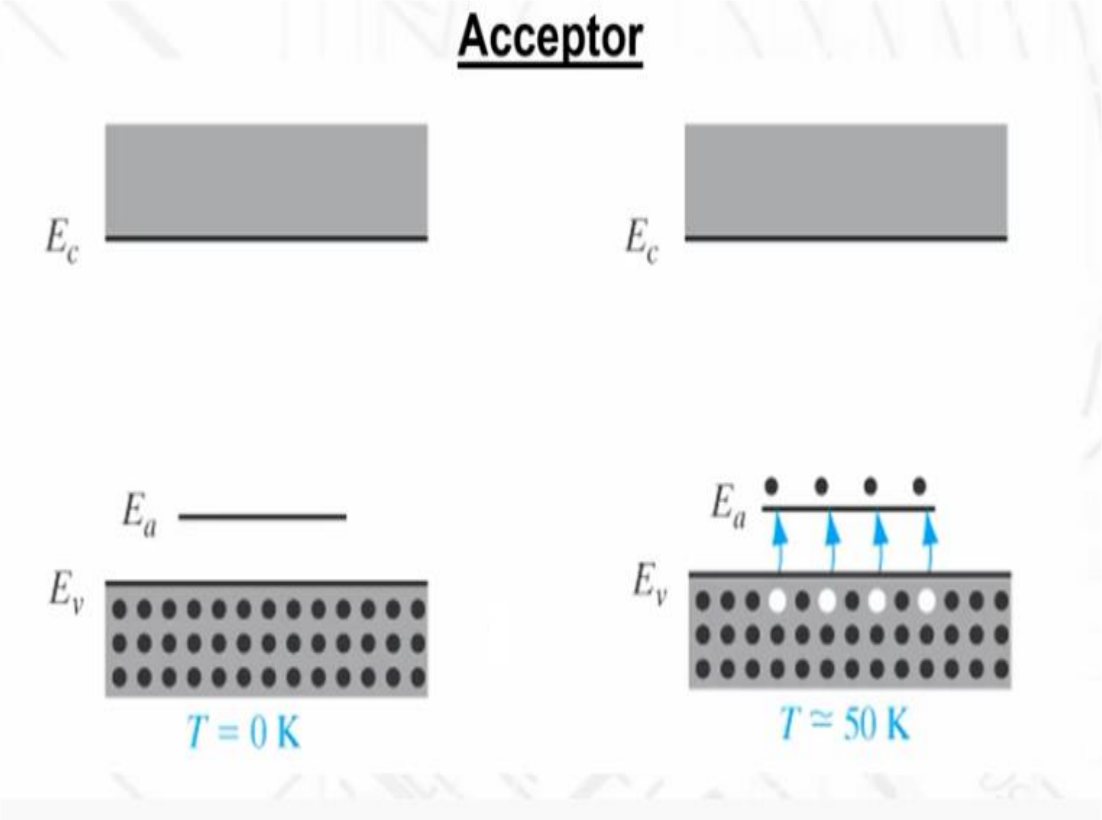
N-type Semiconductor

Number of free electrons (n_e) >> Number of holes (n_h)



Extrinisic Material

P-Type Semiconductor



Number of holes (n_h) >> Number of free electrons (n_e)

Intrinsic Vs Extrinsic Semiconductor

	Intrinsic Semiconductors	**Extrinsic Semiconductors**
1	It is pure semi-conducting material and no impurity atoms are added to it.	It is prepared by doping a small quantity of impurity atoms to the pure semi-conducting material.
2	Examples: crystalline forms of pure silicon and germanium.	Examples: silicon "Si" and germanium "Ge" crystals with impurity atoms of As, Sb, P etc. or In B, Aℓ etc.
3	The number of free electrons in the conduction band and the no. of holes in valence band is exactly equal and very small indeed.	The number of free electrons and holes is never equal. There is excess of electrons in n-type semi-conductors and excess of holes in p-type semi-conductors.
4	Its electrical conductivity is low.	Its electrical conductivity is high.
5	Its electrical conductivity is a function of temperature alone.	Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped the structure.

Extrinisic Material

From Bohr model, the ground state energy of an "extra" electron of the donor is

$$E = \frac{m^* q^4}{2K^2\hbar^2}, \qquad \text{where } K = 4\pi\varepsilon_r\varepsilon_0 \qquad (3\text{-}8)$$

EXAMPLE 3–3 Calculate the approximate donor binding energy for GaAs ($\epsilon_r = 13.2$, $m_n^* = 0.067m_0$).

SOLUTION From Eq. (3–8) and Appendix II we have

$$E = \frac{m_n^* q^4}{8(\epsilon_0\epsilon_r)^2h^2} = \frac{0.067(9.11\times10^{-31})(1.6\times10^{-19})^4}{8(8.85\times10^{-12}\times13.2)^2(6.63\times10^{-34})^2}$$

$$= 8.34\times10^{-22}\,\text{J} = 0.0052\,\text{eV}$$

Thus the energy required to excite the donor electron from the $\mathbf{n} = 1$ state to the free state ($\mathbf{n} = \infty$) is $\simeq 5.2$ meV. This corresponds to the energy difference $E_c - E_d$ in Fig. 3–10a and is in very close agreement with actual measured values.

Thank You

HAVE A NICE DAY