DIODES

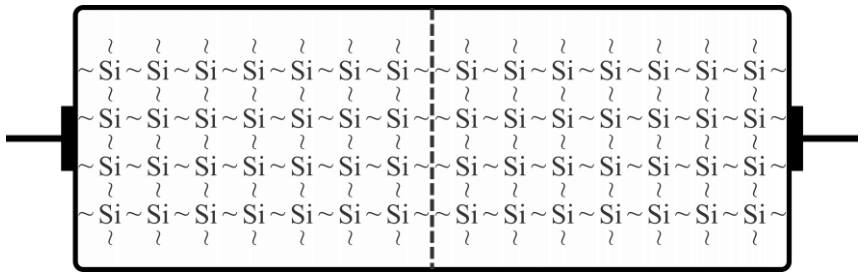
- What is a p-n junction?
- How p-n junction/diode operates?
- How do we address and use diodes in circuits?
- Types of diodes.

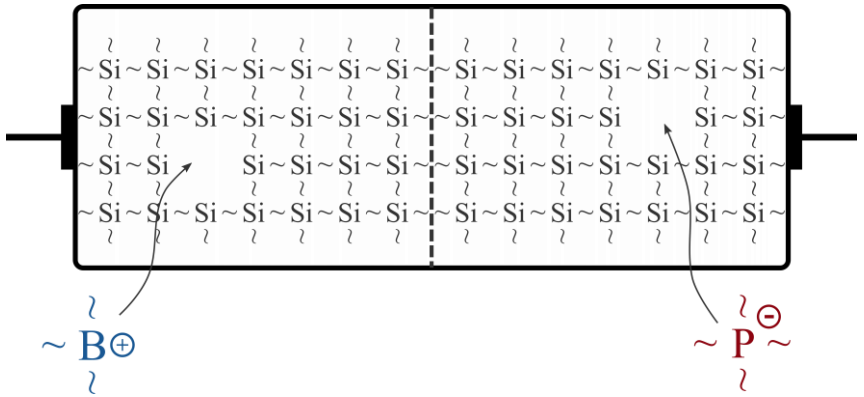
SEMICONDUCTOR DEVICES

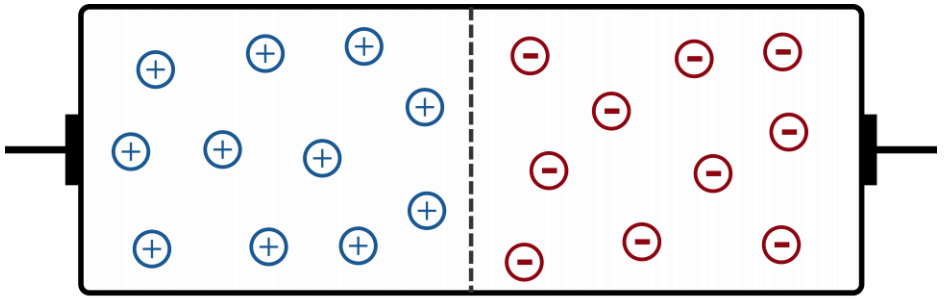
Diodes – p-n junction

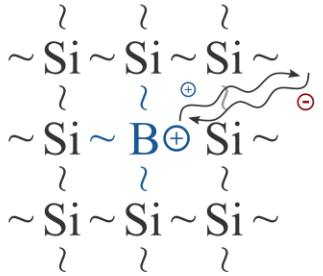
How is the p-n junction created?

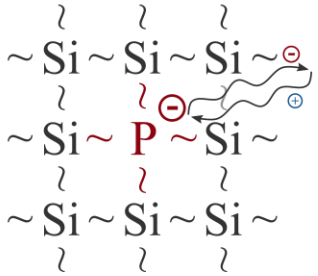
Silicon wafer (substrate, slice)







