IELe

Semiconductors, diodes

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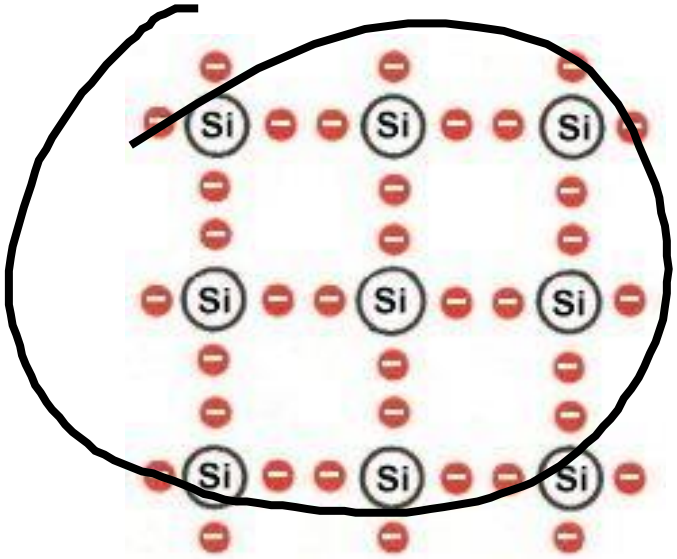
Semiconductors

- Resistance decreases as temperature increases, which is behavior opposite to that of a metal
- Conductive properties might be changed by doping (adding impurities into the crystal structure)

- Intrinsic and doped (extrinsic)
- **Intrinsic**
  - Silicon (Si)
  - Valence layer – 4 electrons, electrically neutral
  - By doping, neutrality is lost → 2 types of semiconductors



- Intrinsic and doped (extrinsic)
- **Intrinsic**
  - Silicon (Si)
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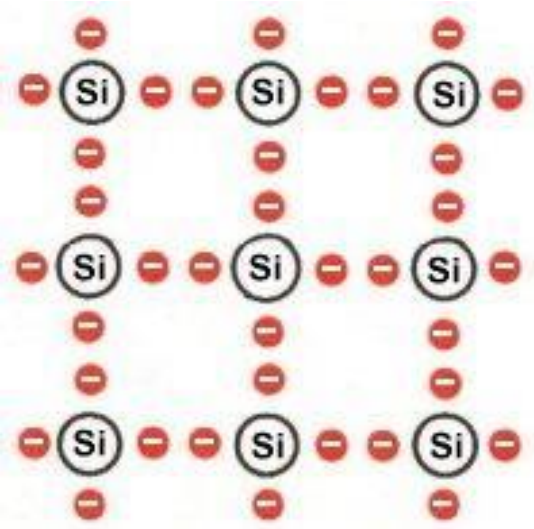
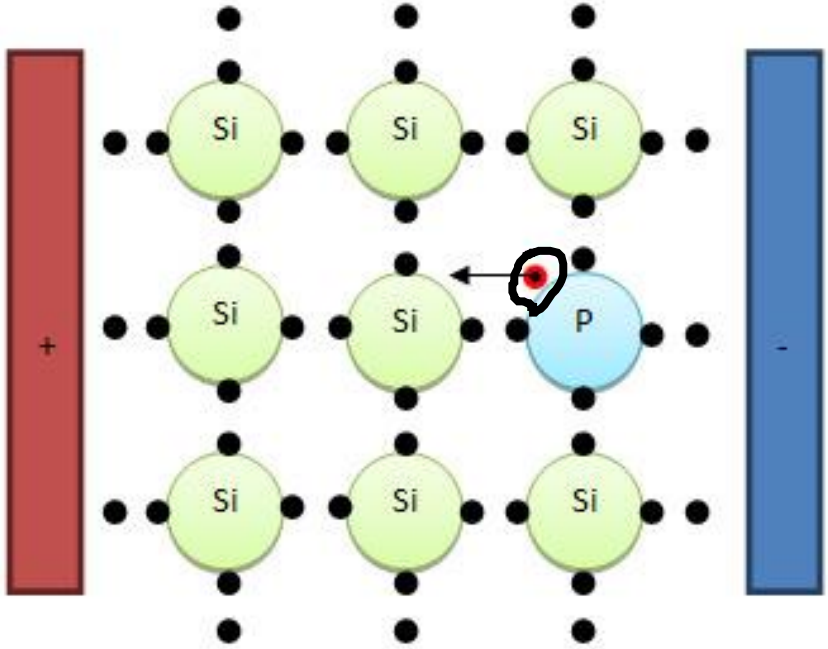
- **Doped (extrinsic)**
  - N type semiconductors
  - P type semiconductors



- **Type N**: electron conductivity, dopand has +1 electron
  - **Example**: phosphorus (P) – 5 electrons in the valence layer



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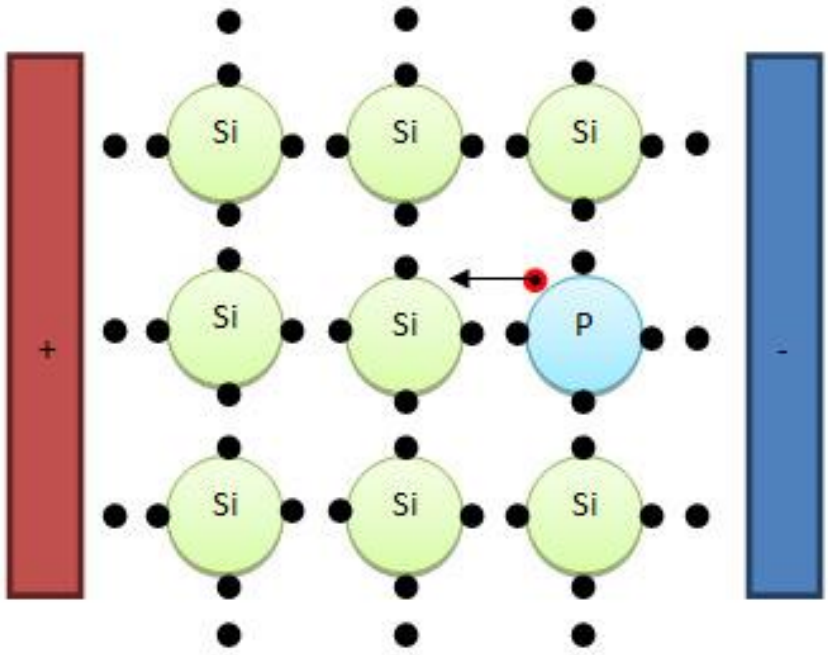
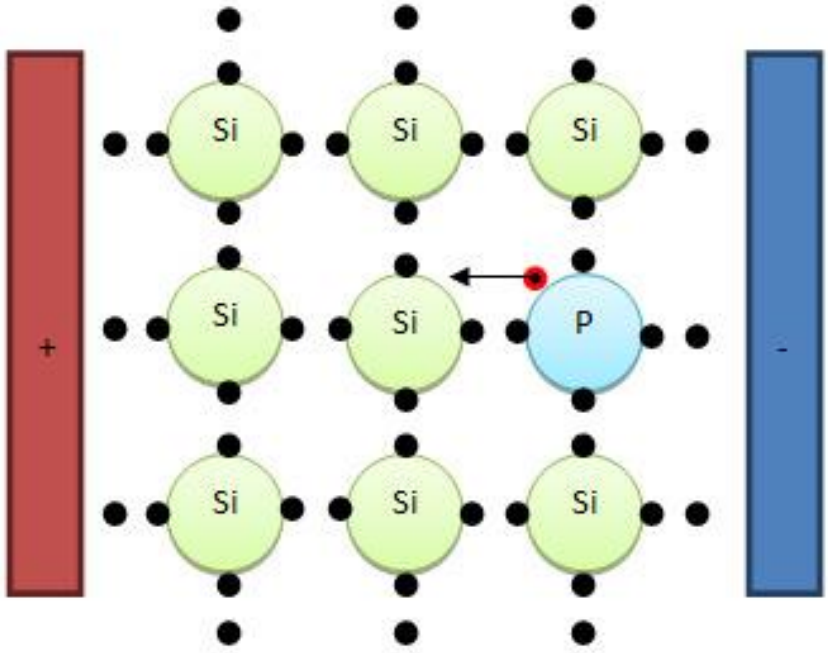
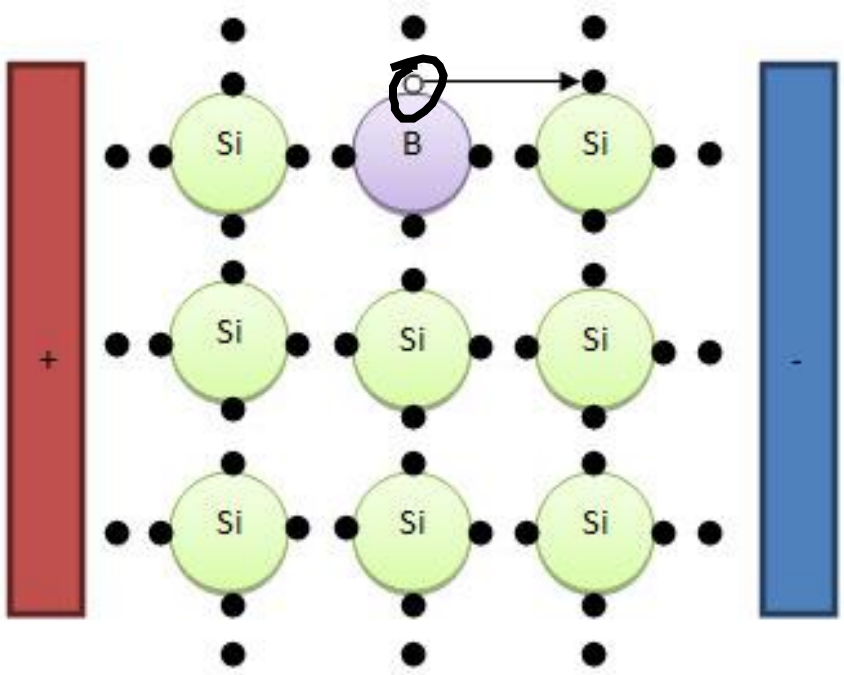
  - Phosphorus adds 1 free electron into the crystal structure



