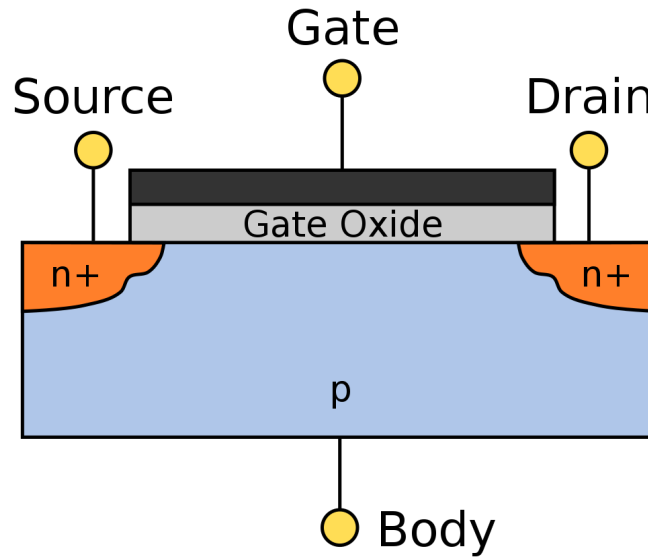
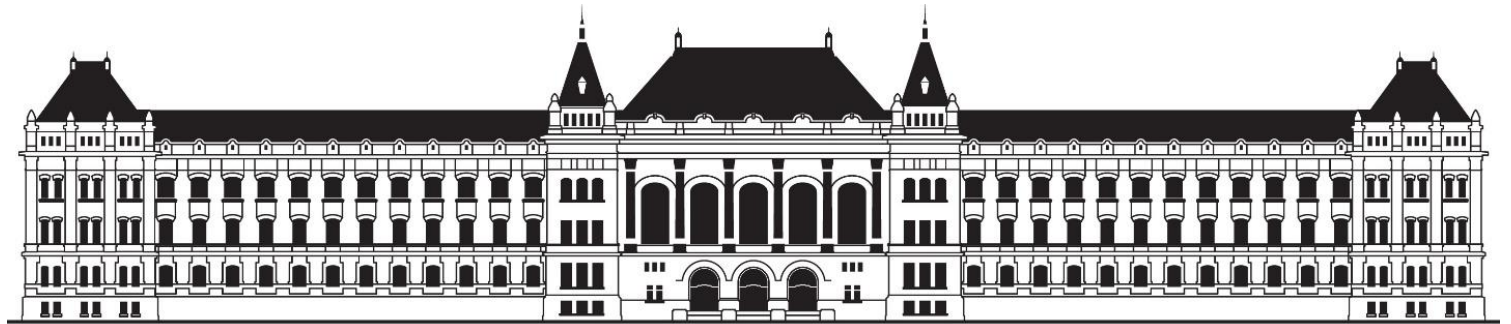
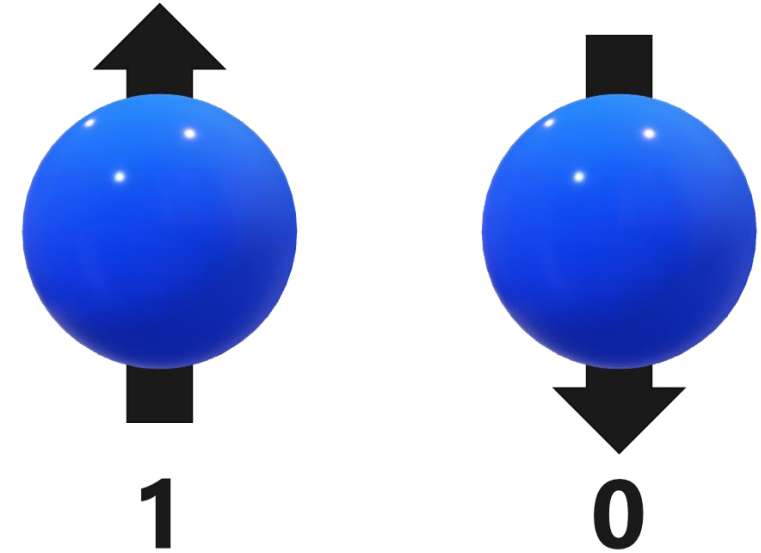


Merre tart az elektronika? I.

Kupás Lőrinc Pál
2025.07.07.



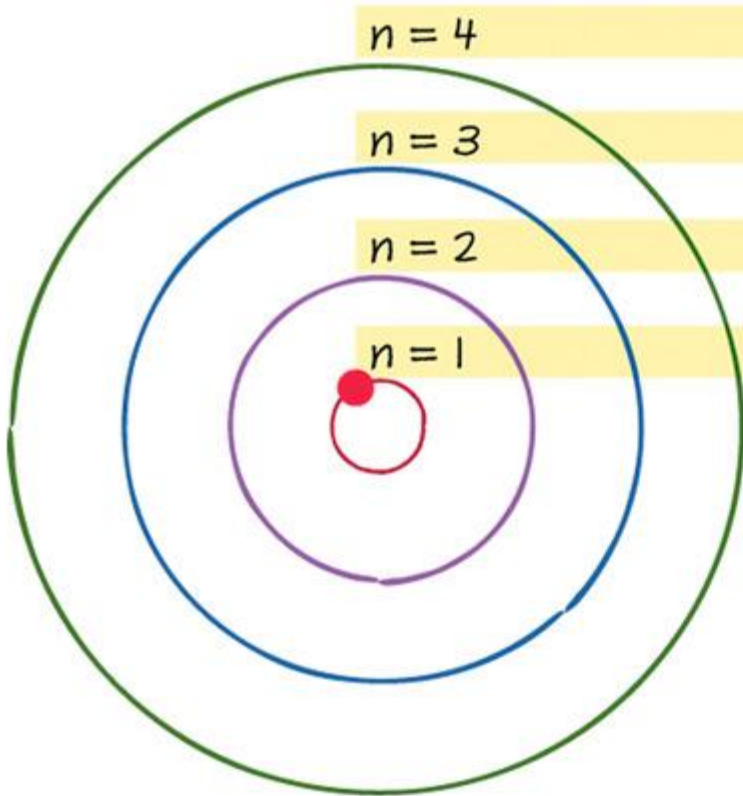
Electron Spin (Up and Down)