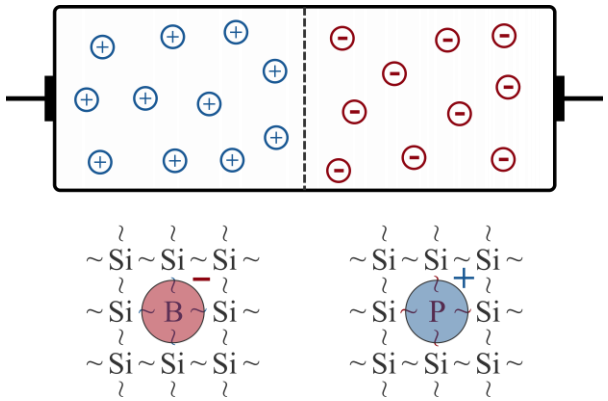


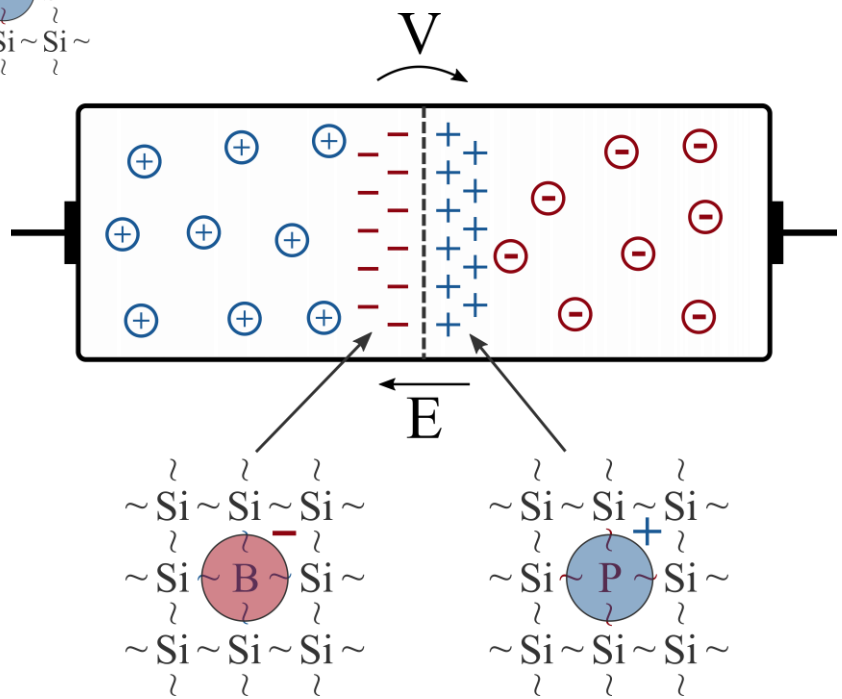


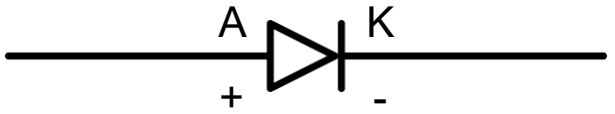
SEMICONDUCTOR DEVICES

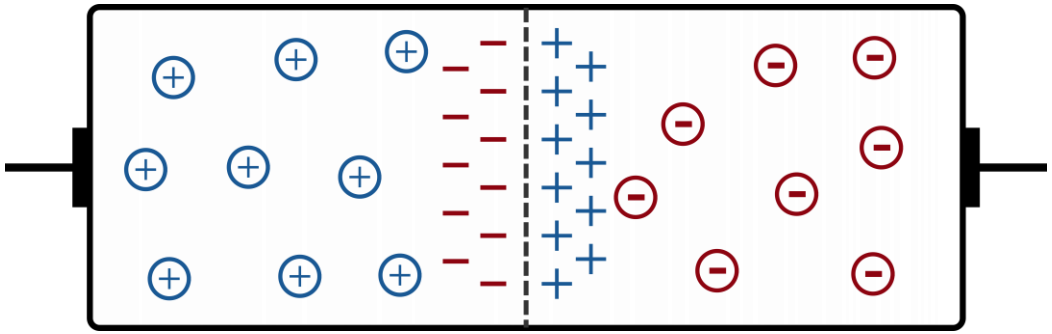
Diodes – p-n junction

How is the p-n junction created?