- **Type N**: electron conductivity, dopand has +1 electron
  - **Example**: phosphorus (P) – 5 electrons in the valence layer
  - Phosphorus adds 1 free electron into the crystal structure
  - Negative charge → N type semiconductor



- **Type P:** electron hole conductivity, dopand has -1 electron
  - **Example**: boron (B) – 3 electrons in valence layer



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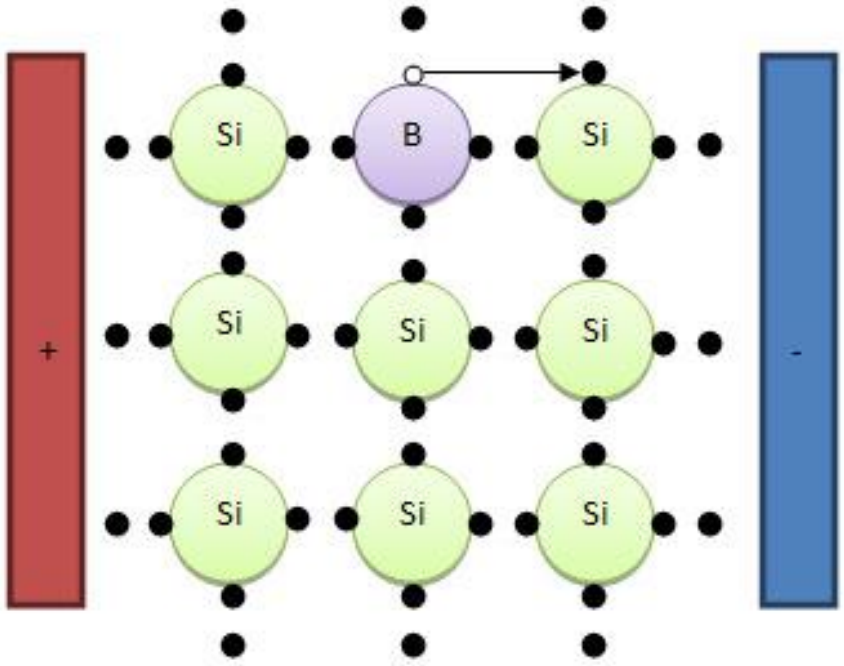
  - The missing electron creates a virtual positively charged particle (“hole”)



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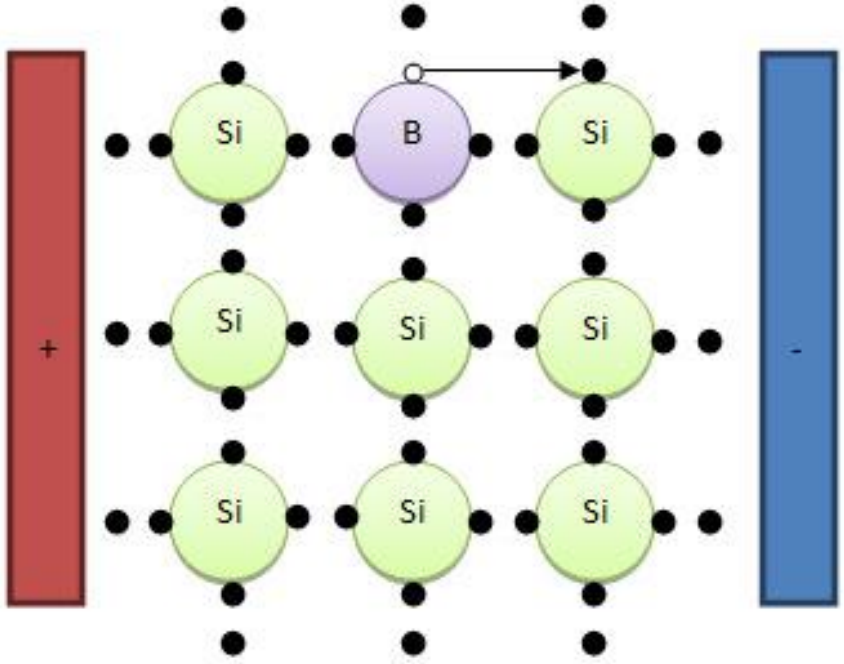
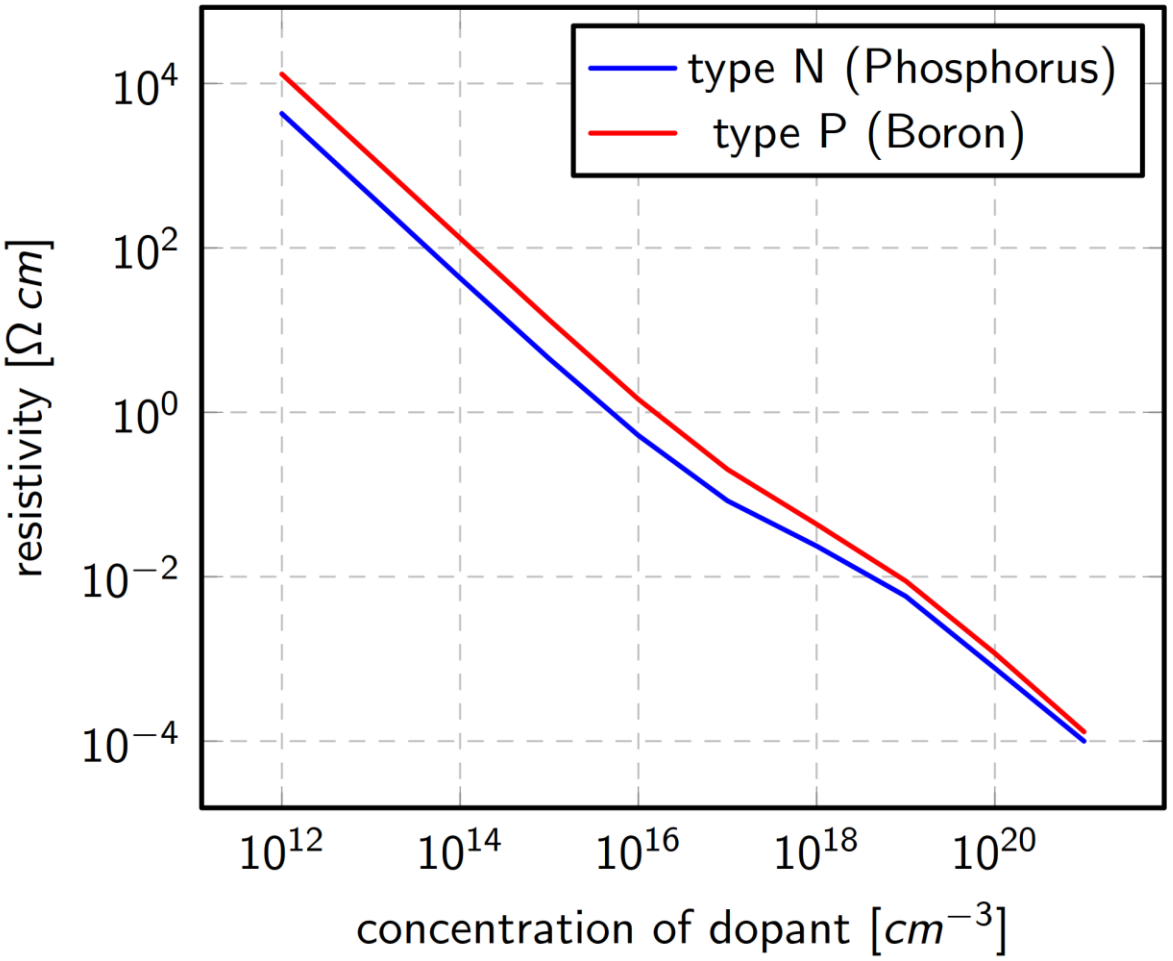
  - **Example**: boron (B) – 3 electrons in valence layer
  - The missing electron creates a virtual positively charged particle (“hole”)
  - Positive charge → P type semiconductor