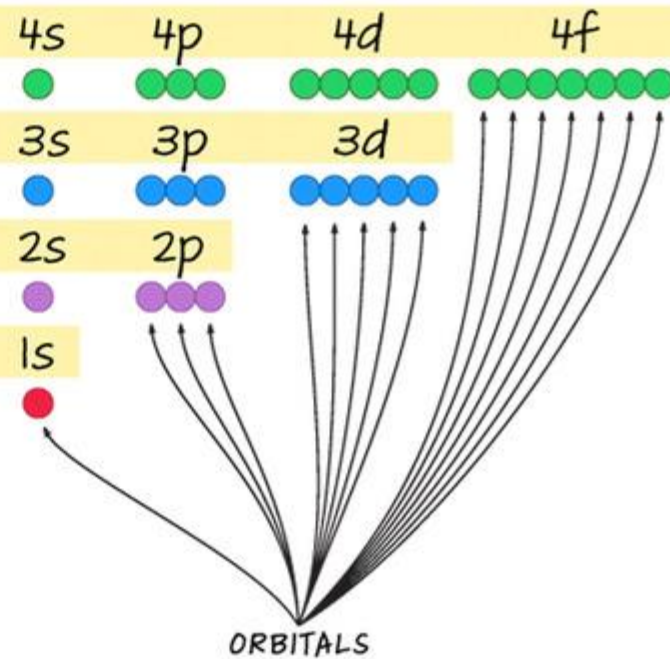
M Ü E G Y E T E M 1 7 8 2

Elektromos vezetés

ELECTRON SHELLS



SUBSHELLS

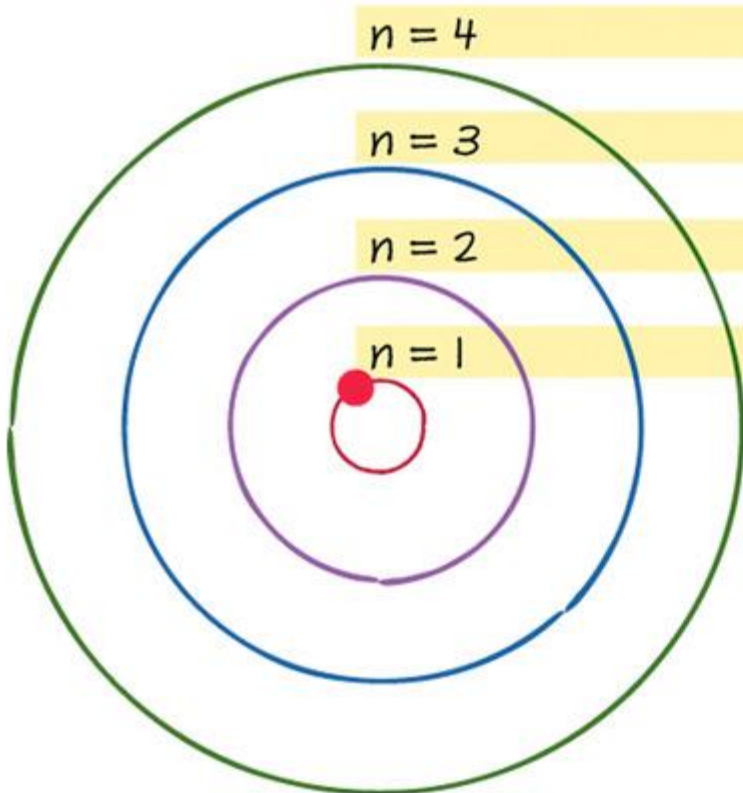


- Kizárási elv
- Diszkrét energianívók
- Részleges betöltés

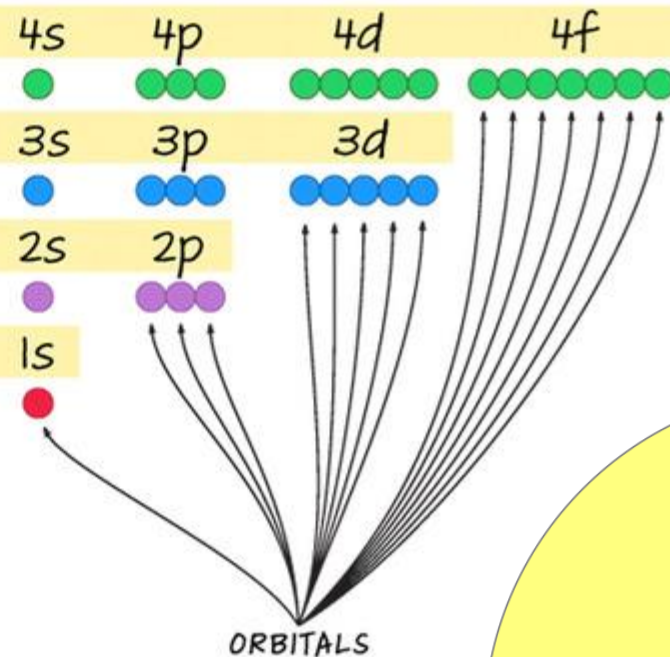


Elektromos vezetés

ELECTRON SHELLS

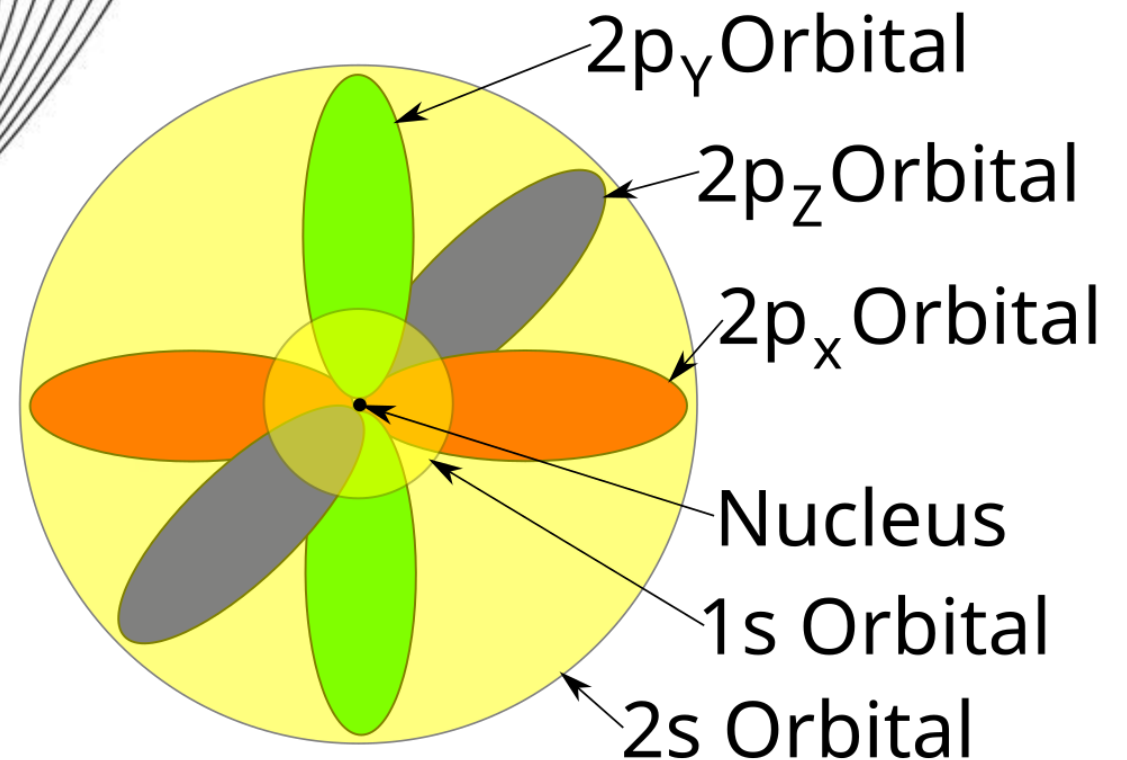


SUBSHELLS

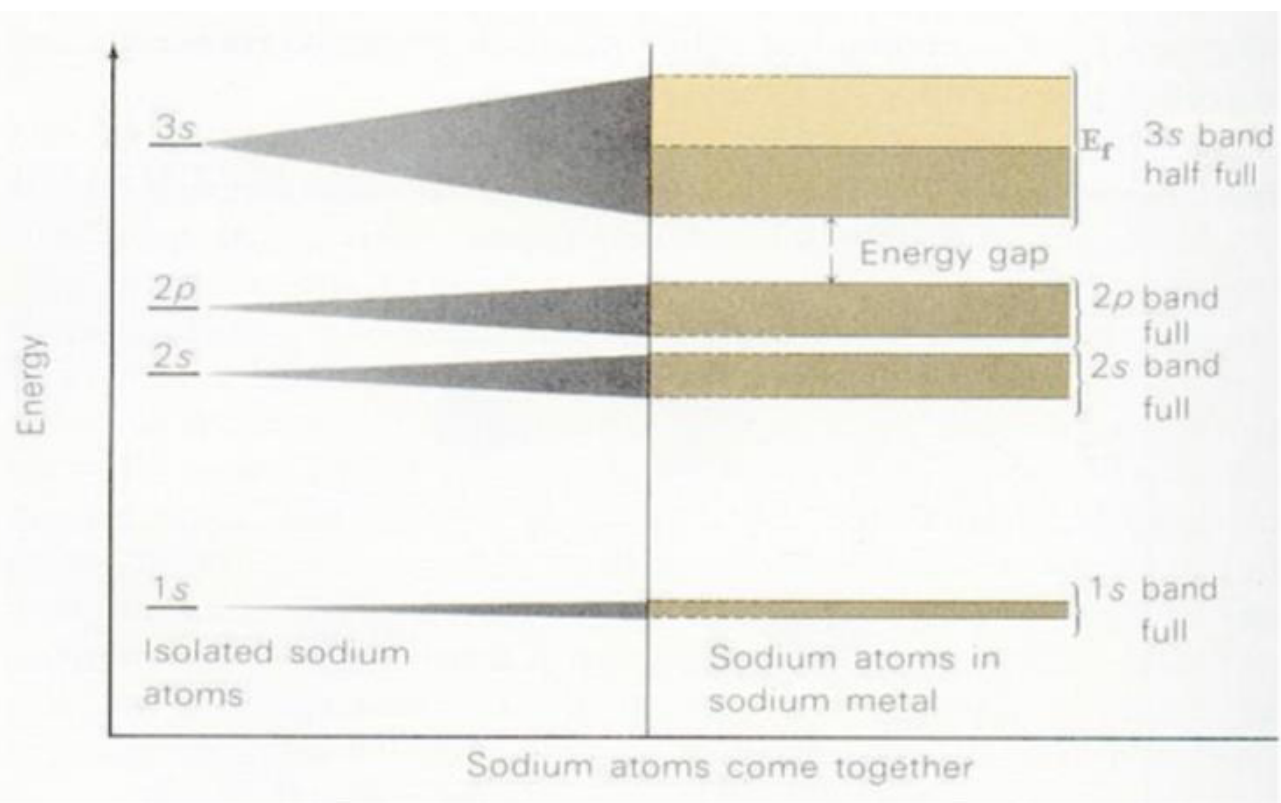


ORBITALS

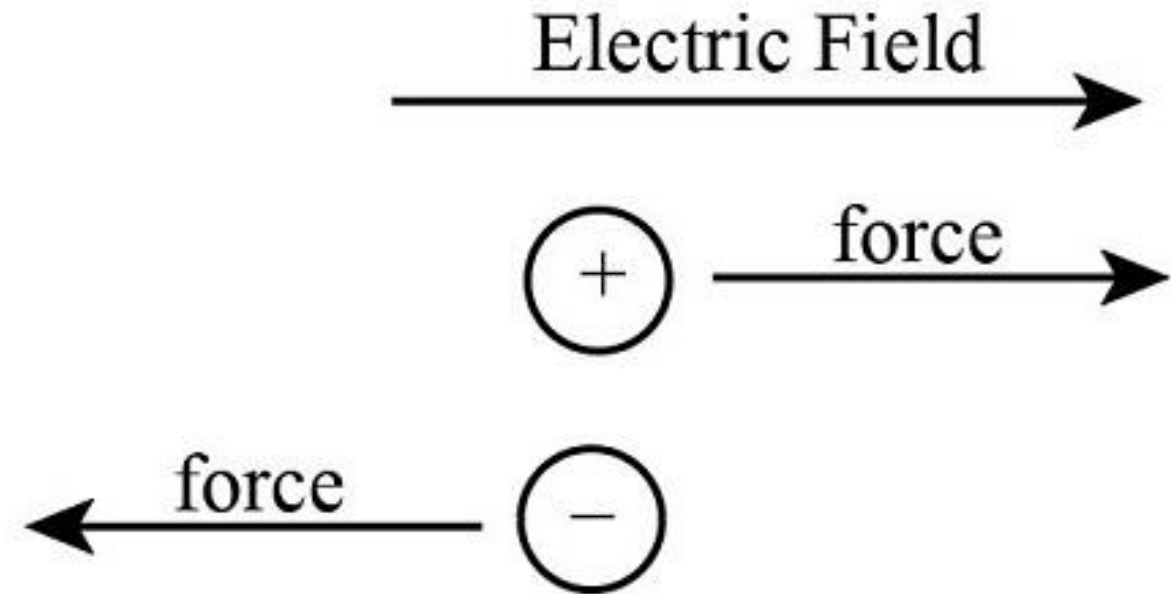
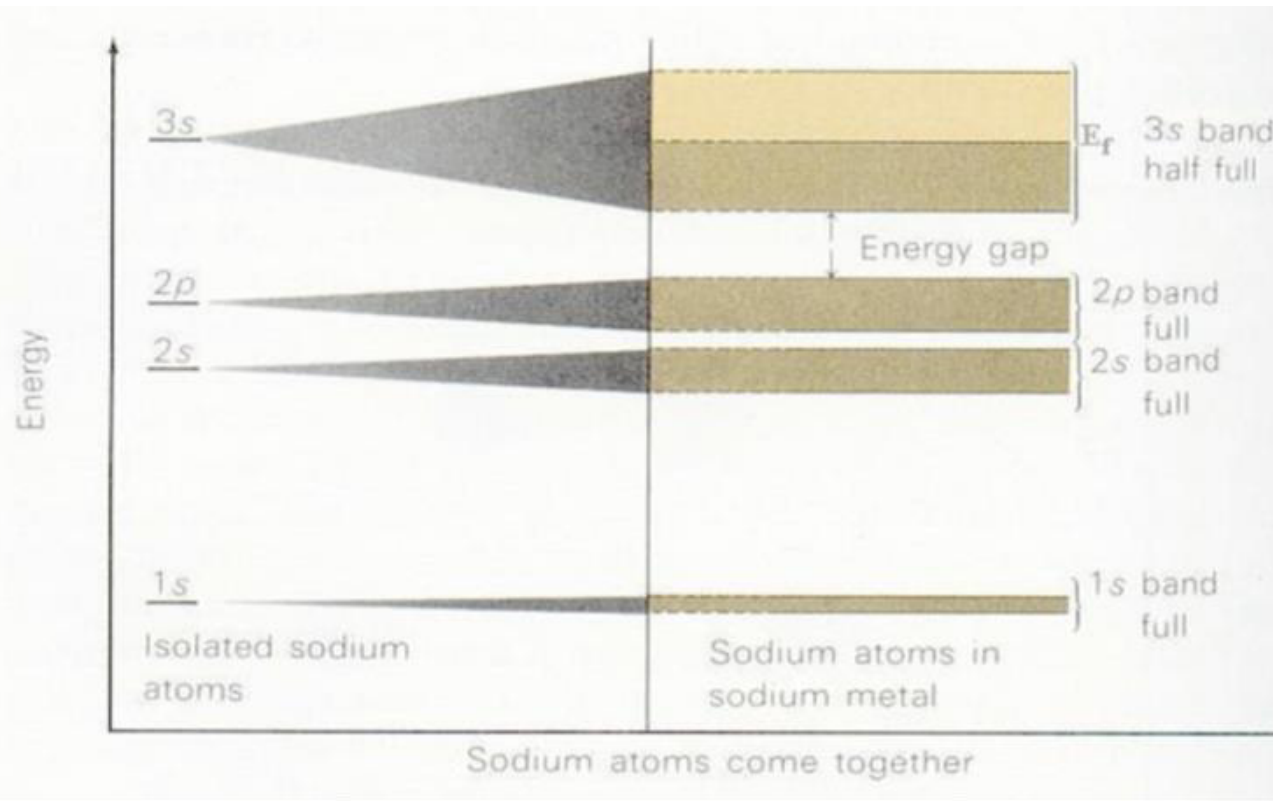
- Kizárási elv
- Diszkrét energianívók
- Részleges betöltés



