Session 8: Solid State Devices

Recombination-Generation

Outline

1. I
2.
3.
4.
5.

- A
  - B
  - C
  - D
  - E
- F
  - G
- H
- I
- J

Outline

- Ref: ?

Non-Equilibrium Process

1. I
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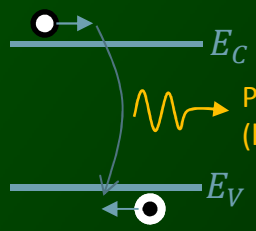
Whenever the thermal-equilibrium condition of a semiconductor system is disturbed $pn \neq n_i^2$ processes exist to restore the system to equilibrium

Generation and recombination processes act to change the carrier concentrations, and thereby indirectly affect current flow

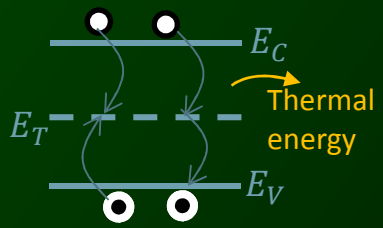
Recombination mechanisms: $pn > n_i^2$

Generation mechanisms: $pn < n_i^2$

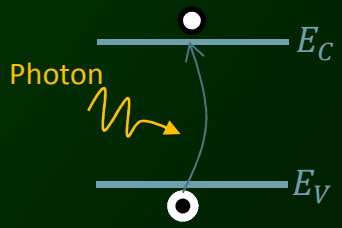
Direct



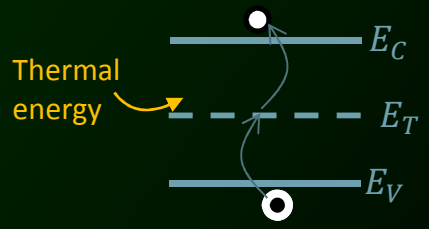
R-G Center



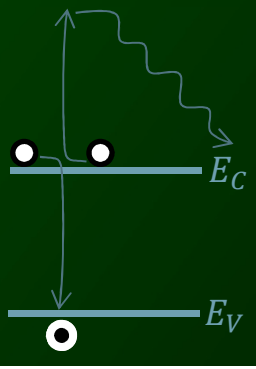
Band-to-band



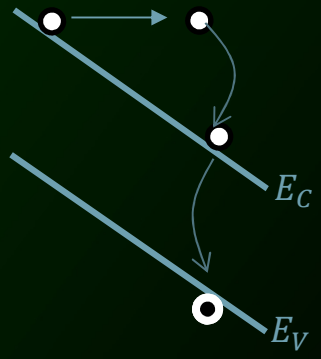
R-G Center



Auger

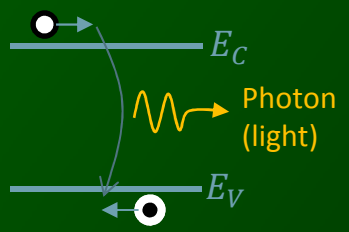


Impact Ionization

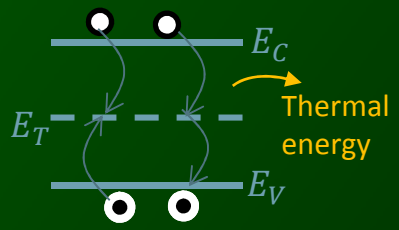


Recombination in Si is primarily via R-G centers

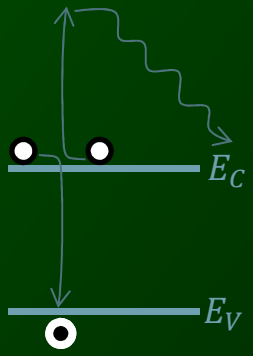
Recombination Mechanisms



Direct or Band to Band:
Basis for light emission devices
Photon (single particle of light) or multiple phonons (single quantum of lattice vibration – equivalent to saying thermal energy)

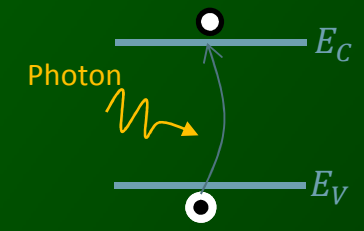


R-G Center:
Also known as Schockley-Read-Hall (SRH) recombination
Photon (single particle of light) or multiple phonons (single quantum of lattice vibration – equivalent to saying thermal energy)
Note: Trap level, Two steps: 1st Carrier is trapped at a defect/impurity, 2nd Carrier (opposite type) is attracted to the RG center and annihilates the 1st carrier

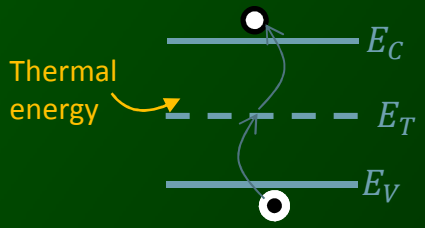


Auger:
Requires 3 particles, Two steps:
1st carrier and 2nd carrier of the same type collide instantly annihilating the electron hole pair (1st and 3rd carrier).
The energy lost in he annihilation process is given o the 2nd carrier.
2nd carrier gives off a series of phonons until it's energy returns to equilibrium energy (E~Ec)

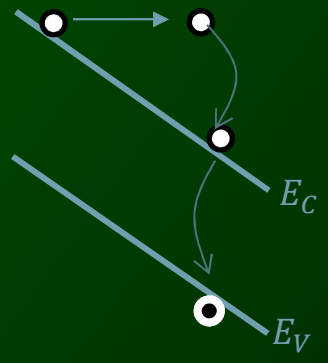
Generation Mechanisms



Direct or Band to Band:
Does not have to be a direct bandgap material
Mechanism that results in n_i
Basis for light absorption devices such as semiconductor photodetectors, solar cells, etc.