- Resistivity of Sillicon



- Dopants with **5 valence electrons (Phosphorus)**
  - **Donors: add free electrons into the crystal**

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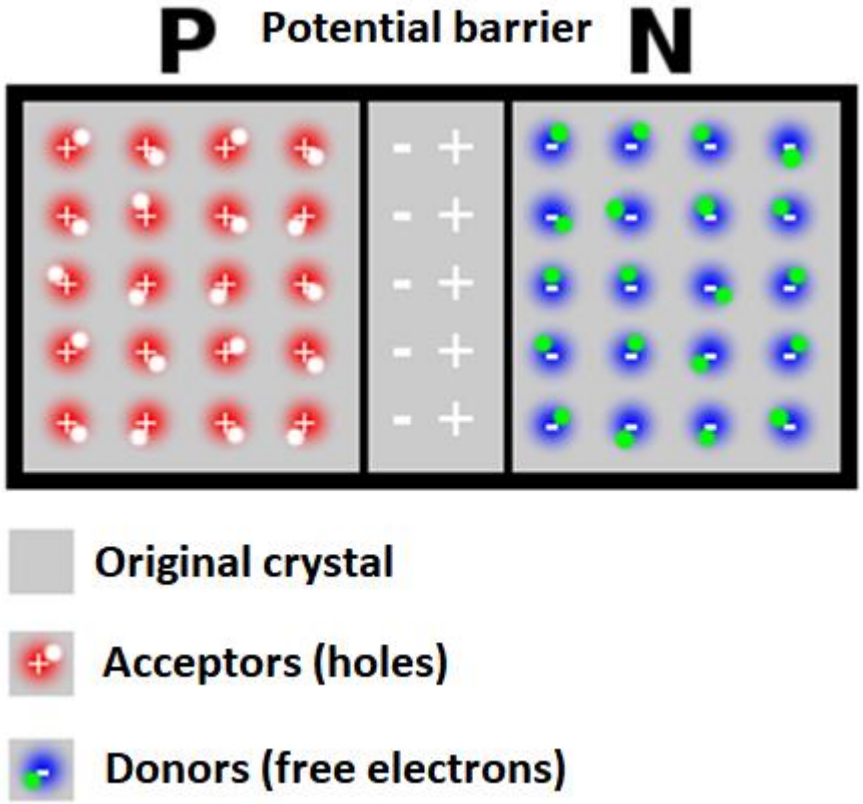
- **Solution**: merging of N type and P type semiconductor → **PN junction**

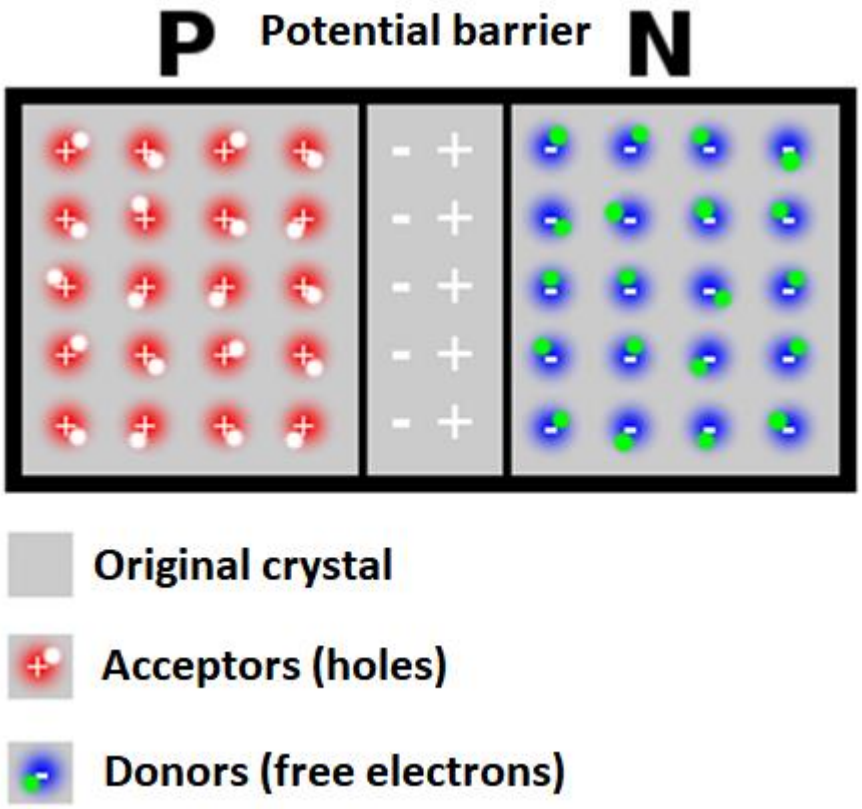
- Junction between P and N semiconductors → **potential barrier**



