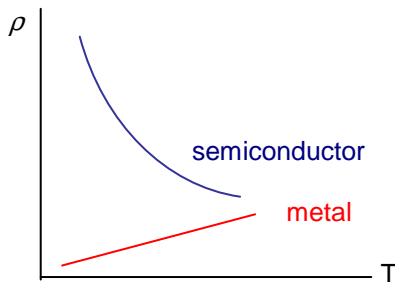# ELECTRIC CURRENT IN SEMICONDUCTORS

## 1. Semiconductors

Semiconductors can change their resistance easily, so they can have properties of both conductors and insulators, it depends e.g. on their temperature, light, extrinsions. They change their resistivity with temperature according to the graph below.



**Experiment: thermistor and photoresistor**

| component | symbol | function |
|---|---|---|
| thermistor | | |
| photoresistor | | |

## 2. Pure and extrinsic semiconductors

- **pure semiconductors**
  - are either elements from group IV. (Si - mainly, Ge, C, Se, Te), or compounds (GaAs, CdS, PbS). At low temperatures all the electrons form bonds so it is an insulator. When the temperature rises to room values, some of the electrons from the last shell have enough energy to leave the bonds = couples of free electron + hole are formed. Both the negative electron and the positive hole (missing an electron in the bond) can conduct current. The hole can move within the structure as it can be occupied by another electron. Generation of the couple can be seen on the figures. The number of free electrons and holes in a pure semiconductor is equal.
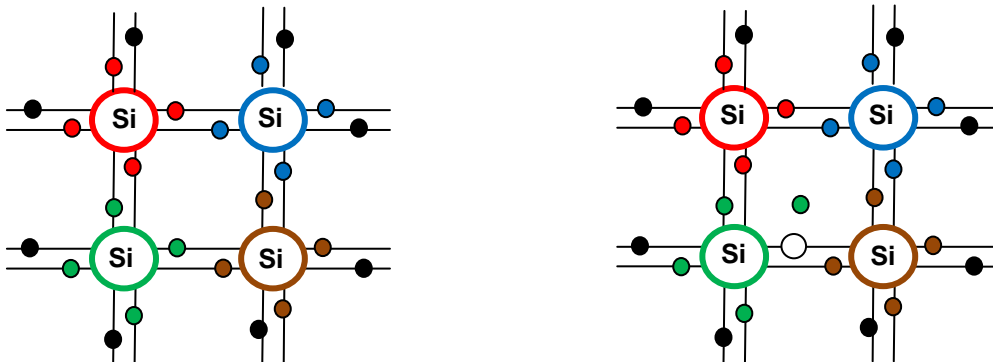
- **extrinsic semiconductors**

Extrinsions can be added to raise the conductivity.

a) n-type semiconductor
   - extrinsion = element from group V. (P, As, Sb)
   - more free electrons than holes, though total $Q = 0$
   - conducts current even at low temperatures

b) p-type semiconductor
   - extrinsion = element from group III. (B, In, Ga)
   - more holes than electrons, though total $Q = 0$
   - conducts current even at low temperatures
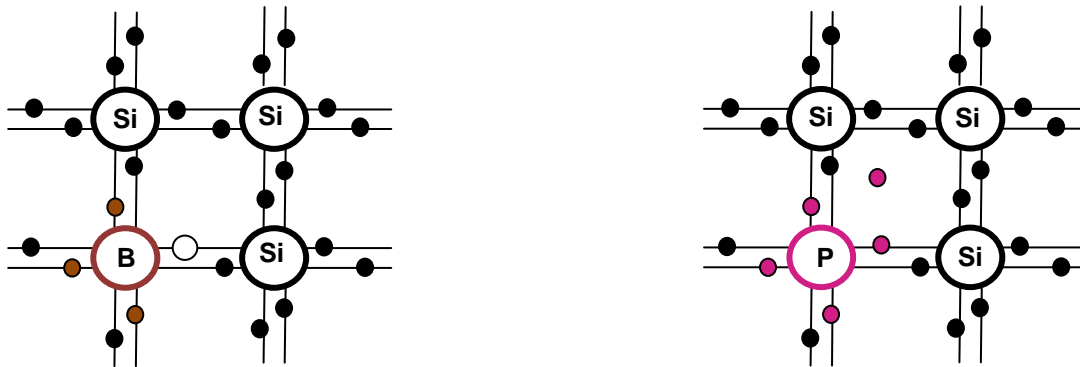