R-G Center:
Two steps:
A bonding electron is trapped at an unintentional defect/impurity generating a hole in the valence band
This trapped electron is then promoted to the conduction band resulting ina new electron-hole pair
Almost always detrimental to electronic devices



Impact Ionization:
Requires 3 particles and typically high electric fields
1st carrier is accelerated by high electric fields
Collides with a lattice atom
Knocks out a bonding electron
Creates an electron hole pair
What is it called when this process repeats and what device is it useful for?

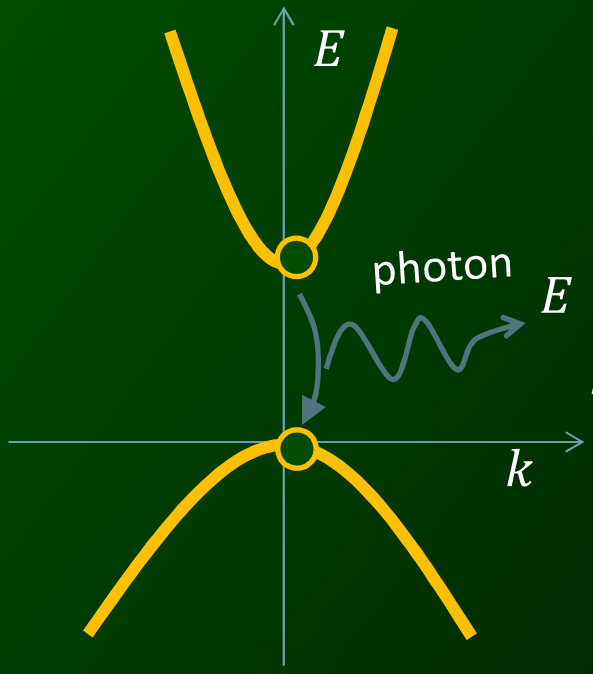
Photon/Phonon Energy and Wavevector

1. I
2.
3.
4.
5.

Direct Materials

GaAs

Conservations of:
1. Energy
2. Momentum

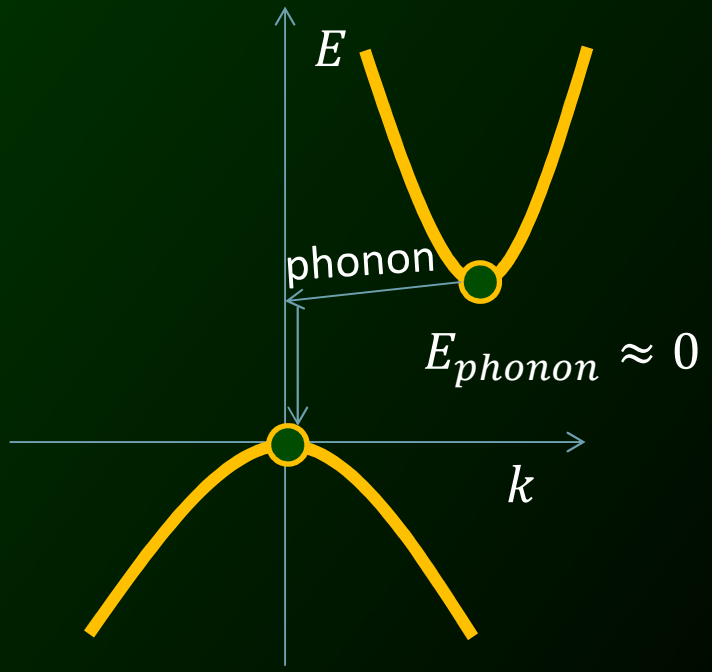


$$E = h\upsilon = E_C - E_V$$

$$\hbar k_{photon} \approx 0$$

Indirect Materials

Si , Ge



$$E_{phonon} \approx 0$$

Applications: LEDs, Lasers

Net Rate of Recombination-Generation

SRH recom-gen:

$$R = \frac{np - n_i^2}{\tau_p(n + n_1) + \tau_n(p + p_1)}$$

$$\tau_n = \frac{1}{c_p N_T}$$

$$\tau_p = \frac{1}{c_n N_T}$$

$$n_1 p_1 = n_i^2$$

$$n_1 = n_i g_D e^{\beta(E_T - E_i)}$$

$$p_1 = n_i g_D^{-1} e^{\beta(E_i - E_T)}$$

$$E_G(Al_xGa_{1-x}As) = 1.24(GaAs) + 1.247x$$

$$\Delta E_c = \Delta E_G$$