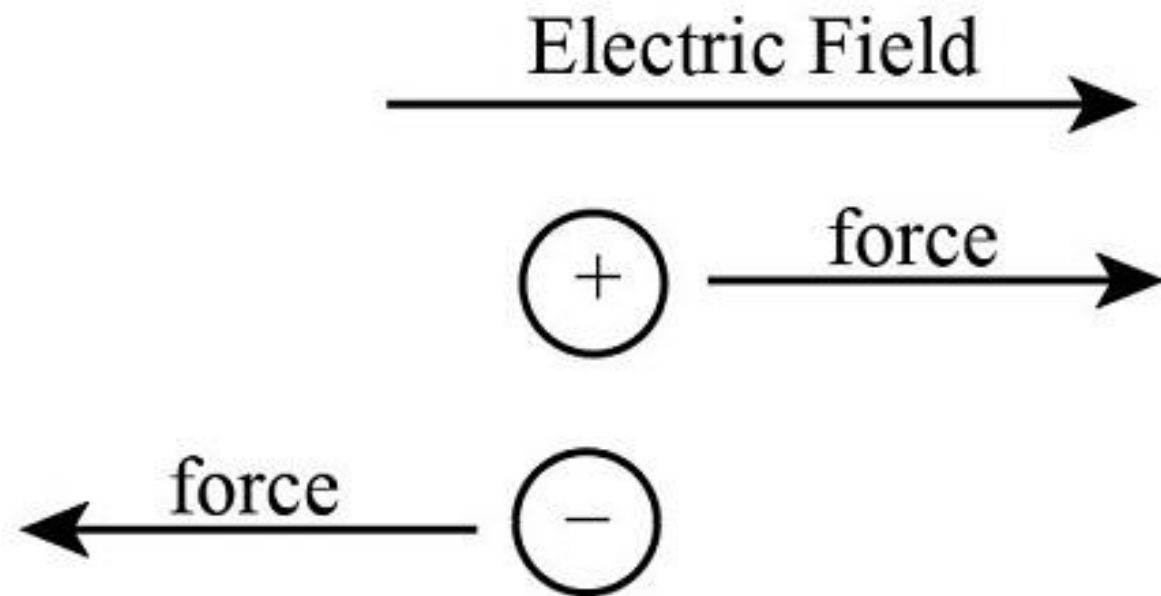
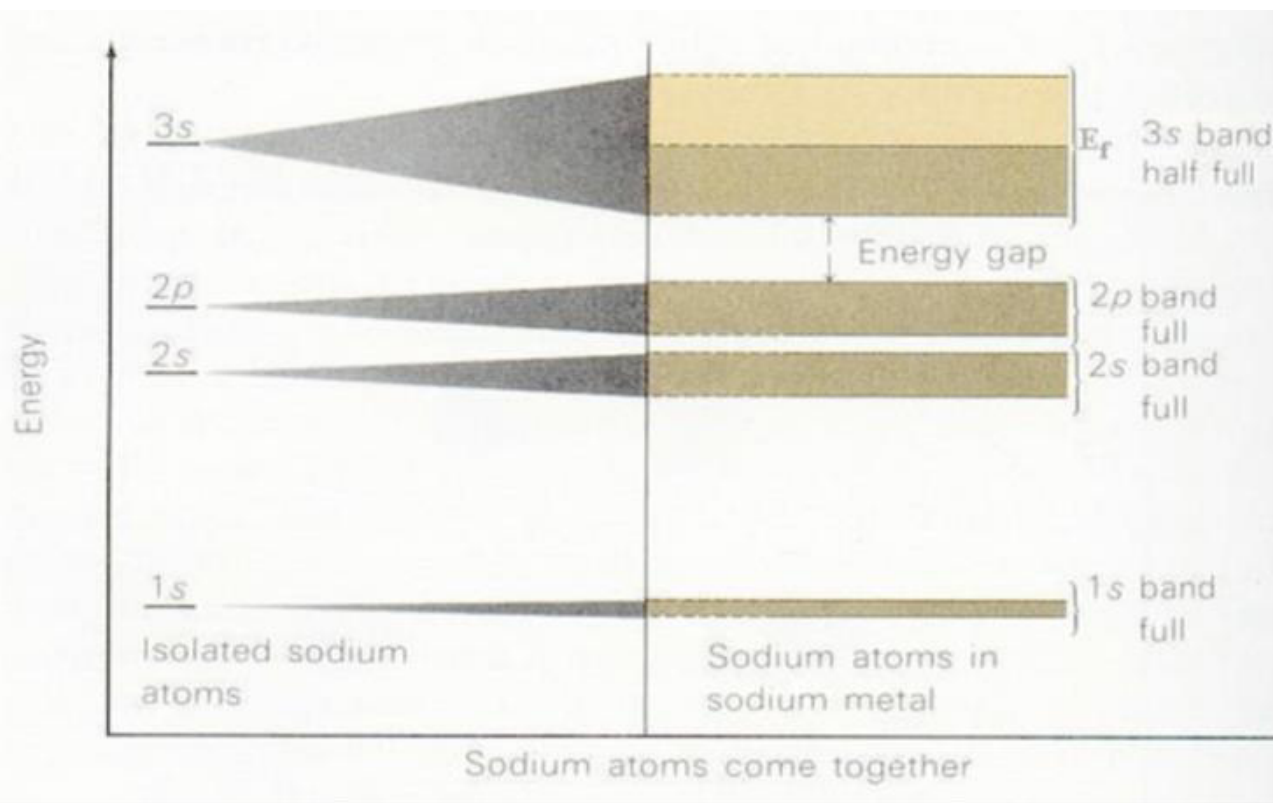
Elektromos vezetés



