Section 16
Recombination & Generation

16.3 Application of SRH formula for special cases

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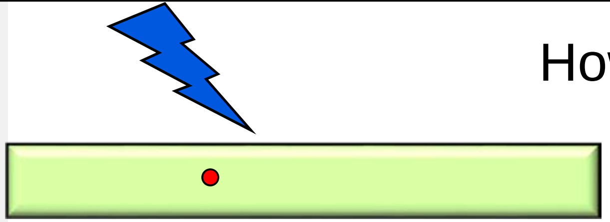
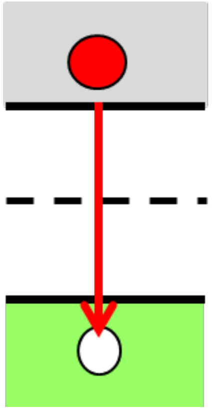


How does the system go BACK to equilibrium?

- 16.1 Capture coefficient & Capture Cross Section
- 16.2 Derivation of SRH formula (Shockley, Reed, Hall)
  - 16.2.1 Trap Assisted Recombination Rates
  - 16.2.2 Capture and emission relationship (n_1 and p_1)
  - 16.2.3 Steady State Trap Population
  - 16.2.4 Recombination-Generation Rate
- 16.3 Application of SRH formula for special cases
  - Low level, high-level injection, depletion region



$$\tau_n = \frac{1}{c_n N_T} \qquad \tau_p = \frac{1}{c_p N_T}$$

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

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

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

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Case 1: Low-level Injection in p-type

p-type: $p_0 \gg n_0$

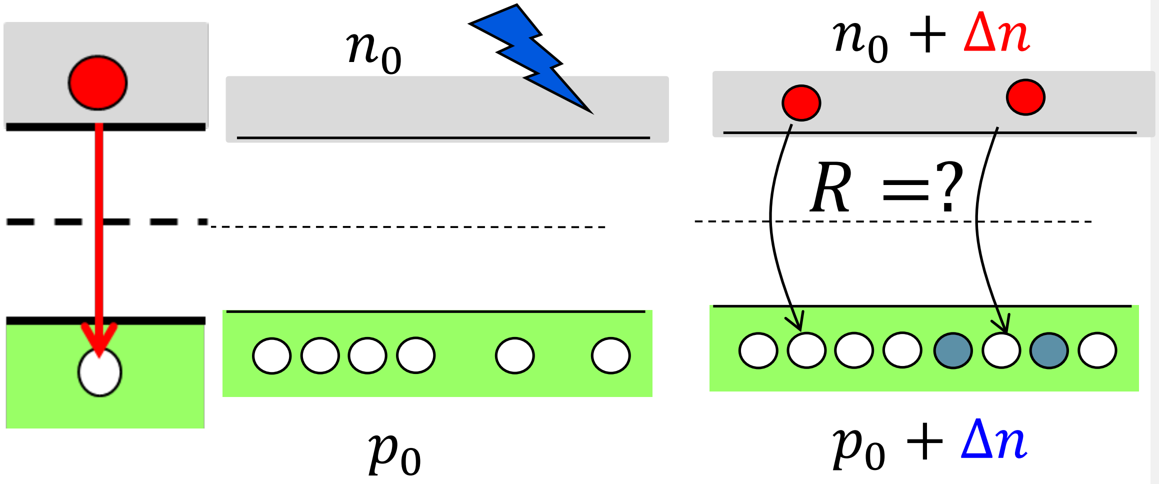
Low-level injection $n_0 \ll \Delta n \ll p_0$

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

$$= \frac{(n_0 + \Delta n)(p_0 + \Delta n) - n_i^2}{\tau_p(n_0 + \Delta n + n_1) + \tau_n(p_0 + \Delta p + p_1)}$$

$$= \frac{\Delta n(n_0 + p_0) + \Delta n^2}{\tau_p(n_0 + \Delta n + n_1) + \tau_n(p_0 + \Delta p + p_1)}$$

