Intrinsic Mobility

μ: mobility $\qquad \mu = |v|/E > 0$

μ is positive for both e^- and holes

μ_e, μ_h

The electric conductivity

$$\sigma = ne\mu_e + pe\mu_h$$

The drift velocity of a charge q

$$v = q\frac{\tau E}{m}$$

τ: colision time
m: effective mass

$$\mu_e = \frac{e\tau_e}{m_e} \qquad \mu_h = \frac{e\tau_h}{m_h}$$

$\Rightarrow$ Mobility follows power law w.r.t. the T
conductivity $\Rightarrow \propto \exp\left[-\frac{E_g}{2k_BT}\right]$

- mobility is limited by scattering with phonons
- Degeneracy of bands on the valence band limits the mobility $\Rightarrow$ interband scattering

In ionic crystals holes are essentially immobile and can only hop from one ion to the next, provided they have enough thermal energy.

This self-trapping is due to the orbital degeneracy $\Rightarrow$ most common in holes

Impurity conductivity

Change the conductivity

In a Silicon (Si) lattice; if we replace some Si for Boron (B) atoms

$1:10^5$ → cond. inceases by 10^3

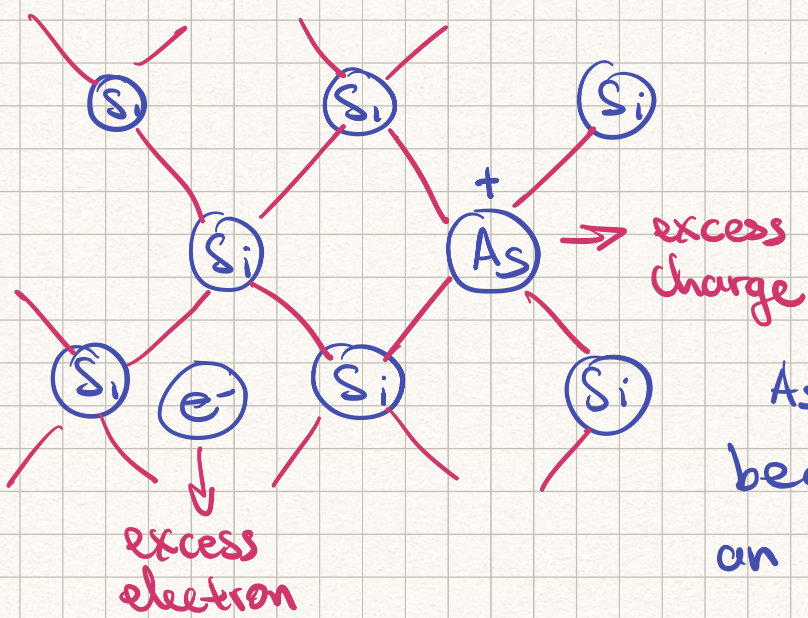
→ Deliberately adding of impurities → doping

Donor states

→ Si or Ge

- 4 valence electrons → outer most shell
- Replace an atom Si or Ge with an atom of valence 5
  - ↳ P, As, Sb

we will have a charge excess → valence electron that is not paired



As gives 1 e^- to the crystal ⇒ DONOR

As is positively charged because it has lost an electron

The crystal remains neutral because the e^- remains in the crystal.

The extra e^- moves in a Coulomb potential

$$\frac{1}{4\pi\epsilon_0}\frac{e}{r}\frac{1}{\epsilon}$$

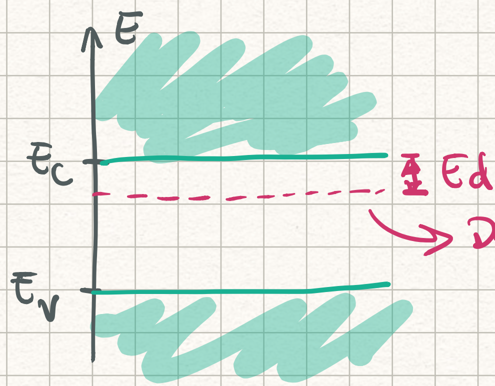
ϵ: dielectric constant of the crystal

$\frac{1}{\epsilon}$: takes into account the reduction of the C. potential between charges.