Elektromos vezetés

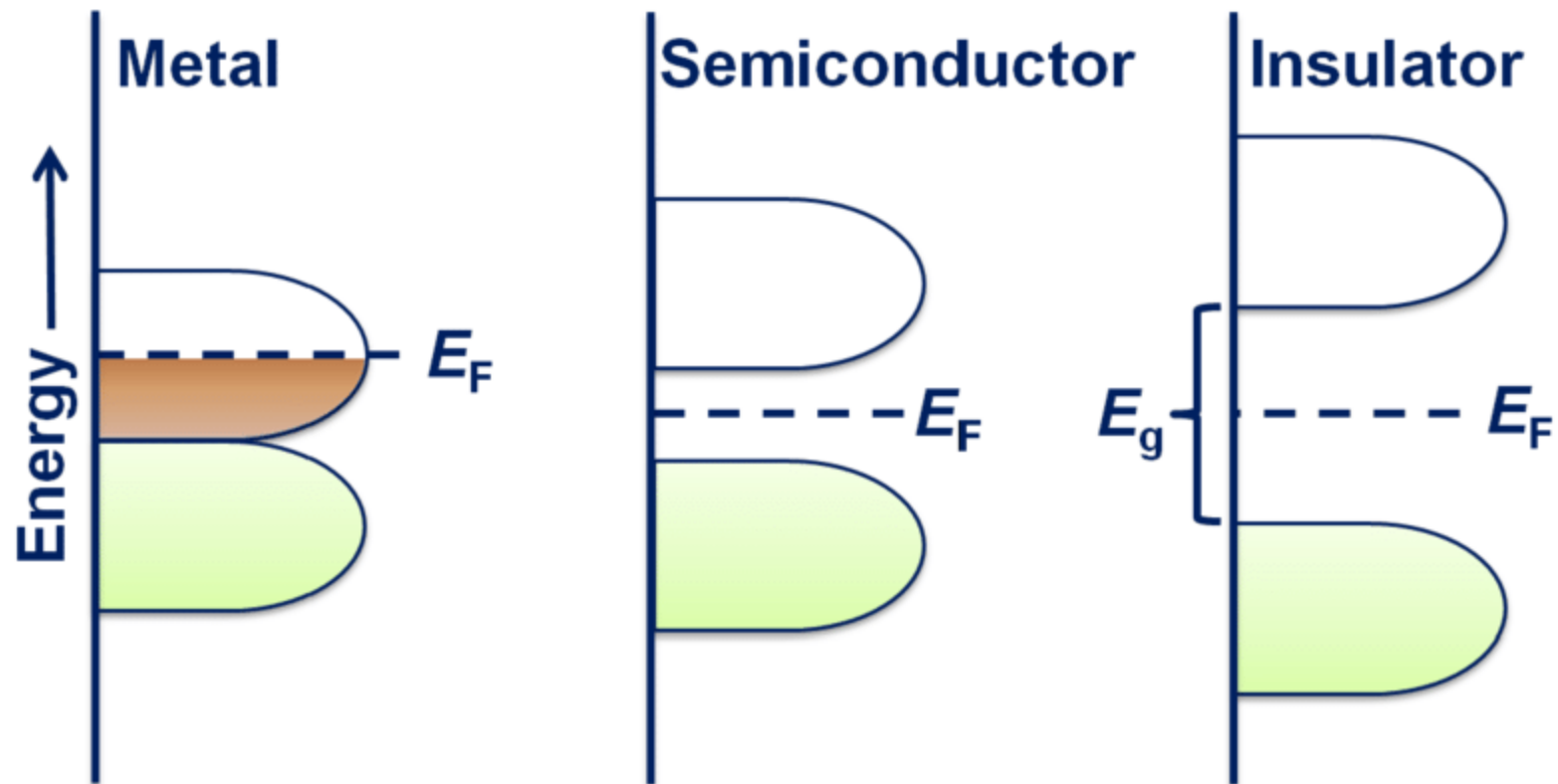


Elektromos vezetés

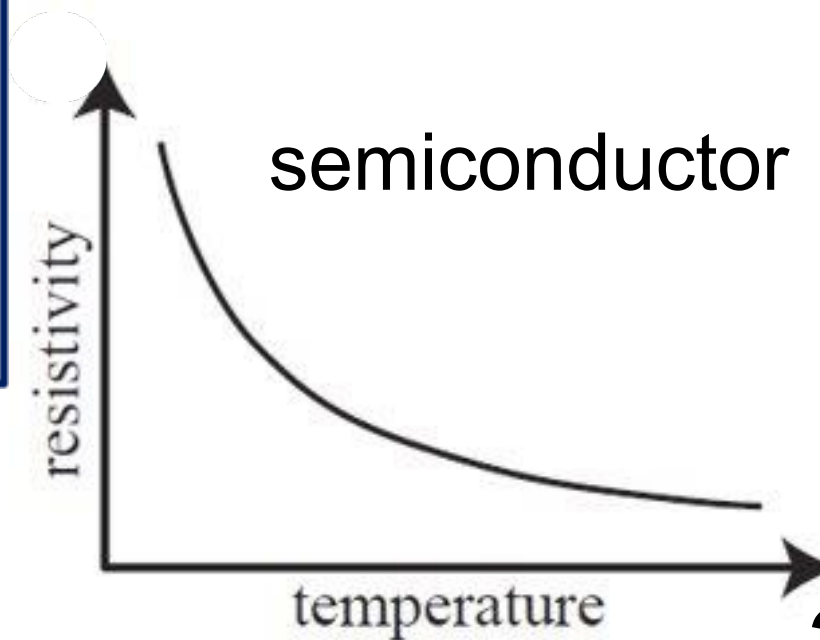
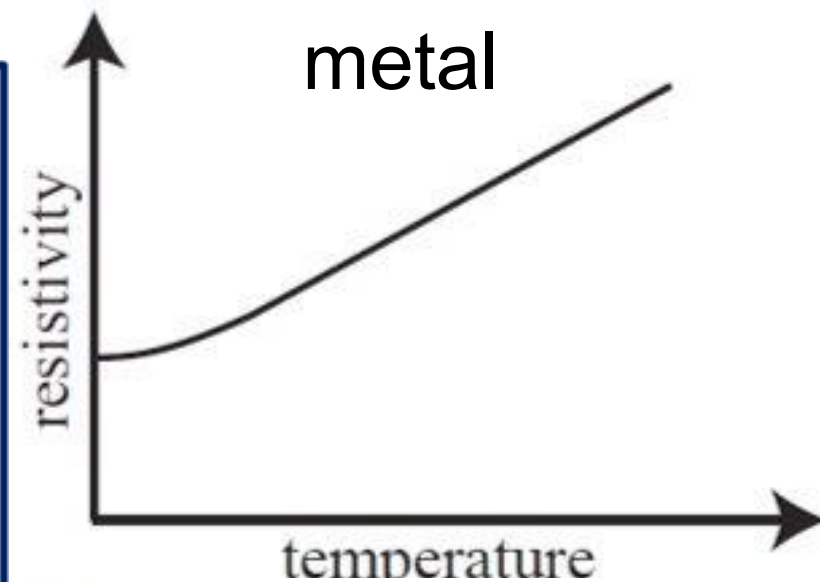
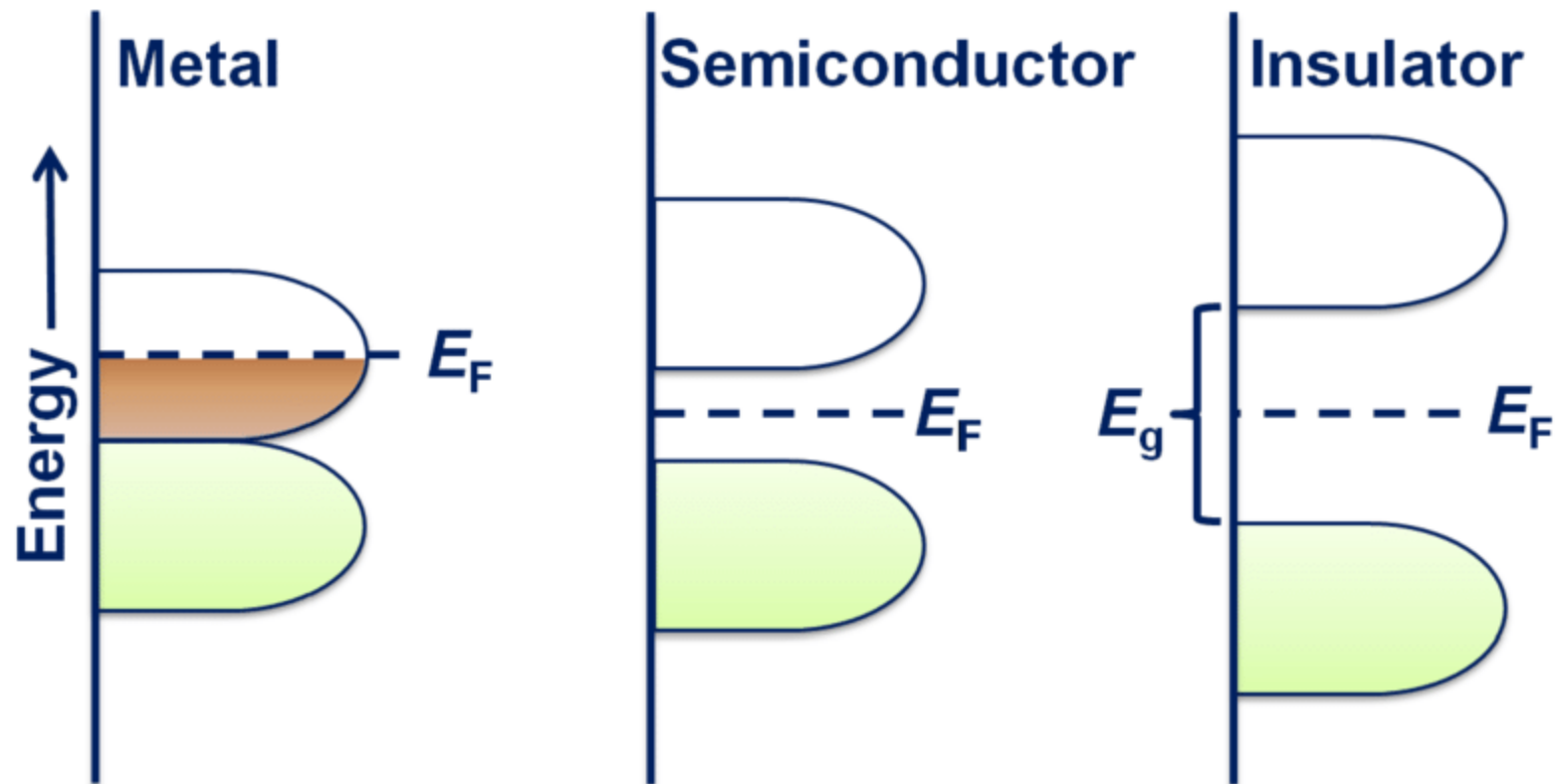