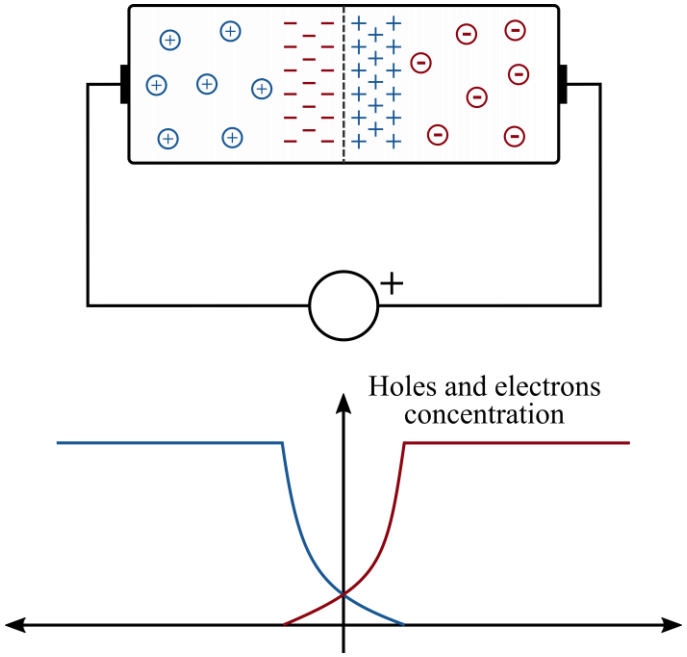
P-type junction
p^+ majority charge
e^- minority charge

N-type junction
p^+ minority charge
e^- majority charge

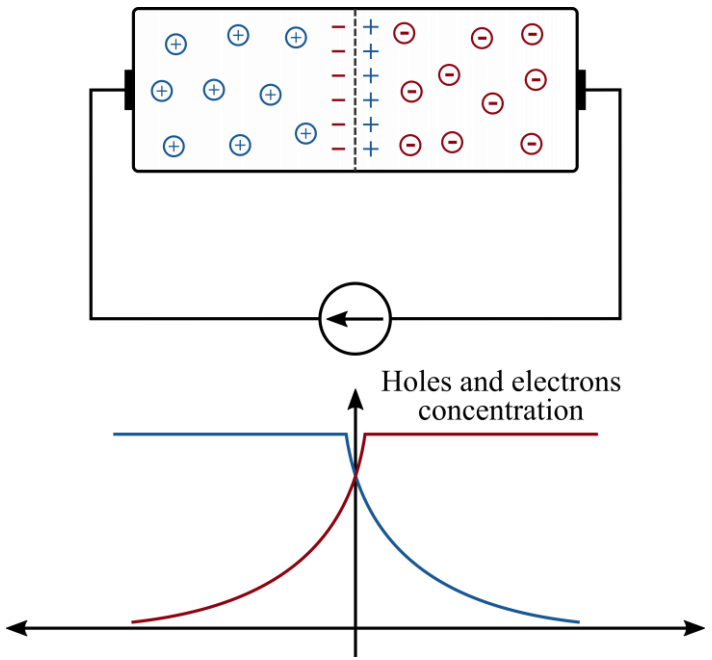
SEMICONDUCTOR DEVICES

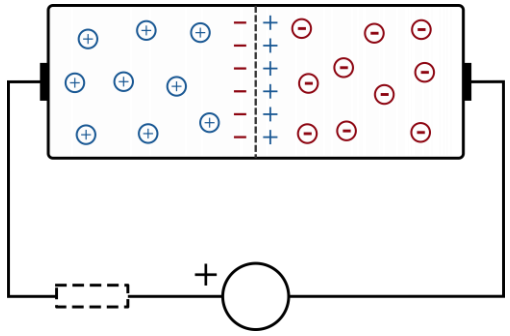
Diodes – p-n junction polarization

p-n junction reverse biased



p-n junction forward biased





$$p_c = p_{c0}\left(e^{kTv_d/q_e} - 1\right)$$

$$\frac{dq(t)}{dt} = i(t) - \frac{q(t)}{\tau_L}$$

$$i(t) = \frac{q(t)}{\tau_L} = \frac{Q}{\tau_L}\left(e^{kTv_d(t)/q_e} - 1\right)$$