Hydrogen atom:

- Ionization energy is $-\frac{e^4 m}{2(4\pi\epsilon_0\hbar)^2}$

- $E_d = \frac{e^4 m_e}{2(4\pi\epsilon_0\epsilon\hbar)^2}$

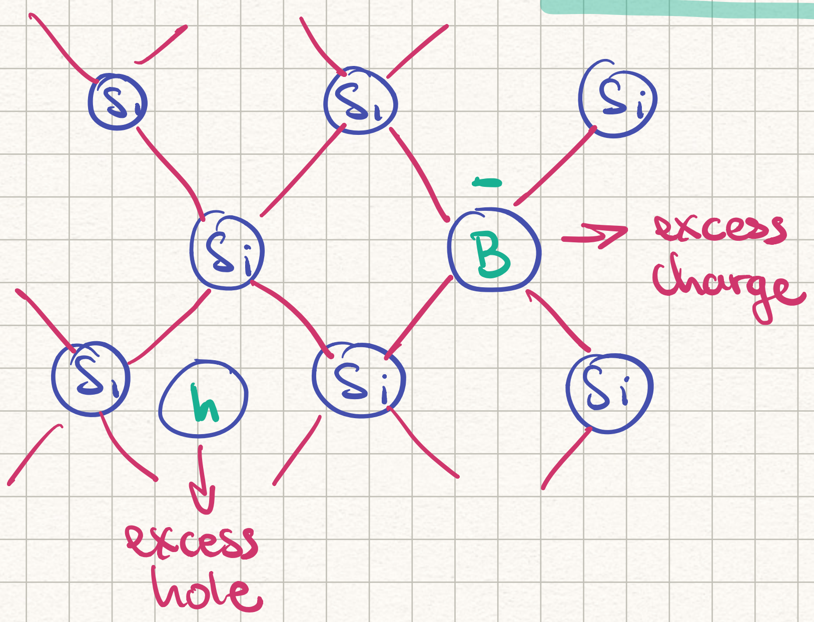


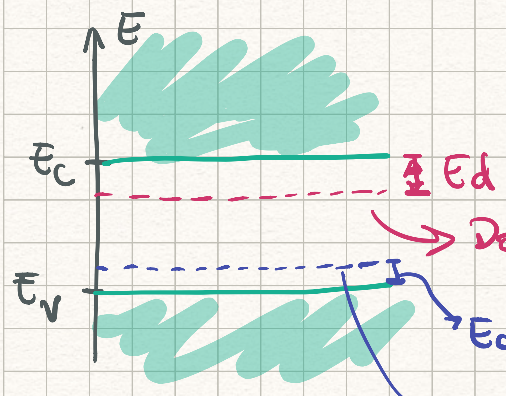
Acceptor state

Replace an atom with another one with less valence electron → available to make bond

Si or Ge → B, Al, Ga, In

will need to take an e^- from the valence band to complete the bond





The Bohr model also applies to the holes, but the degeneracy complicates the problem

If

donor ≫ acceptors : n-type doping semiconductor

donor ≪ acceptors : p-type doping semiconductor

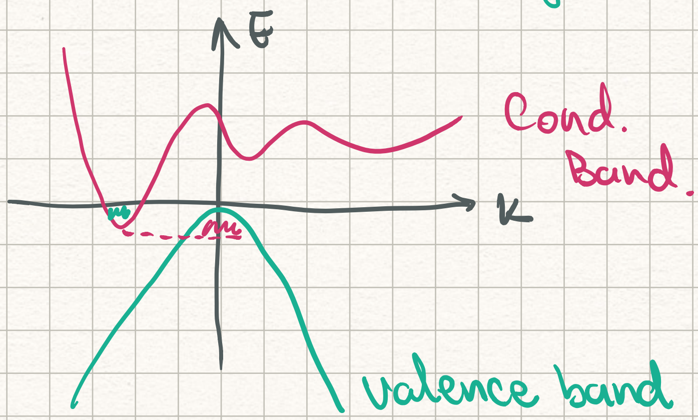
The Hall effect can be used to determine the type of semiconductor and the density of carriers

Semimetal

→ Arsenic (As); Antimony (Sb); Bismuth (Bi) → group V

→ Graphite

Conduction band edge is slightly below the valence band edge



The overlap in energy leads to a small amount of holes in the valence band and of e^- in the conduction band.

→ They could be insulators

→ presure can change the overlap → concentration of carriers