Ohm-törvény: $\vec{J} = \sigma \vec{E} = -\sigma \vec{\nabla} V$

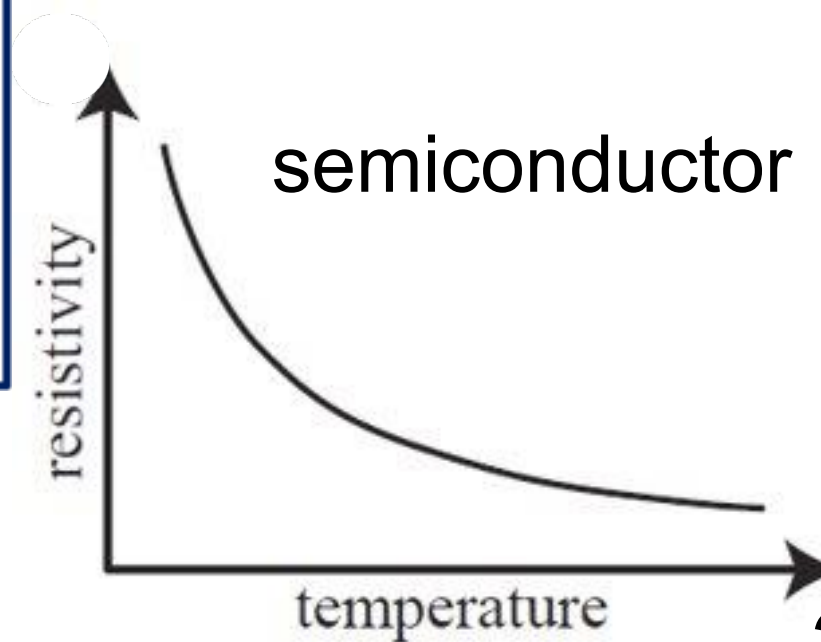
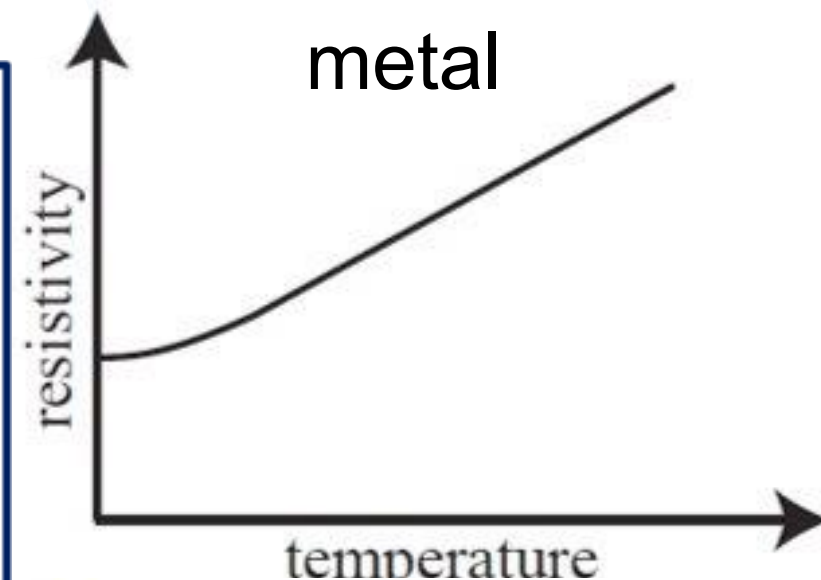
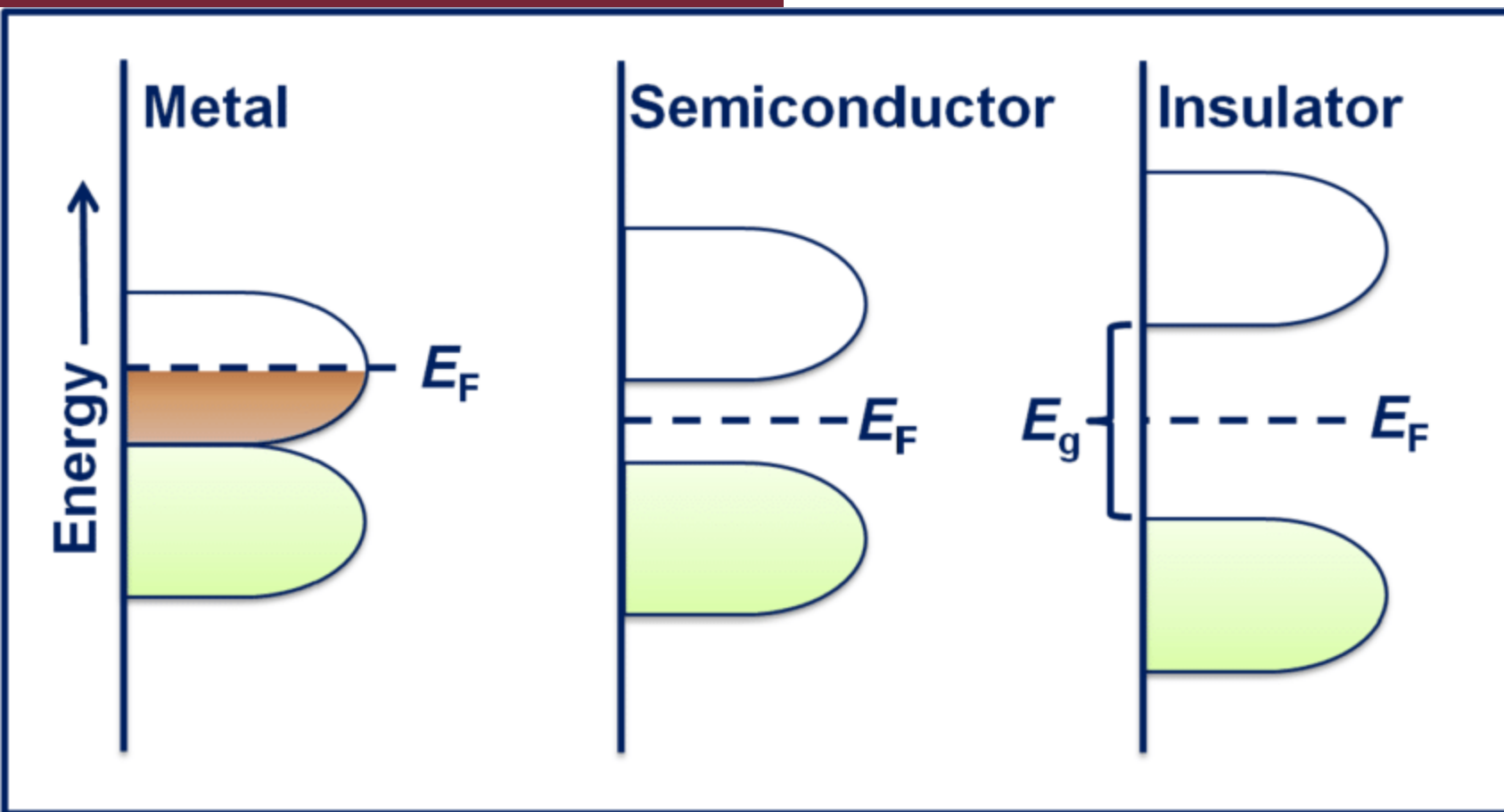
Fém, félvezető, szigetelő