$$= \frac{\Delta n(p_0)}{\tau_n(p_0)} = \frac{\Delta n}{\tau_n}$$



$\Delta n^2 \approx 0$

$p_0 \gg \Delta n \gg n_0$

$$R = \frac{\Delta n}{\tau_n}$$

Lots of holes, few electrons => independent of holes

Decay with minority carrier lifetime

Case 2: High-level Injection in p-type

p-type: $p_0 \gg n_0$

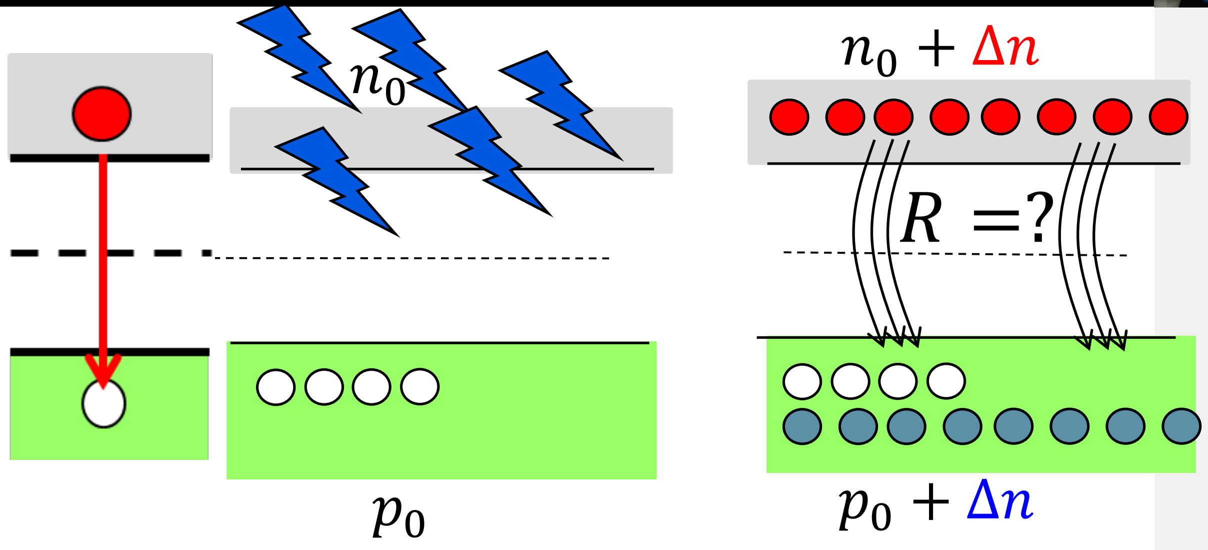
High-level injection $\Delta n \gg p_0 \gg n_0$

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

$$= \frac{(n_0 + \Delta n)(p_0 + \Delta p) - n_i^2}{\tau_p(n_0 + \Delta n + n_1) + \tau_n(p_0 + \Delta p + p_1)}$$

$$= \frac{\Delta n(n_0 + p_0) + \Delta n^2}{\tau_p(n_0 + \Delta n + n_1) + \tau_n(p_0 + \Delta n + p_1)}$$

$$= \frac{\Delta n^2}{(\tau_n + \tau_p)\Delta n} = \frac{\Delta n}{(\tau_n + \tau_p)}$$

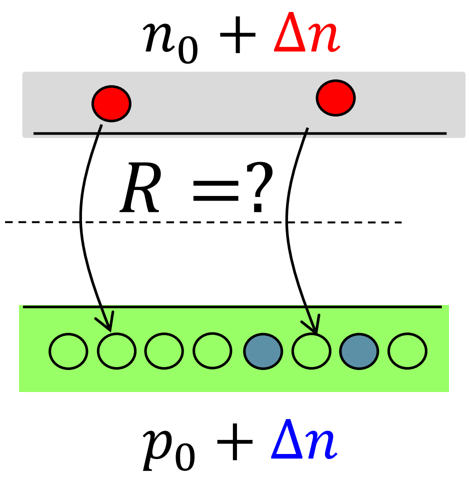


$\Delta n \gg p_0 \gg n_0$

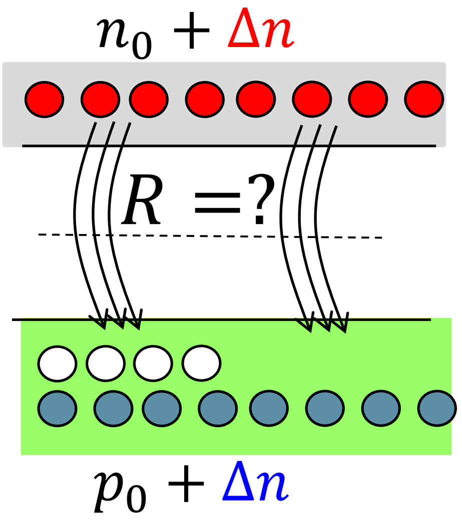
$$R = \frac{\Delta n}{(\tau_n + \tau_p)}$$