## 3. PN junction, (junction) diodes

Diodes are non-linear components made of two types of semiconductor (P and N) and their main function is to enable the current to flow only in one direction = forward bias. The other is called reverse bias.
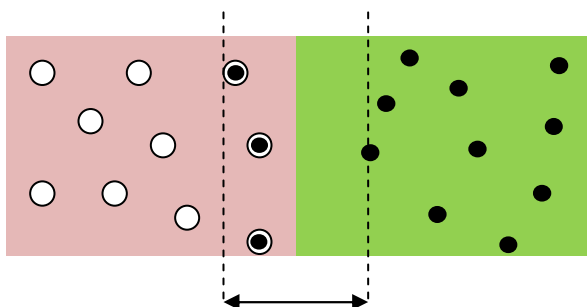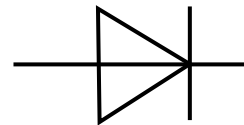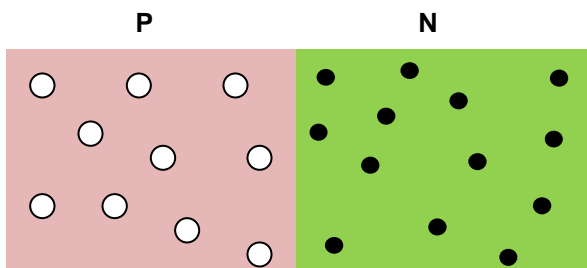


diode phenomenon
Electrons move from n-type to p-type „to please the structure", but this changes the charge – voltage is created = a depletion layer about 1μm wide. This allows electrons to pass only in one direction – from n to p, so the current can pass only from p to n $\Rightarrow$ forward bias - "p-type positive". If the outer voltage is in the opposite direction, the depletion layer is getting wider and no current will pass.

the characteristic



http://kabinet.fyzika.net/aplety/dioda/dioda.html
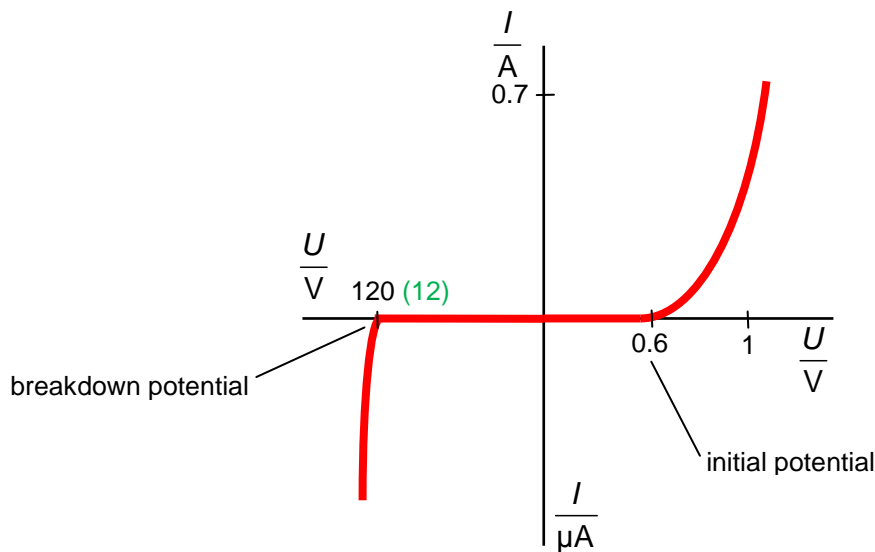
types of diodes and their uses
- „ordinary" – used just to rectify current – in rectifiers, see later (breakdown potential can be more than 100 volts, depends on construction)
- LED = light emitting diodes – produce light (different colours) when forward biased, used as control lights – TV sets etc., less energy needed than for bulbs!
- Zener diodes – used when reverse biased and „ broken" as a very stable source of voltage (breakdown potential can be smaller, several volts, depends on construction)
- photodiodes – light supplied = energy supplied – depletion layer affected, can work either as changing resistance resistors when reverse biased or a source of voltage when forward biased
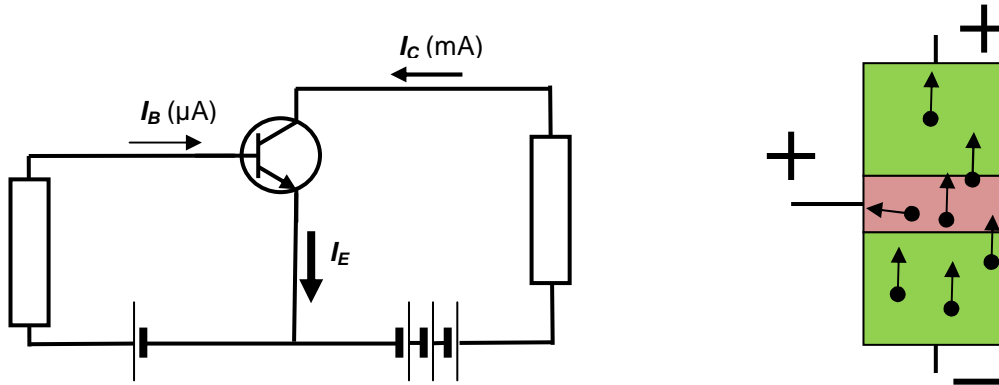
## 4. Transistors