Fém, félvezető, szigetelő



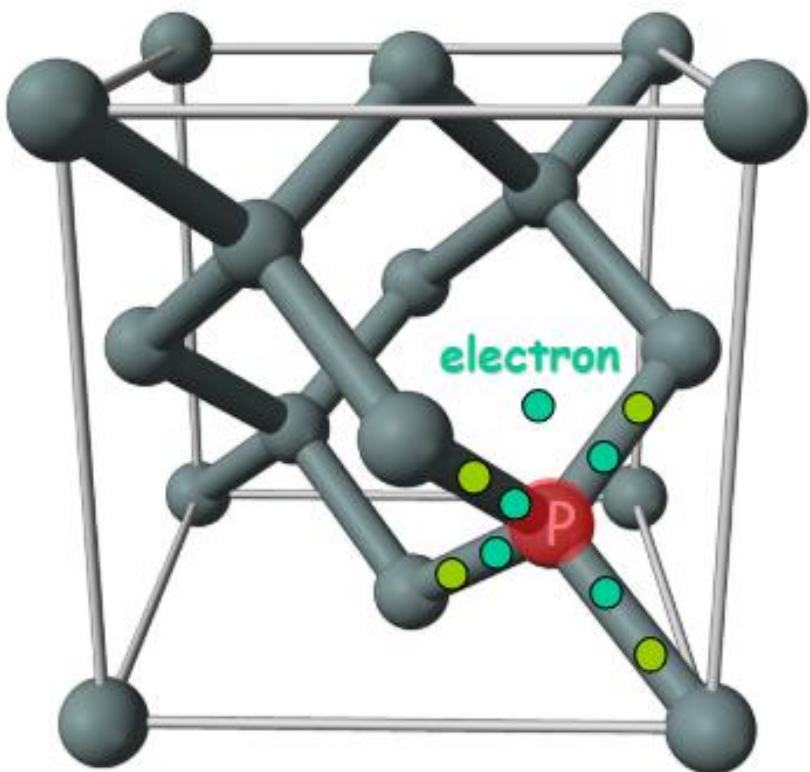
Fém, félvezető, szigetelő



- Si, Ge – IV. főcsoport

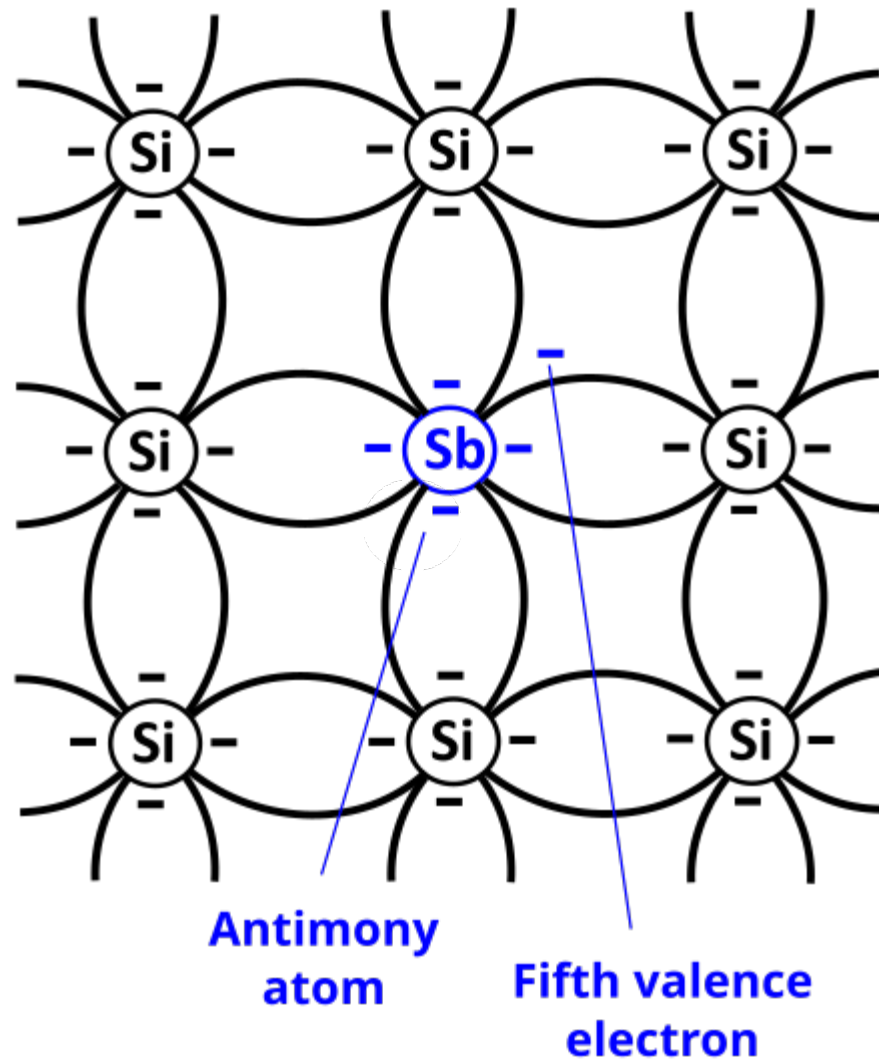
N típusú félvezető

N típusú félvezető



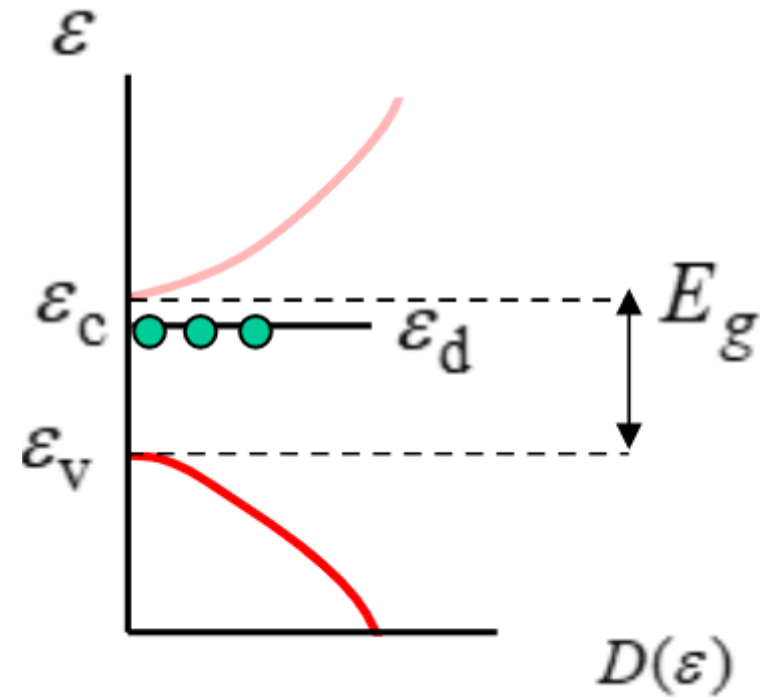
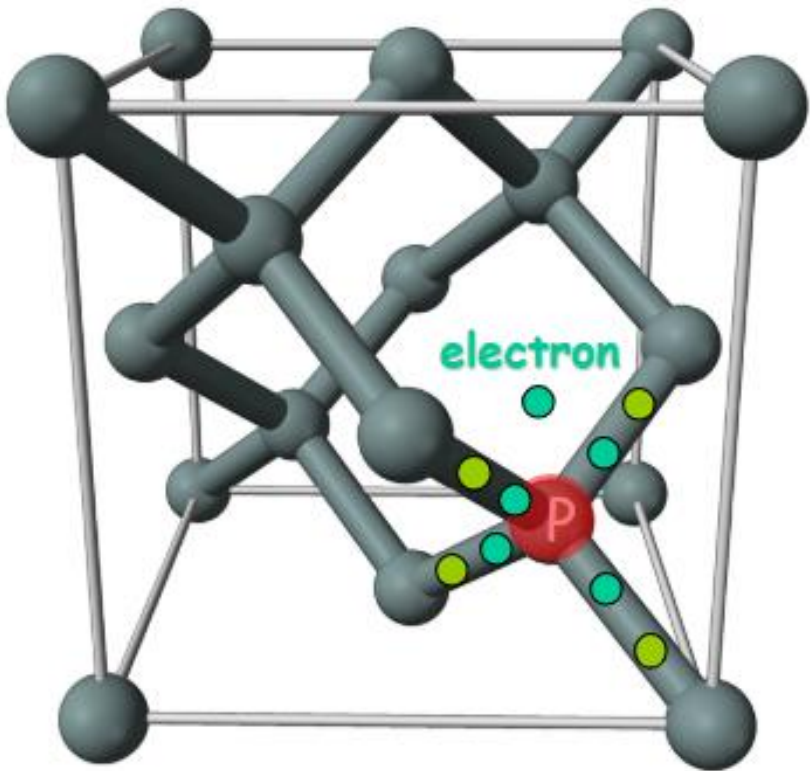
5-ös főcsoport elemei: P, As, Sb