PN junction

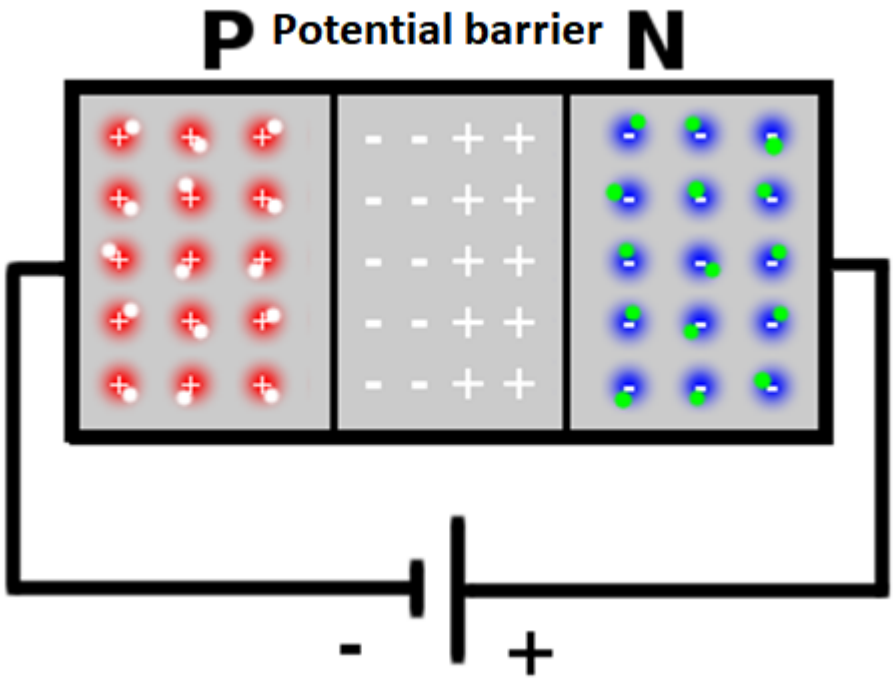
- Junction between P and N semiconductors → **potential barrier**

- Free electrons (-) are attracted to the holes (+)
  - **Recombination** – destruction of the pair (electron srandomly meets with a hole, looses part of his energy and fills the hole)



Closed PN junction

- Connected voltage source
- **Positive polarity (+)** of the voltage source **attracts electrons** (-)



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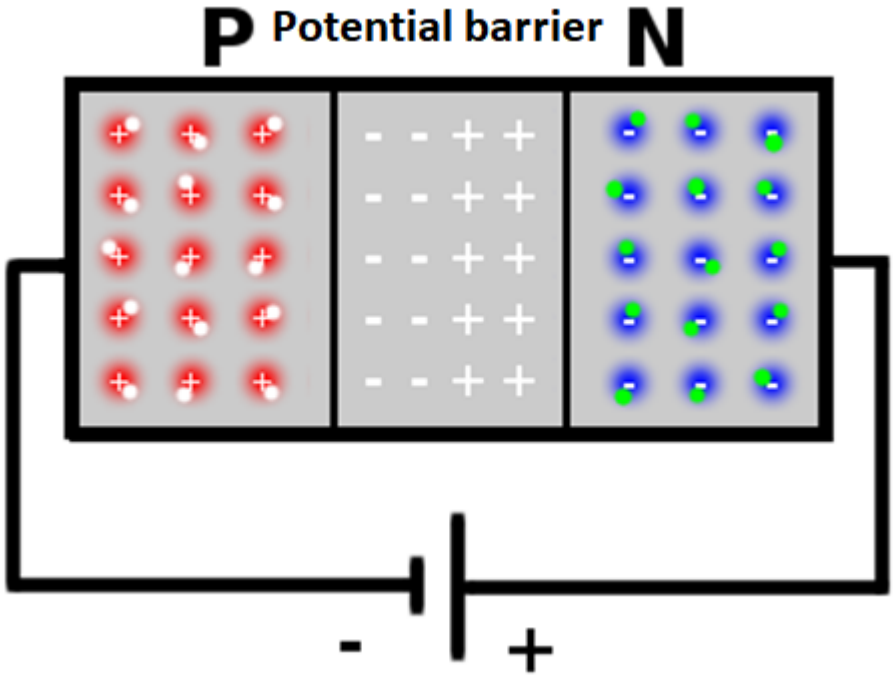

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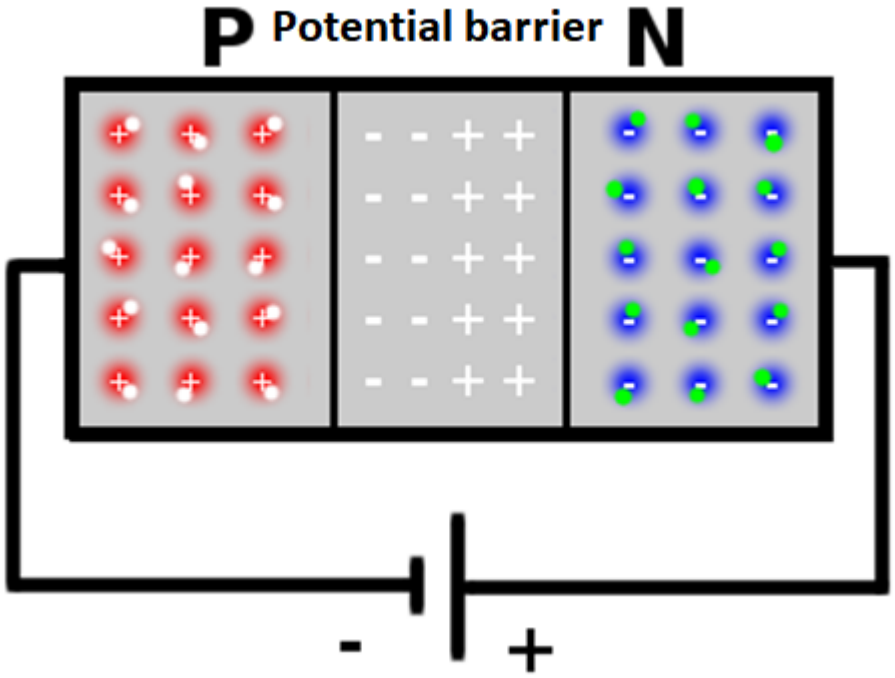
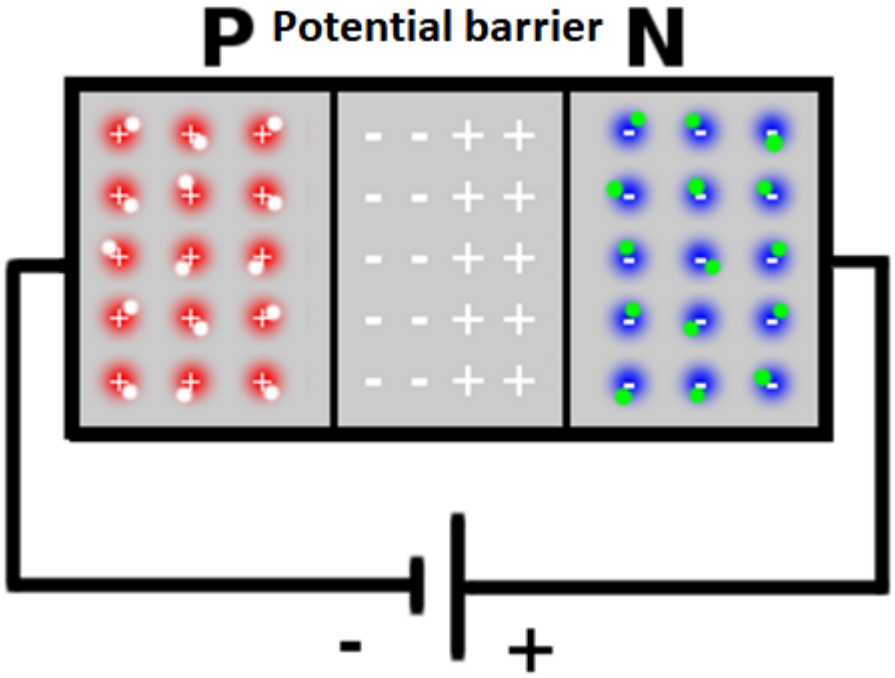