$$= I_0\left(e^{kTv_d(t)/q_e} - 1\right)$$

k - Boltzmann's constant

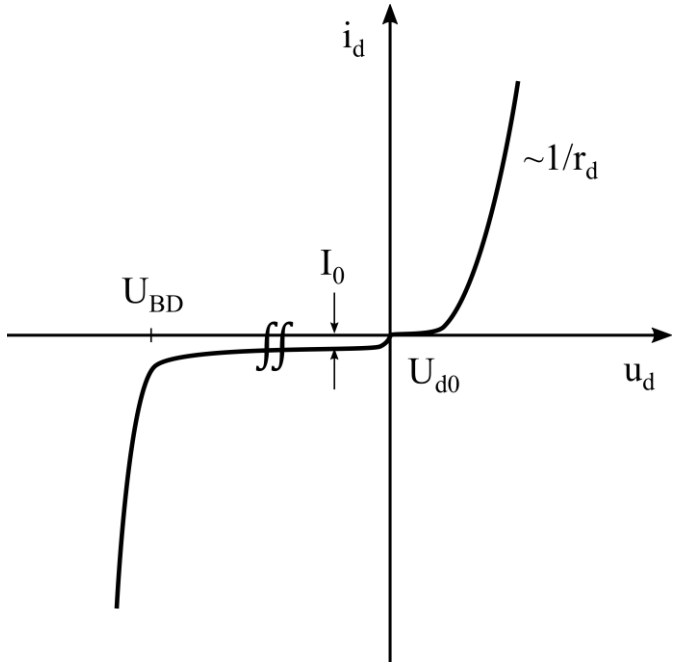
T - temperature

q_e - the charge of the electron

τ_L - minority carriers (recombination) lifetime

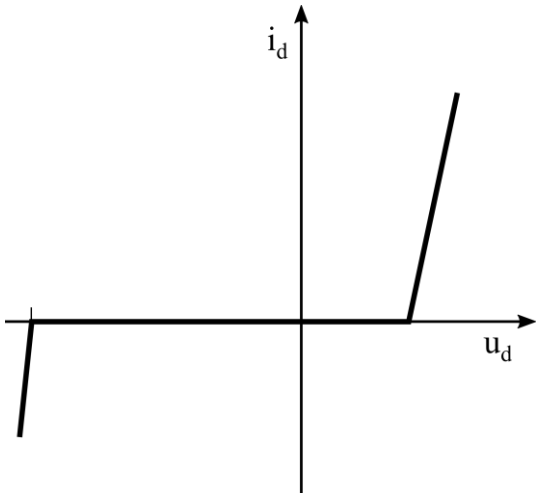
SEMICONDUCTOR DEVICES

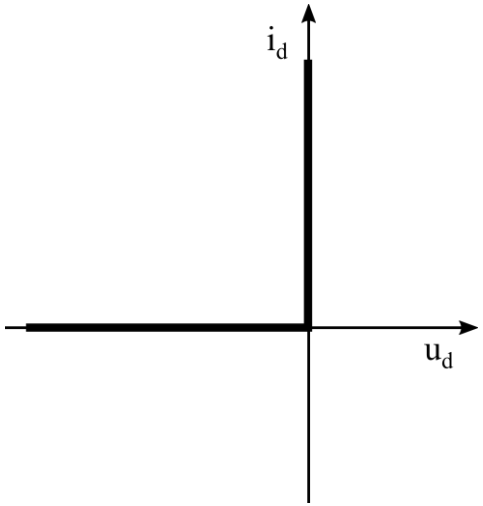
Diodes – I-V curve (static)

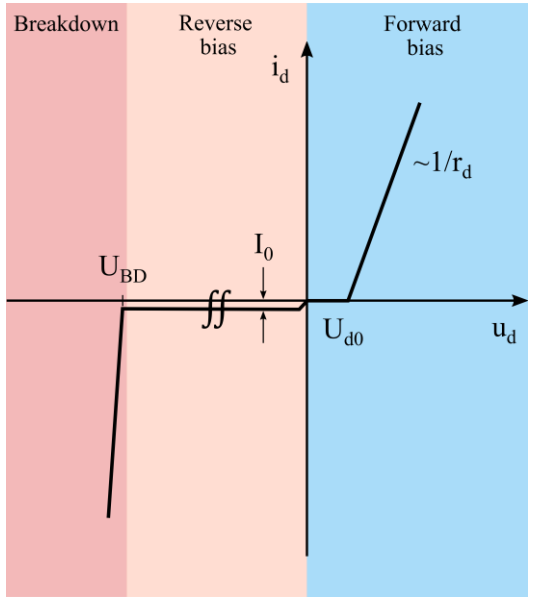


u_d – diode voltage
i_d – diode current
U_{d0} – diode turn-on voltage
r_d – diode internal resistance
I_0 – diode leakage current
U_{BD} – diode breakdown voltage