N-Type



N típusú félvezető

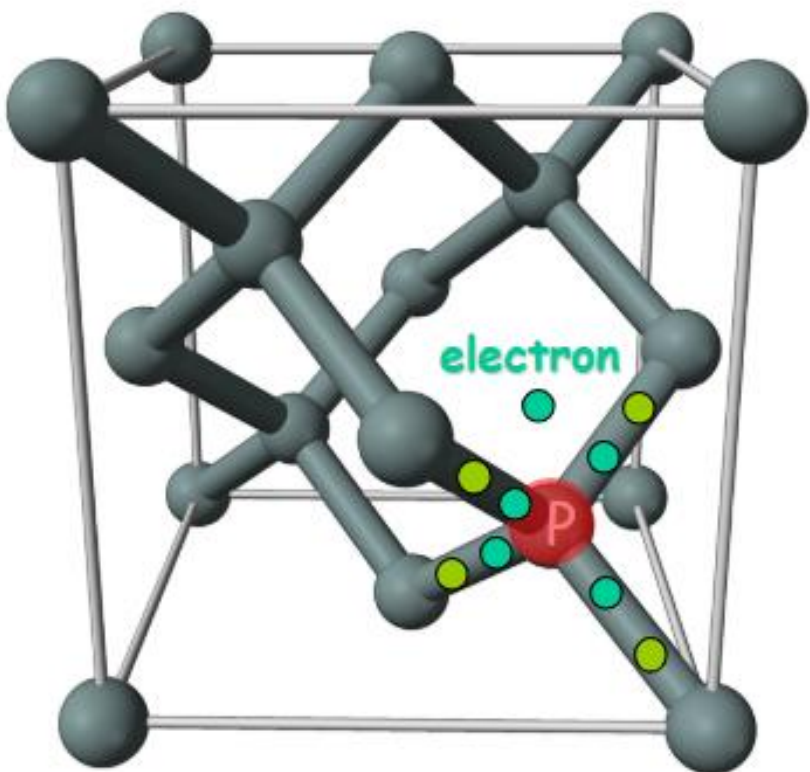
N típusú félvezető



5-ös főcsoport elemei: P, As, Sb

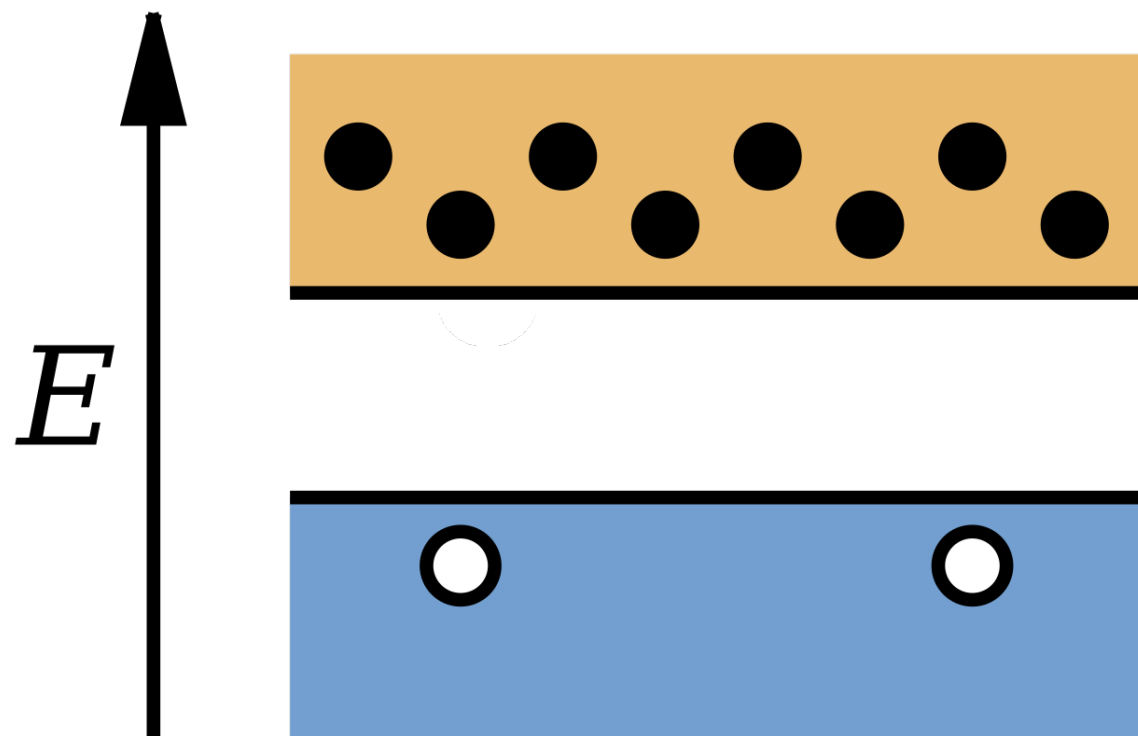
N típusú félvezető

N típusú félvezető



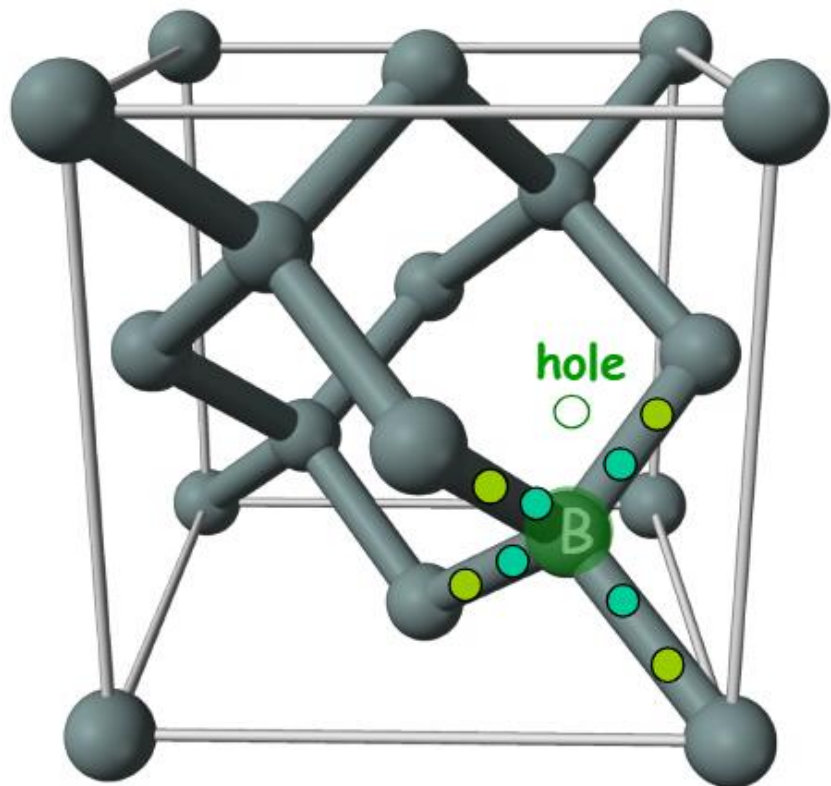
5-ös főcsoport elemei: P, As, Sb

- Többségi töltéshordozó: elektron
- Kisebbségi töltéshordozó: lyuk



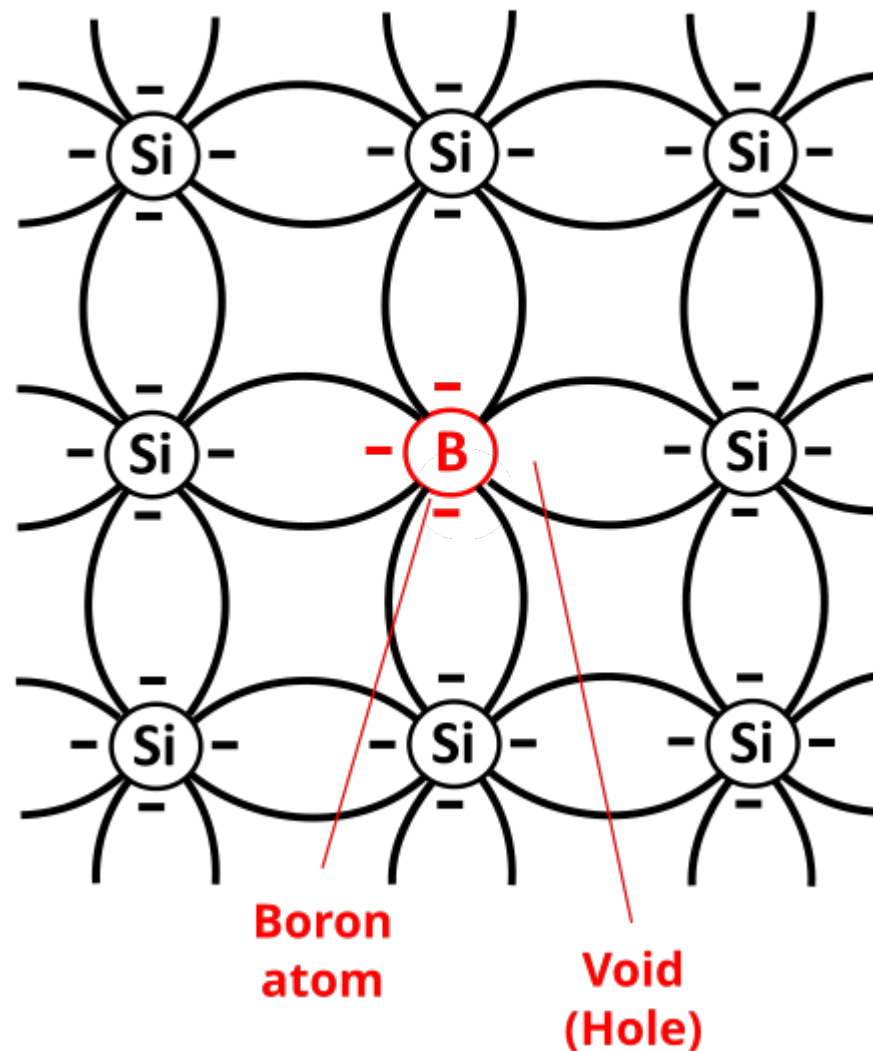
P típusú félvezető

P típusú félvezető



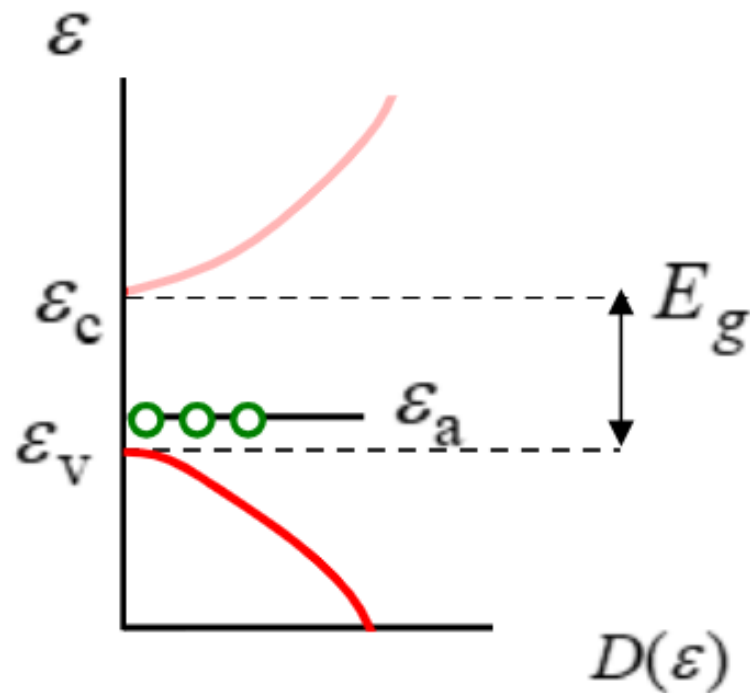
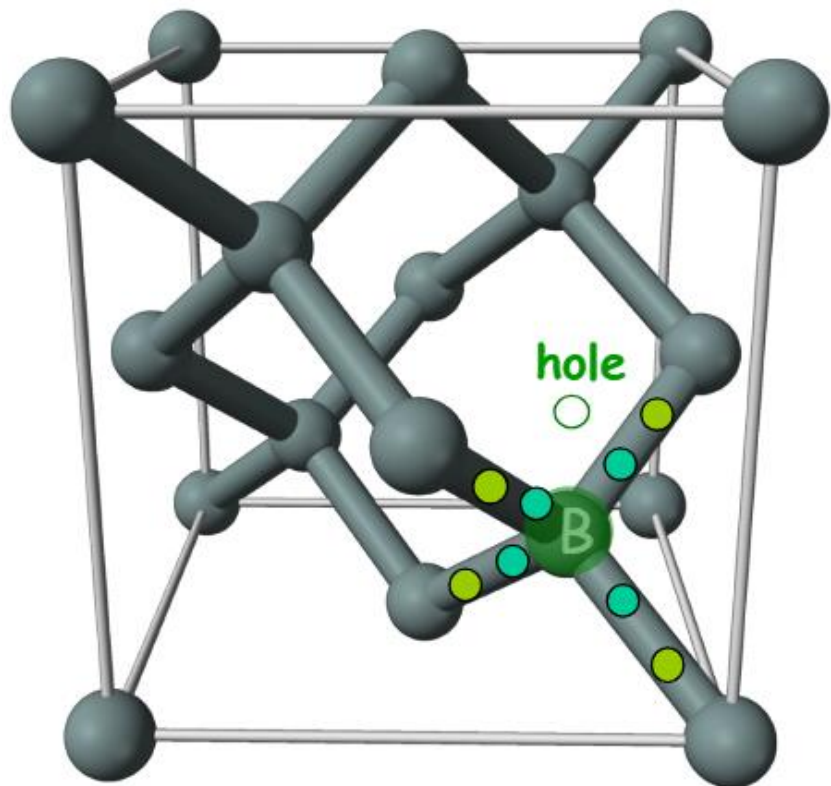
3-as főcsoport elemei: B, Ga, In