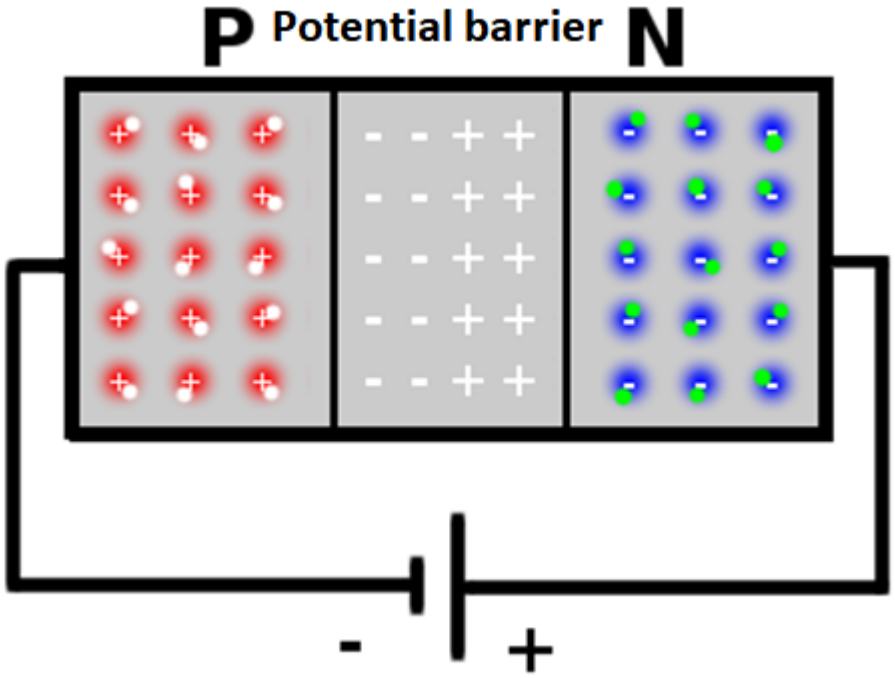
Closed PN junction

- Connected voltage source
- **Positive polarity (+)** of the voltage source **attracts electrons** (-)
- **Negative polarity (-)** of the voltage source **attracts holes** (+)



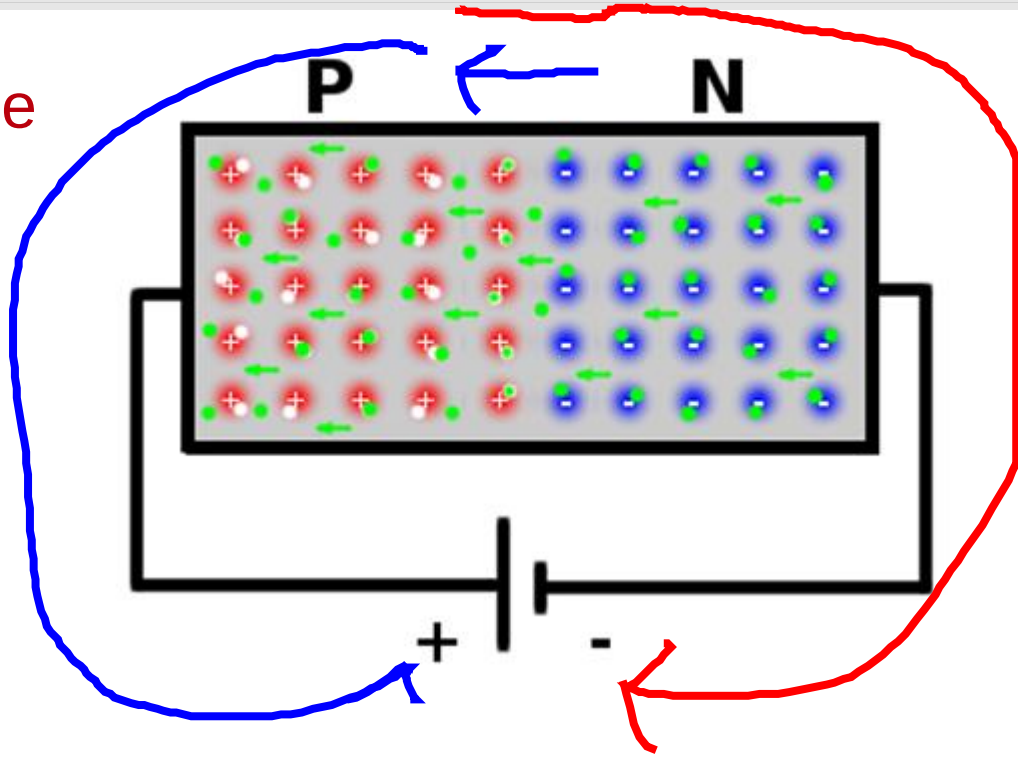
Closed PN junction

- Connected voltage source
- **Positive polarity (+)** of the voltage source **attracts electrons** (-)
- **Negative polarity (-)** of the voltage source **attracts holes** (+)
- **Larger potential barrier, almost no current**



Open PN junction

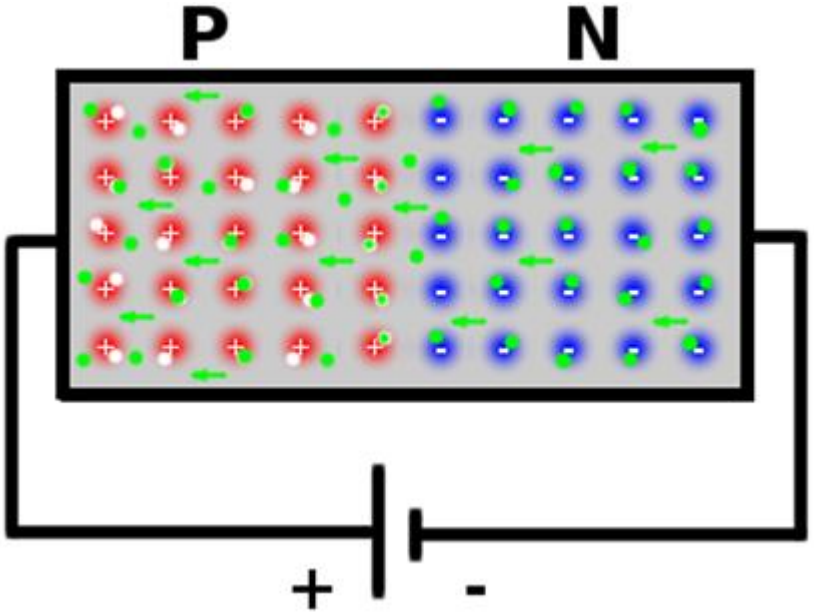
- Connected external voltage source



Recombination of holes and electrons

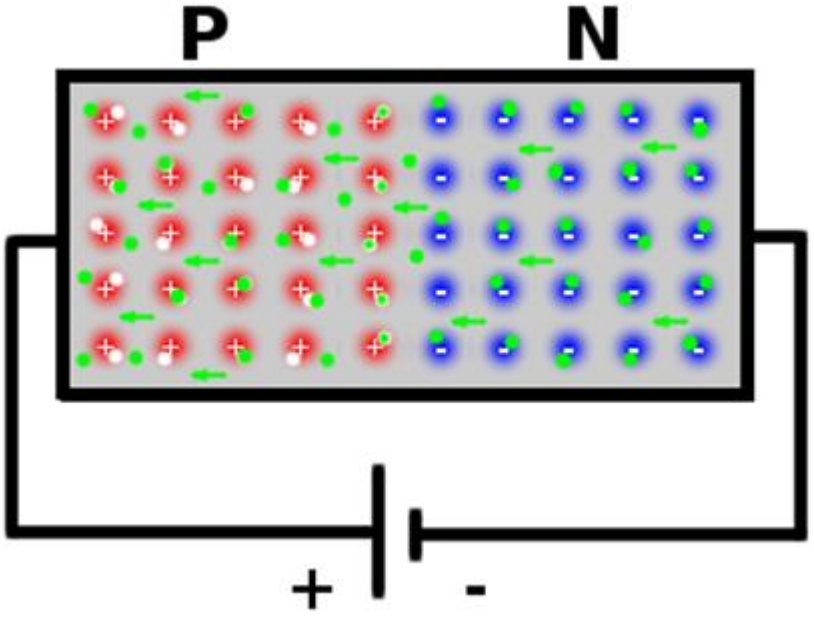
Open PN junction

- Connected external voltage source
- **Positive polarity (+)** of the voltage source **repels the holes** (**+**)