Transistors - are components used to amplify the changes of electric current. They are made of p- and n-type semiconductors. They contain 3 layers (pnp or npn) and three contacts – one from each layer. The structure of a npn transistor and the symbols of the npn and pnp are on the figure



C... collector

B... base

E ... emitter

PNP          NPN
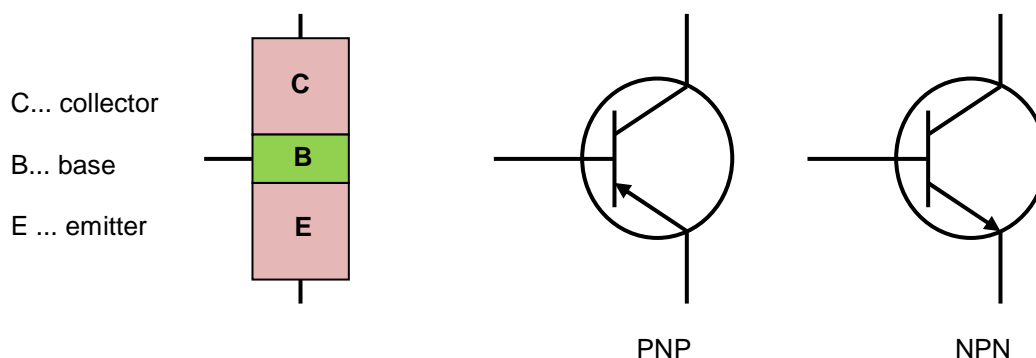
transistor phenomenon

- is explained on a common-emitter connection of a npn transistor
- BE is forward biased
- CE – 2 diodes, one forward and one reverse biased – no current
- when *I* passes from B to E – thin layer of B changes its character (not a typical p-type with lack of electrons) – CB is not reverse - current can flow
- result : small changes of $I_B \Rightarrow$ big changes of $I_C$
  *(of course, it is essential to fix a working point of the transistor using steady $I_B$ and $I_C$)*
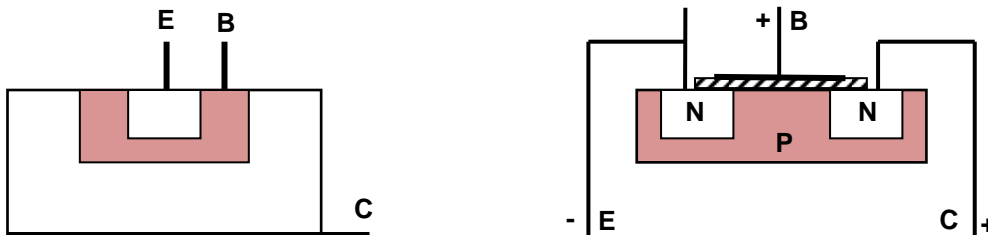
the characteristic of a transistor

current gain of a transistor ( $\beta$ )

$$\beta = \frac{\Delta I_C}{\Delta I_B} \qquad \text{for } U_{CE} = const.$$
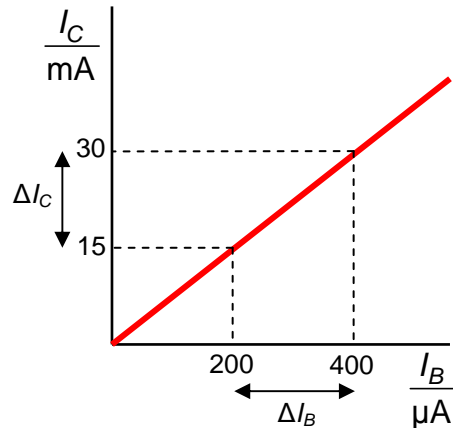
types of transistors

- bipolar – mentioned before, controlled by CURRENT through the base
- unipolar or FET (field effect transistors) controlled by VOLTAGE applied between the base and e.g. emitter, as seen on the figure. Widely now used in microelectronics.

**Questions:**

1. Explain what happens with resistance when we heat a pure or extrinsic semiconductor.
2. Is a p-type semiconductor positive and n-type negative? Explain.
3. Explain diode phenomenon.
4. Mention basic types of diodes and their uses.
5. Sketch the characteristic of a diode. Explain the importance of breakdown potential and initial potential, compare their values.
6. Explain the function of transistors, find their uses.
7. Working point of a transistor – what does it mean?
8. Define the current gain of a transistor.
9. What is the difference between bipolar and unipolar (FET) transistors?

L5/ 211-222, x223, 225-227