I-V diode curve approximations:

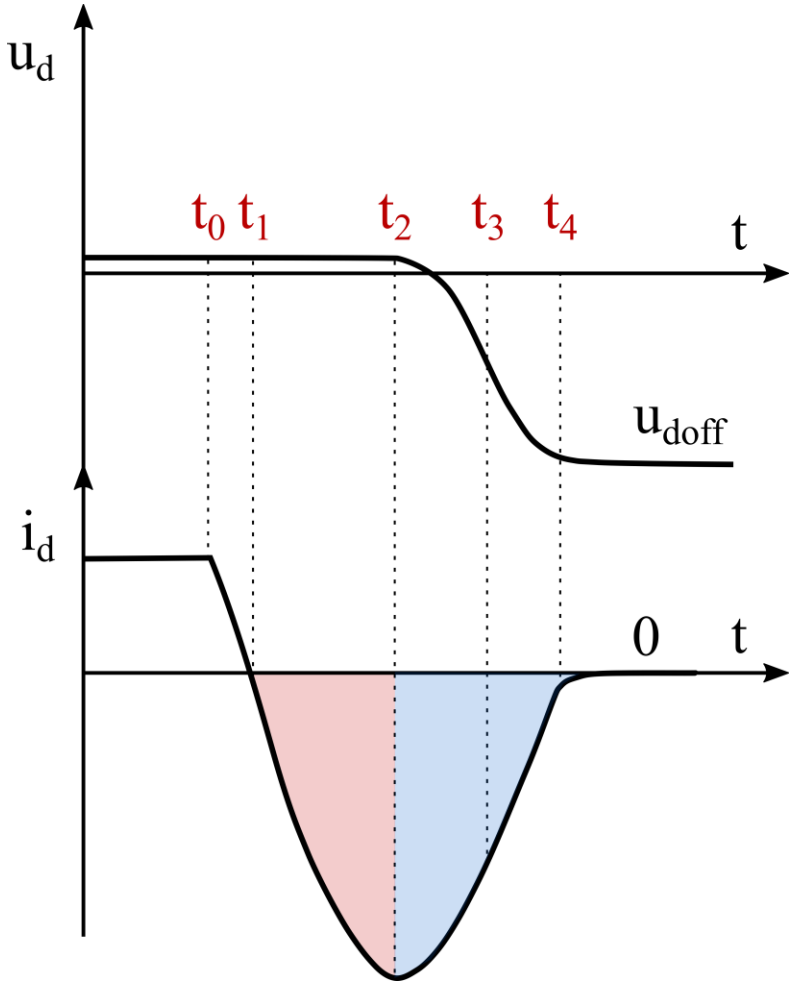


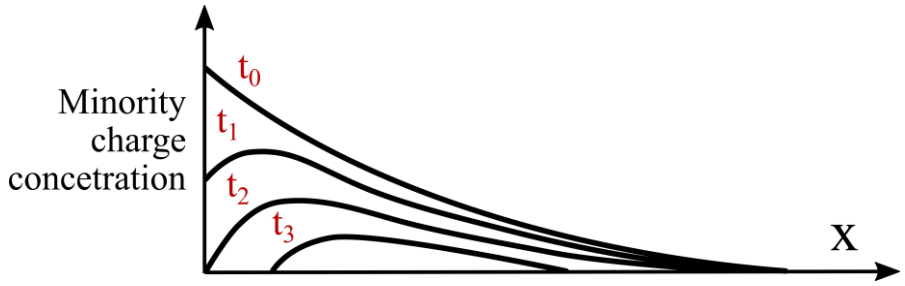




SEMICONDUCTOR DEVICES

Diodes – Reverse recovery process





$$\frac{dq(t)}{dt} = i(t) - \frac{q(t)}{\tau_L}$$

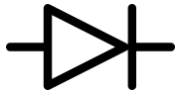
$$i(t) = I_0\left(e^{kTv_d(t)/q_e} - 1\right)$$

$$p_c = p_{c0}\left(e^{kTv_d/q_e} - 1\right)$$

SEMICONDUCTOR DEVICES

Diodes – types

Power diodes:



- Rectifying diodes

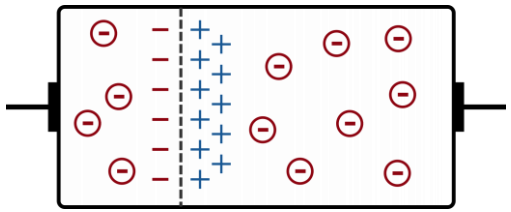
$t_{rr} = n \cdot \mu s$

- Fast

$t_{rr} < \mu s$, $t_{rr} > 100$ ns,

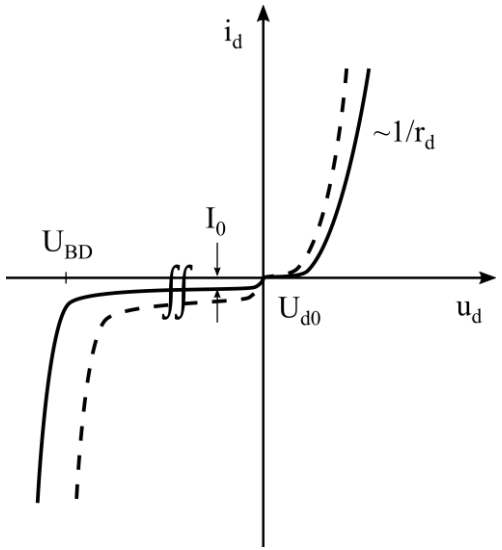
- Ultrafast

$t_{rr} < 100$ ns,

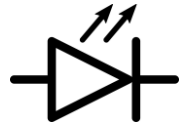


- Schottky

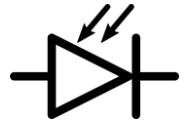
Unipolar (majority carrier) device
Small(er) U_{do} (0.3 - 0.6 V),
More efficient,
Negligible reverse recovery process,
Smaller U_{BD},
Higher I_0.



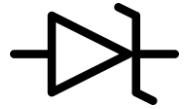
Light-emitting diodes



Photodiodes



Zener diodes



SEMICONDUCTOR DEVICES

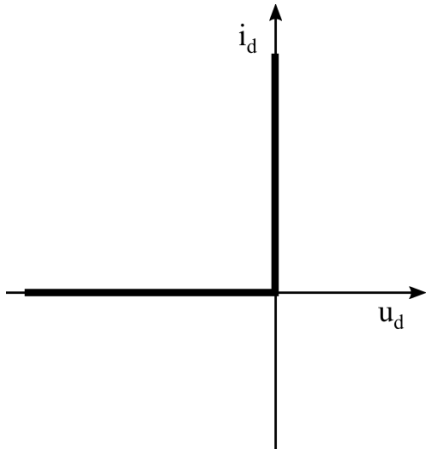
Diodes - packages

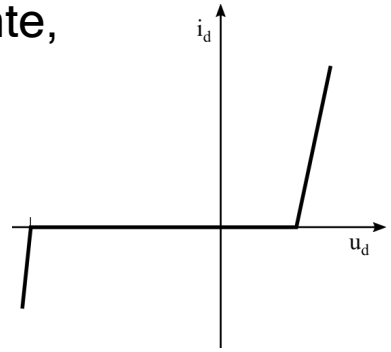
SEMICONDUCTOR DEVICES

Diodes – important notes

Diodes are:

- Uncontrollable semiconductor devices,
- Turned ON and OFF by the circuit in which they are placed,
- Turned ON when the circuit imposes the “higher-than-zero” u_d *voltage*,
- Turned OFF when the circuit forces the diode *current* to fall to “zero”,
- The first approximation is used for diode losses estimation in the ON state,





Diodes have complicated turn OFF process (reverse recovery process).