Recombination of holes and electrons

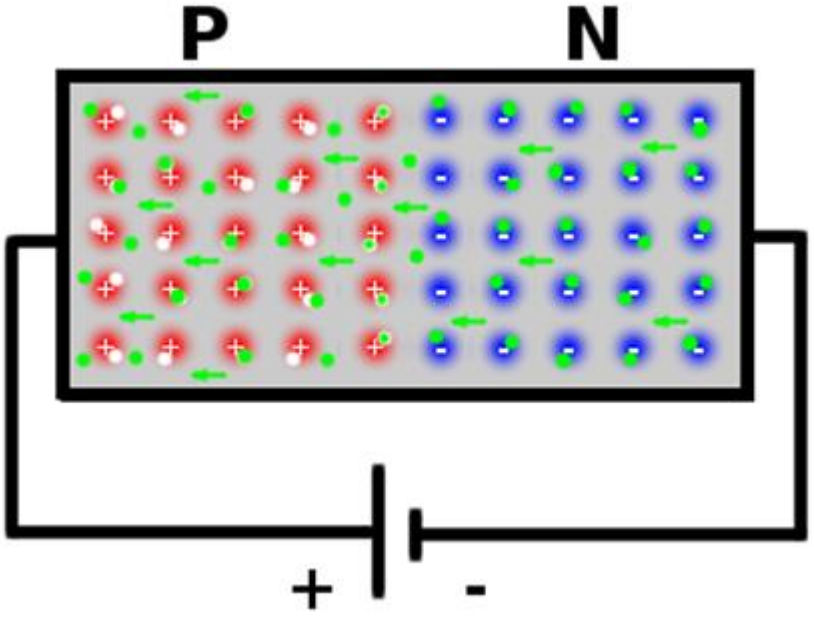
- Connected external voltage source
- **Positive polarity (+)** of the voltage source **repels the holes** (+)
- **Negative polarity (-)** of the voltage source **repels the electrons** (-)



Recombination of holes and electrons

- Connected external voltage source
- **Positive polarity (+)** of the voltage source **repels the holes** (+)
- **Negative polarity (-)** of the voltage source **repels the electrons** (-)

- **Potential barrier shrinks, current flows**



Recombination of holes and electrons

- Analytical solution

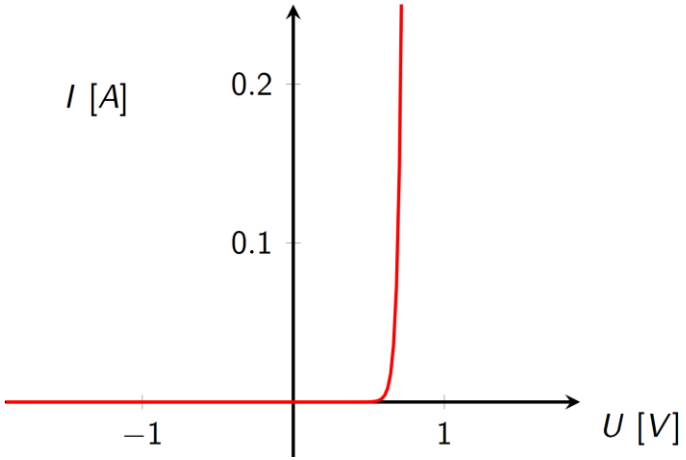
$$I = I_0(e^{\frac{eU}{kT}} - 1)$$

where:

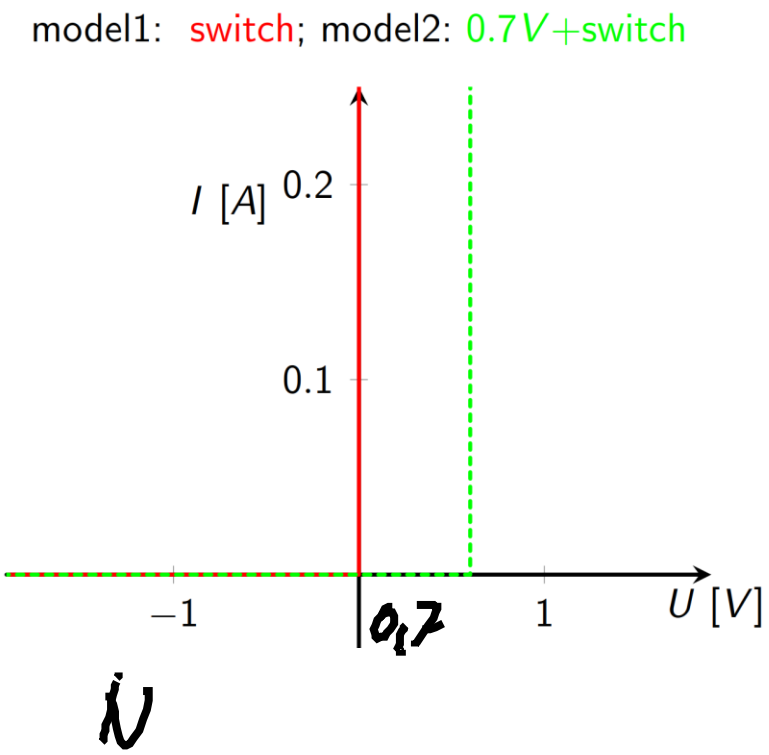
e charge of a electron ($1.6x10^{-19}C$),

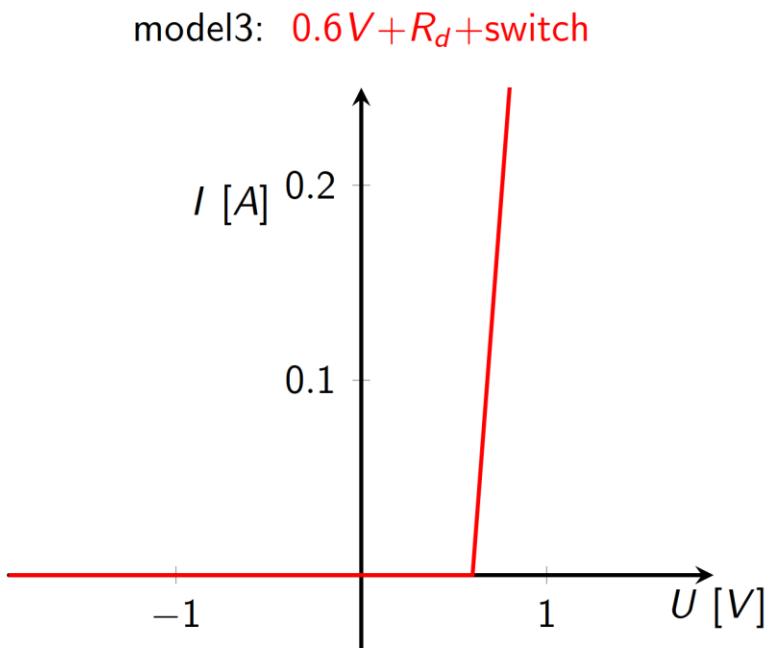
k Boltzmann constant ($1.38x10^{-23}JK^{-1}$),