Lots of holes, lots of electrons => dependent on both relaxations

Case 1+2: Injection in p-type



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



Low-level injection $n_0 \ll \Delta n \ll p_0$

High-level injection $\Delta n \gg p_0 \gg n_0$

$$R = \frac{\Delta n}{\tau_n}$$

$$R = \frac{\Delta n}{(\tau_n + \tau_p)}$$

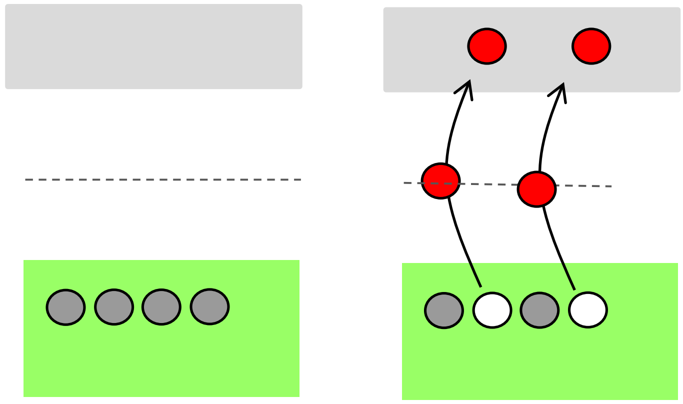
Lots of holes, few electrons => independent of holes
Decay with minority carrier lifetime

Lots of holes, lots of electrons => dependent on both relaxations

Case 3: Generation in Depletion Region

Depletion region in a pn-diode – no free carriers: $p = n = 0$

Lots of available traps: $n_1 \gg n \quad p_1 \gg p$



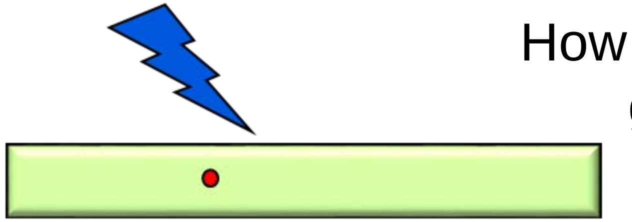
$$R = \frac{p\cancel{n} - n_i^2}{\tau_p(\cancel{n} + n_1) + \tau_n(\cancel{p} + p_1)}$$

$$= \frac{-n_i^2}{\tau_p\left(n_1\right) + \tau_n\left(p_1\right)}$$

NEGATIVE Recombination => Generation

n=p=0 << n_i => generation to create n,p

Equilibrium restoration!



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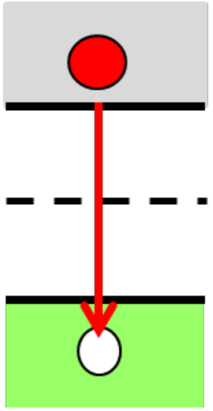

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- 16.6
- 16.7

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$$R = \frac{\Delta n}{\tau_n}$$

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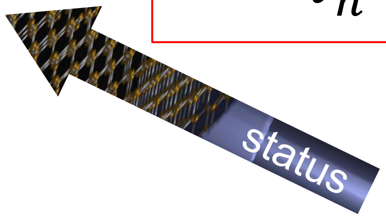

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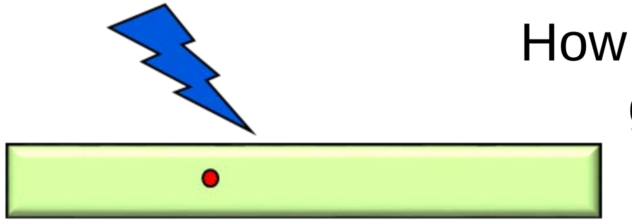

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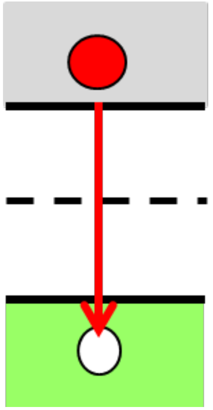

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$$R = \frac{\Delta n}{\tau_n} \qquad R = \frac{\Delta n}{(\tau_n + \tau_p)}$$