T temperature of the PN junction ($300K$)



- We can approximate the analytical solution

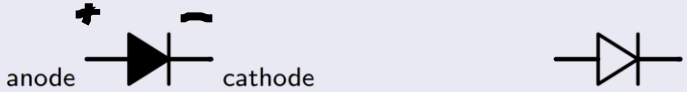




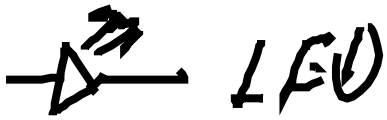
Typical usage of the PN junction – **diode**

- Symbol of a diode:

Symbol: (anode=P, cathode=N)

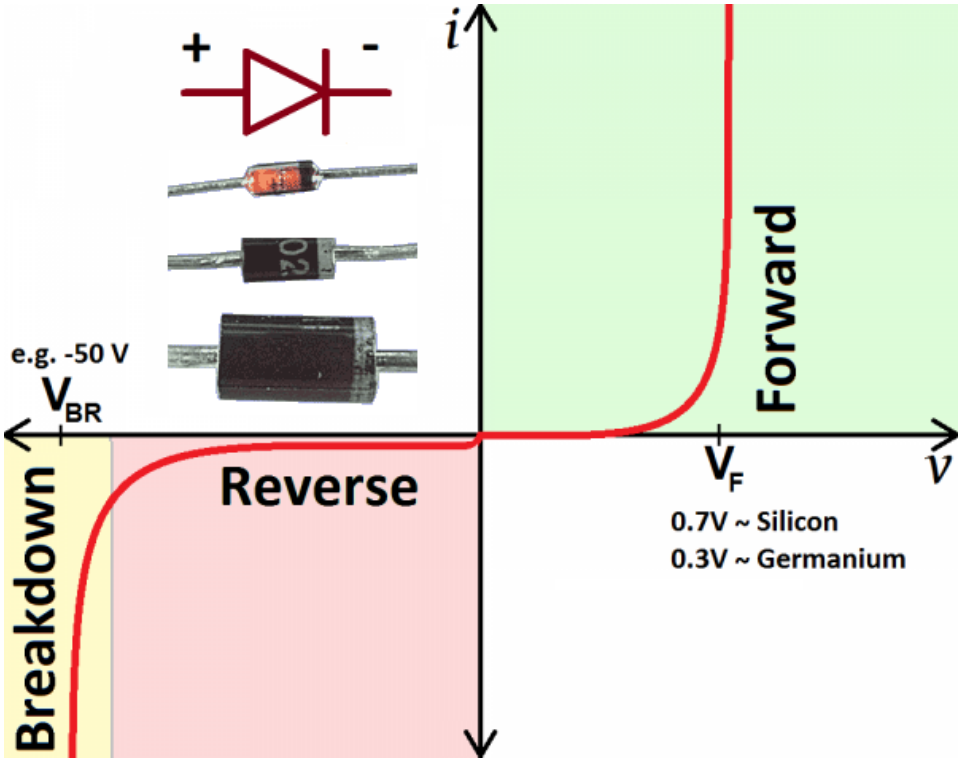


- Packaged **PN junction**
- Two electrodes
  - Positive: **anode, P**
  - Negative: **cathode, N**



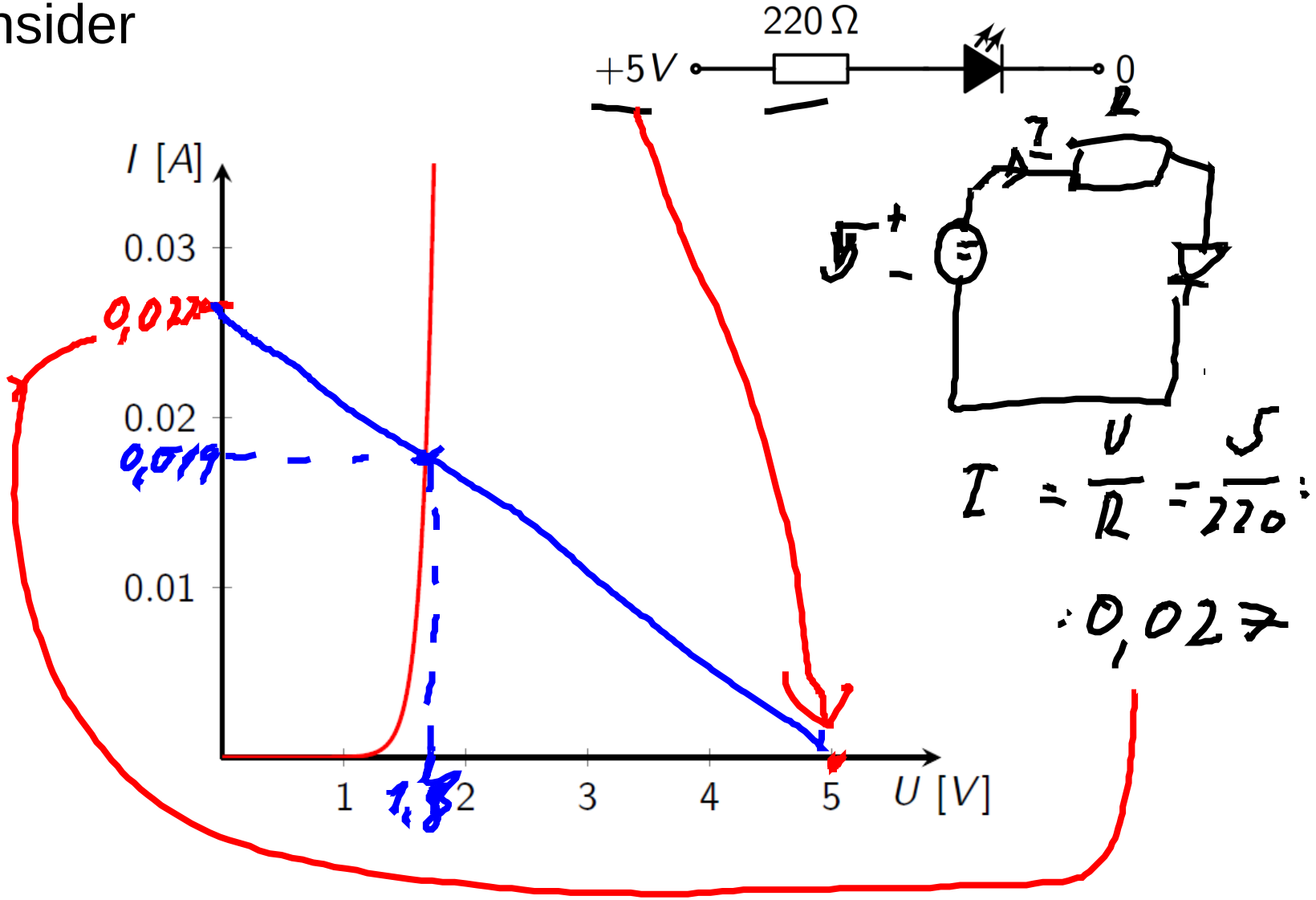
Real VA characteristic

- Real characteristic of the diode:

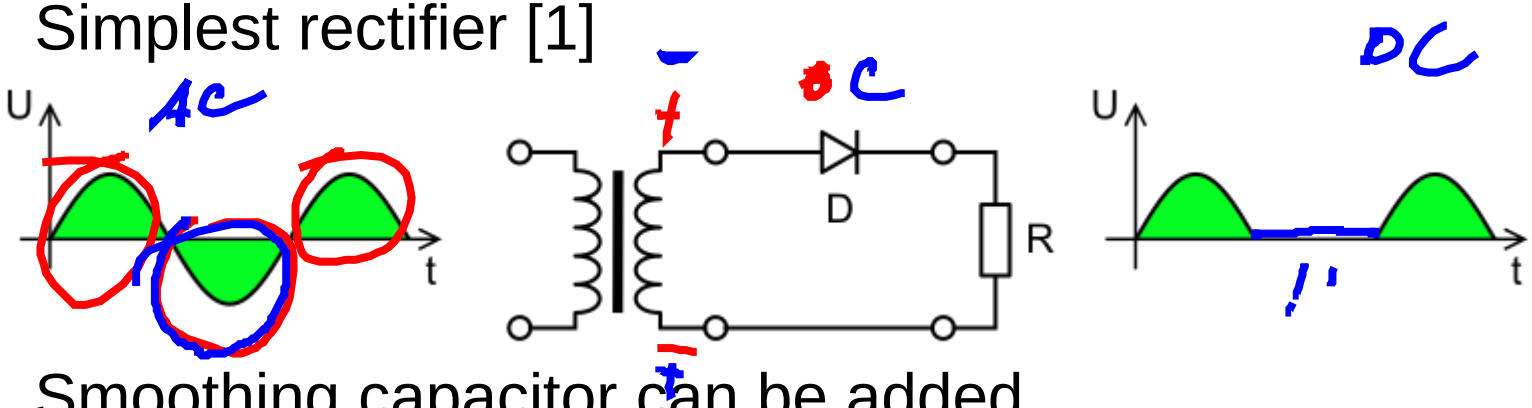


- Current flows even if the diode is connected in reverse. If the reverse current exceeds the maximum allowed value
  - Destructive breakdown of the diode and its destruction (exception – **Zener diode**)

- Consider

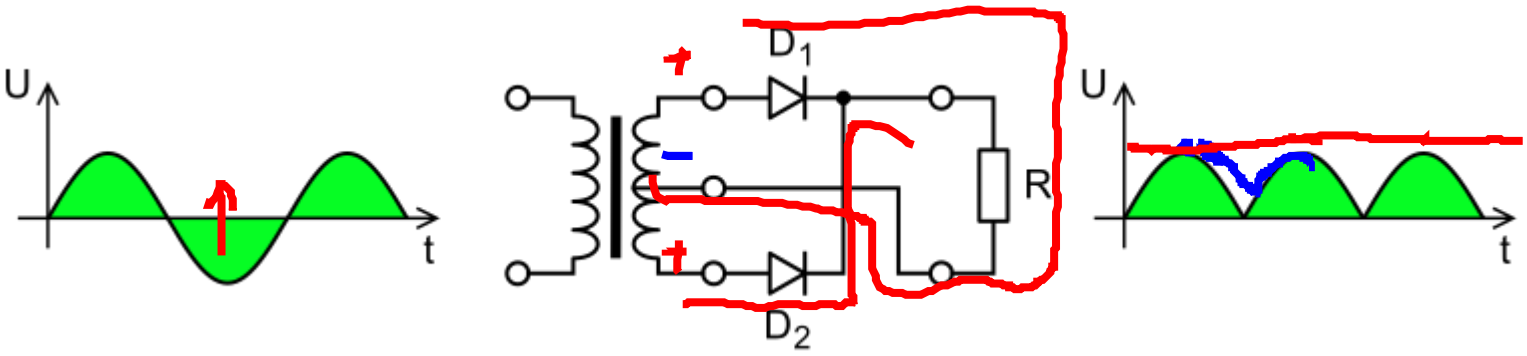


- For example **rectifiers**
  - Convert AC voltage to DC voltage
  - Simplest rectifier [1]

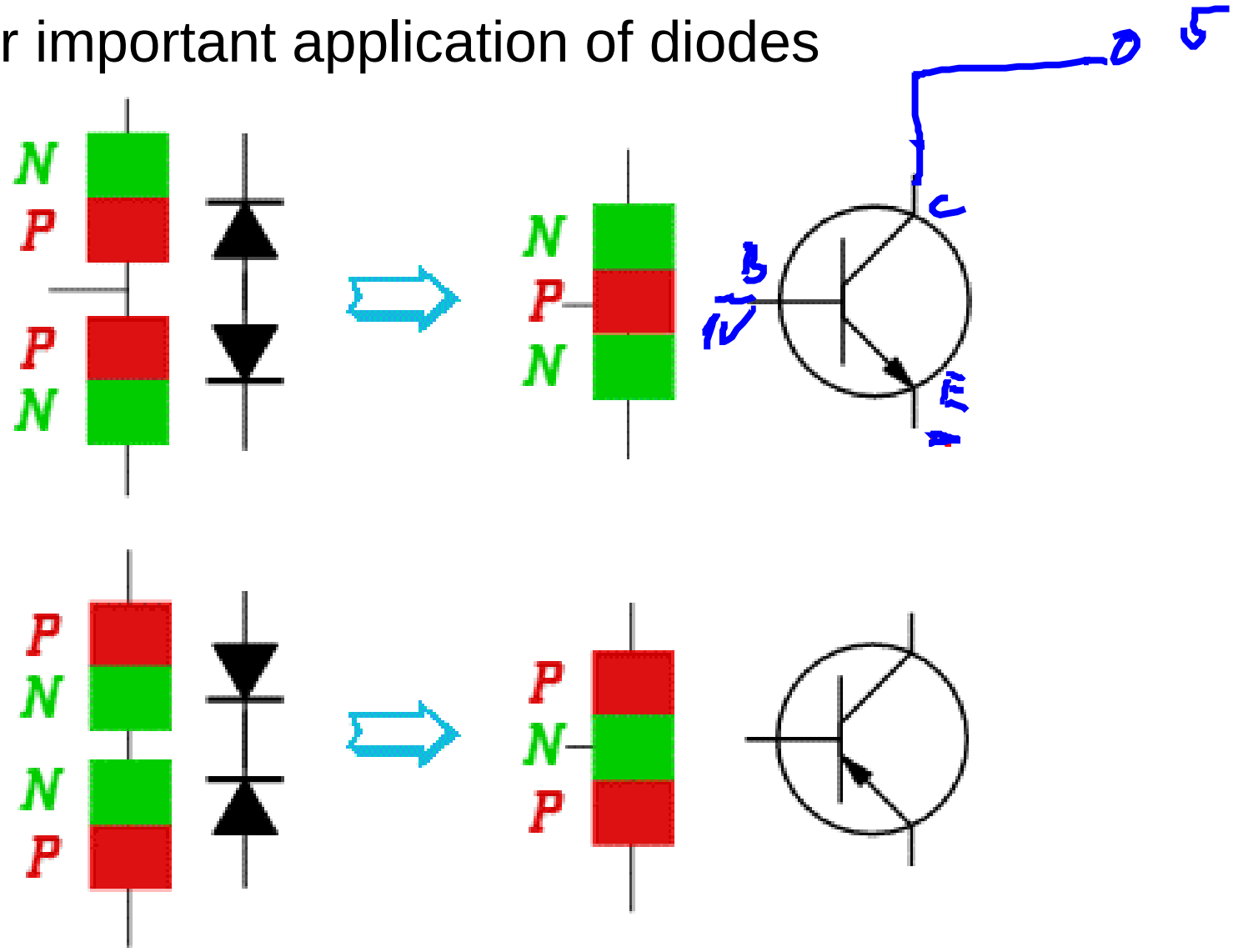


  - Smoothing capacitor can be added

- Full wave rectifier [1]



- Another important application of diodes



Thank you for your attention!