P-Type



P típusú félvezető

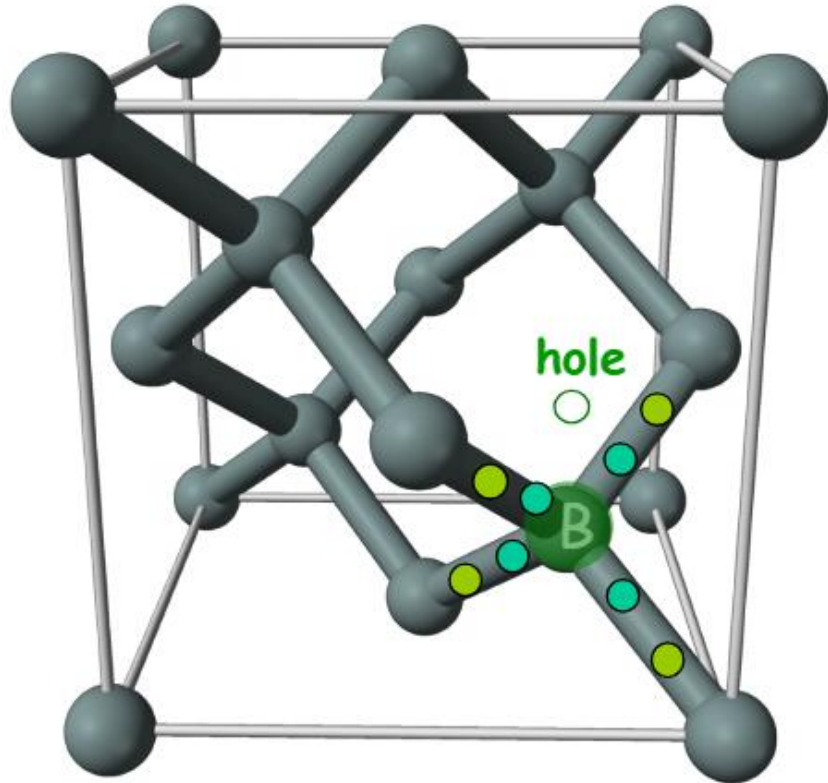
P típusú félvezető



3-as főcsoport elemei: B, Ga, In

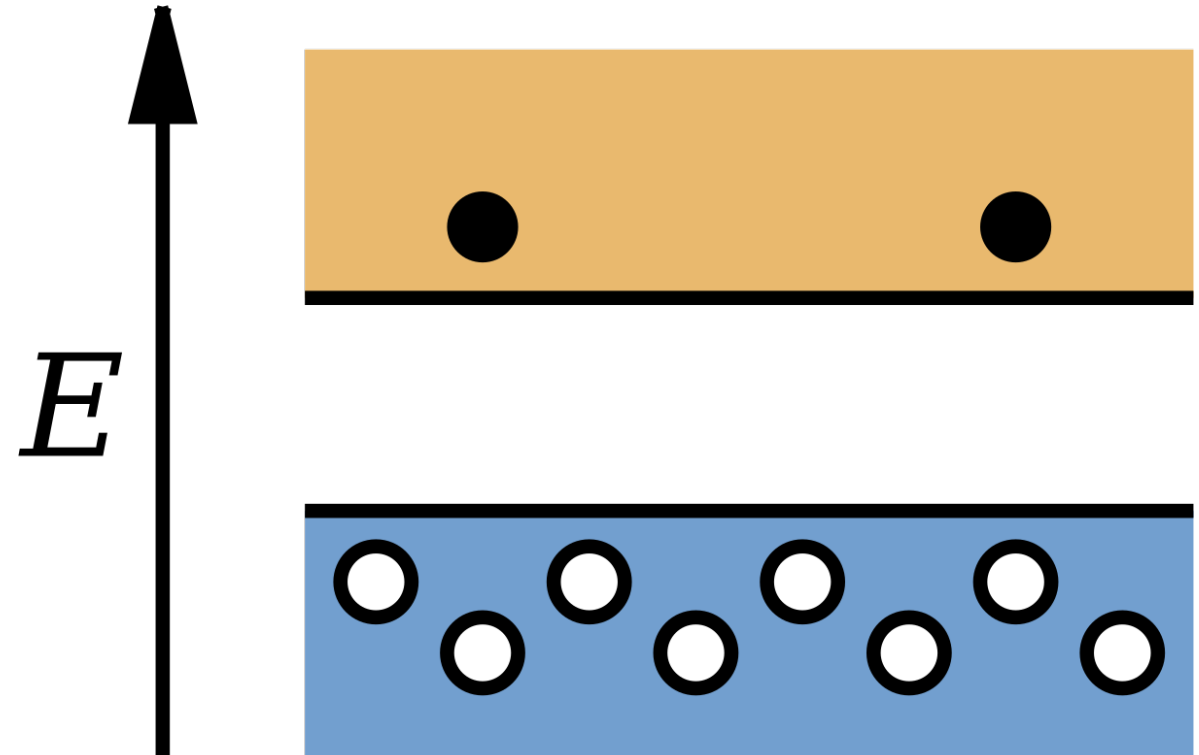
P típusú félvezető

P típusú félvezető

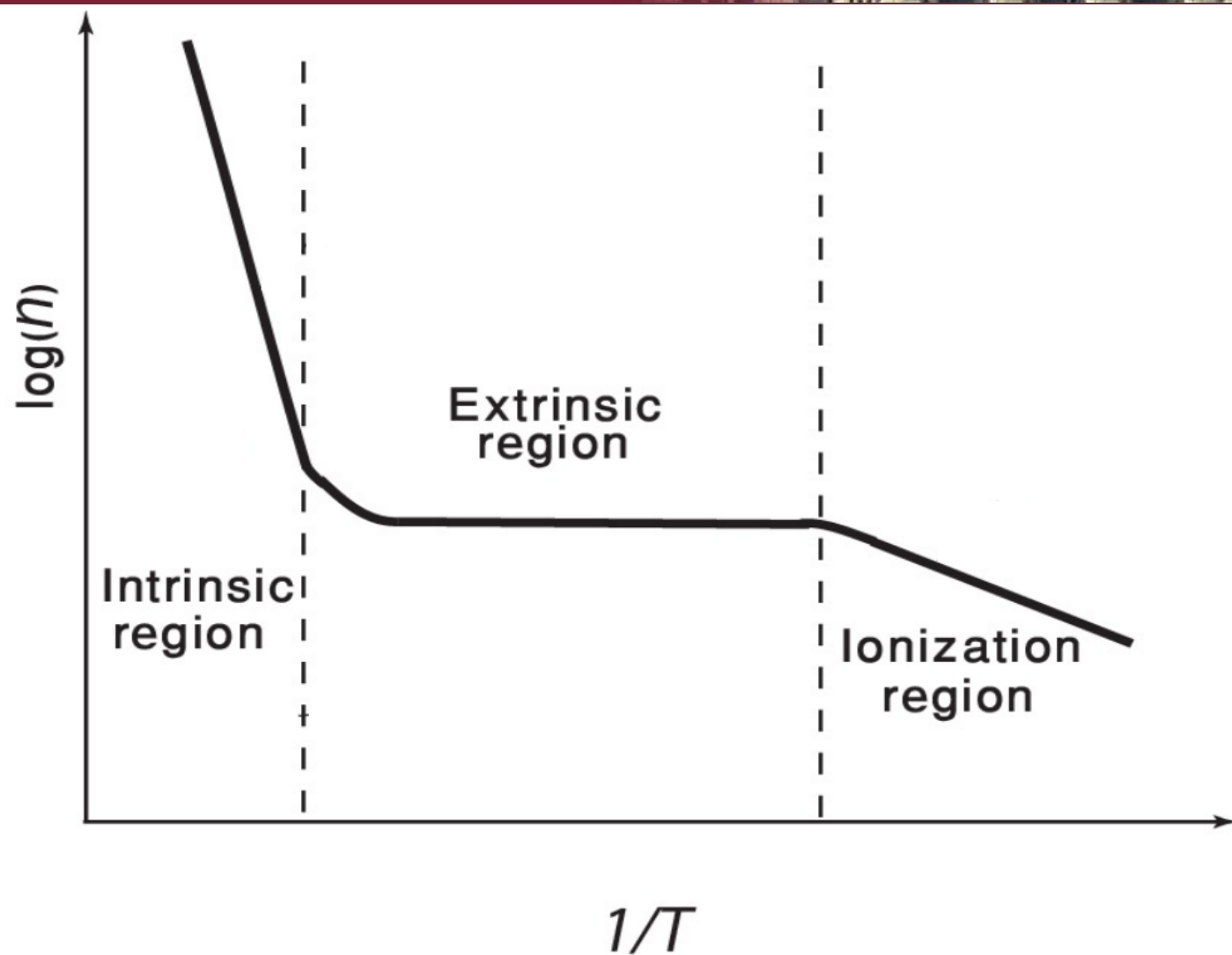


3-as főcsoport elemei: B, Ga, In

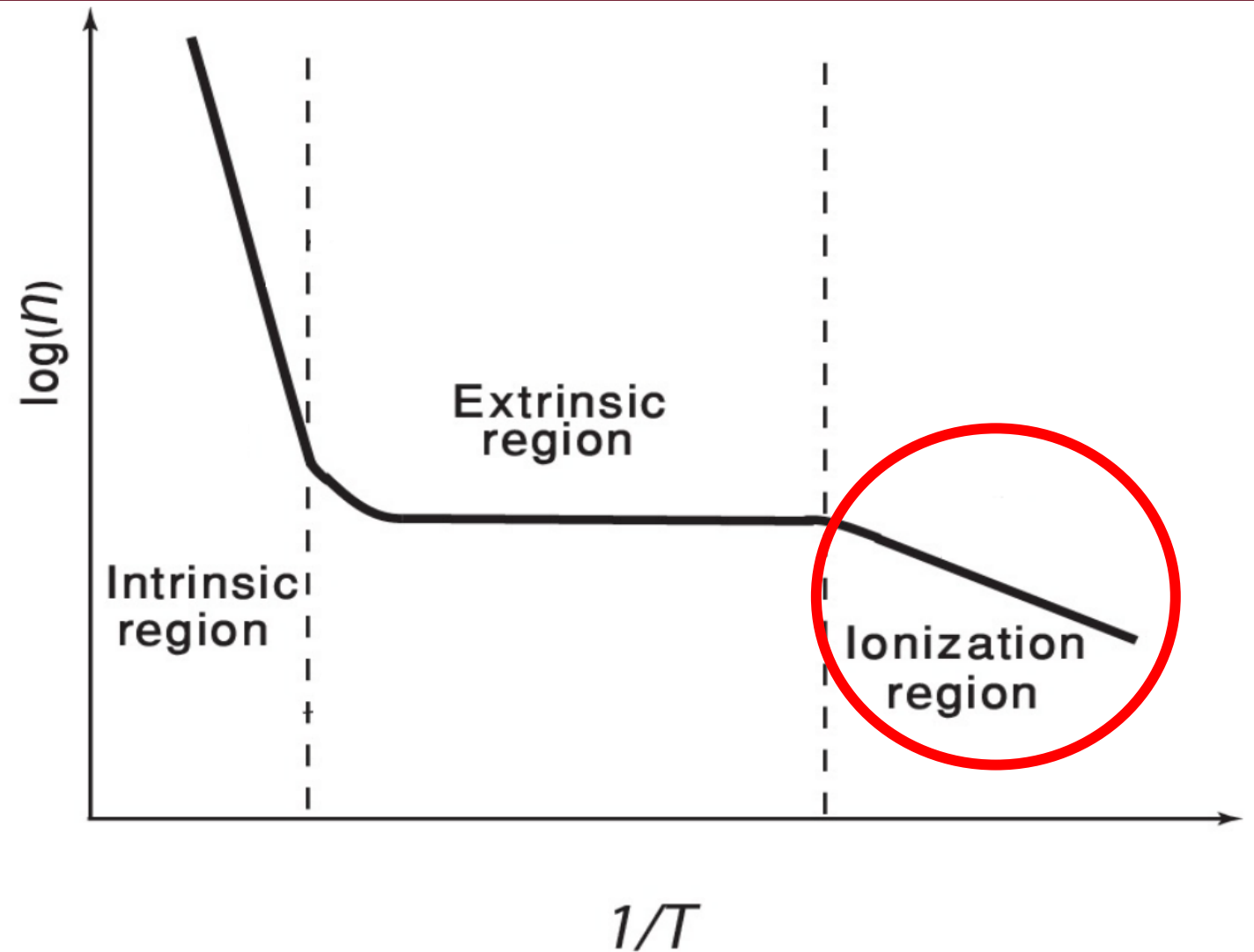
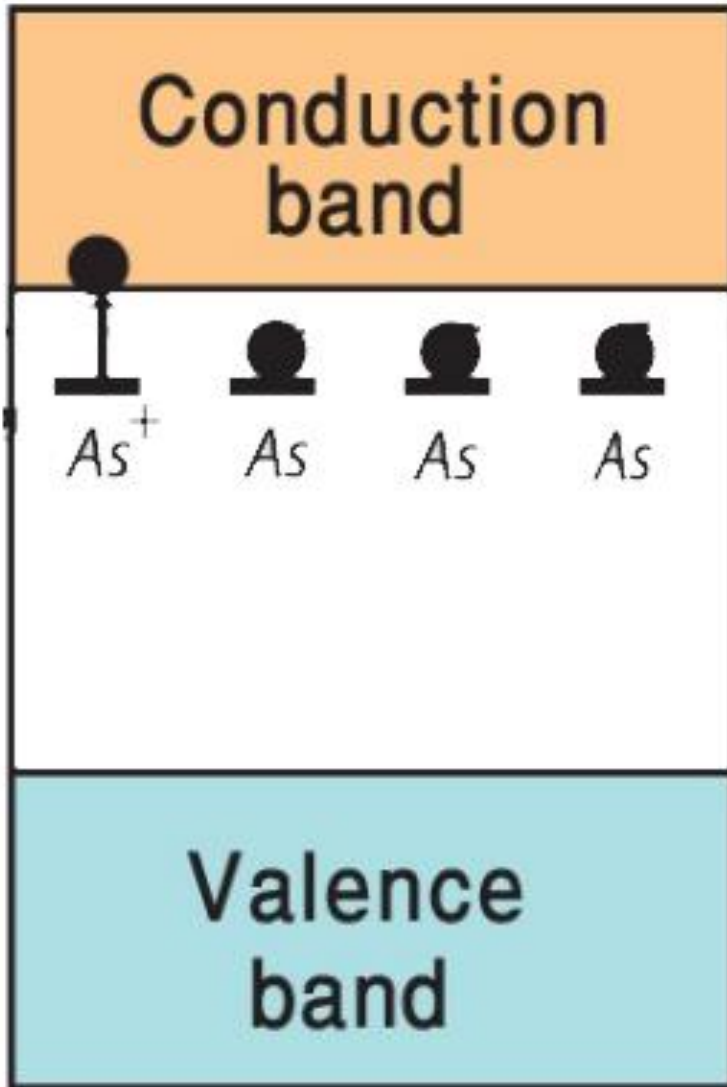
- Többségi töltéshordozó: lyuk
- Kisebbségi töltéshordozó: elektron



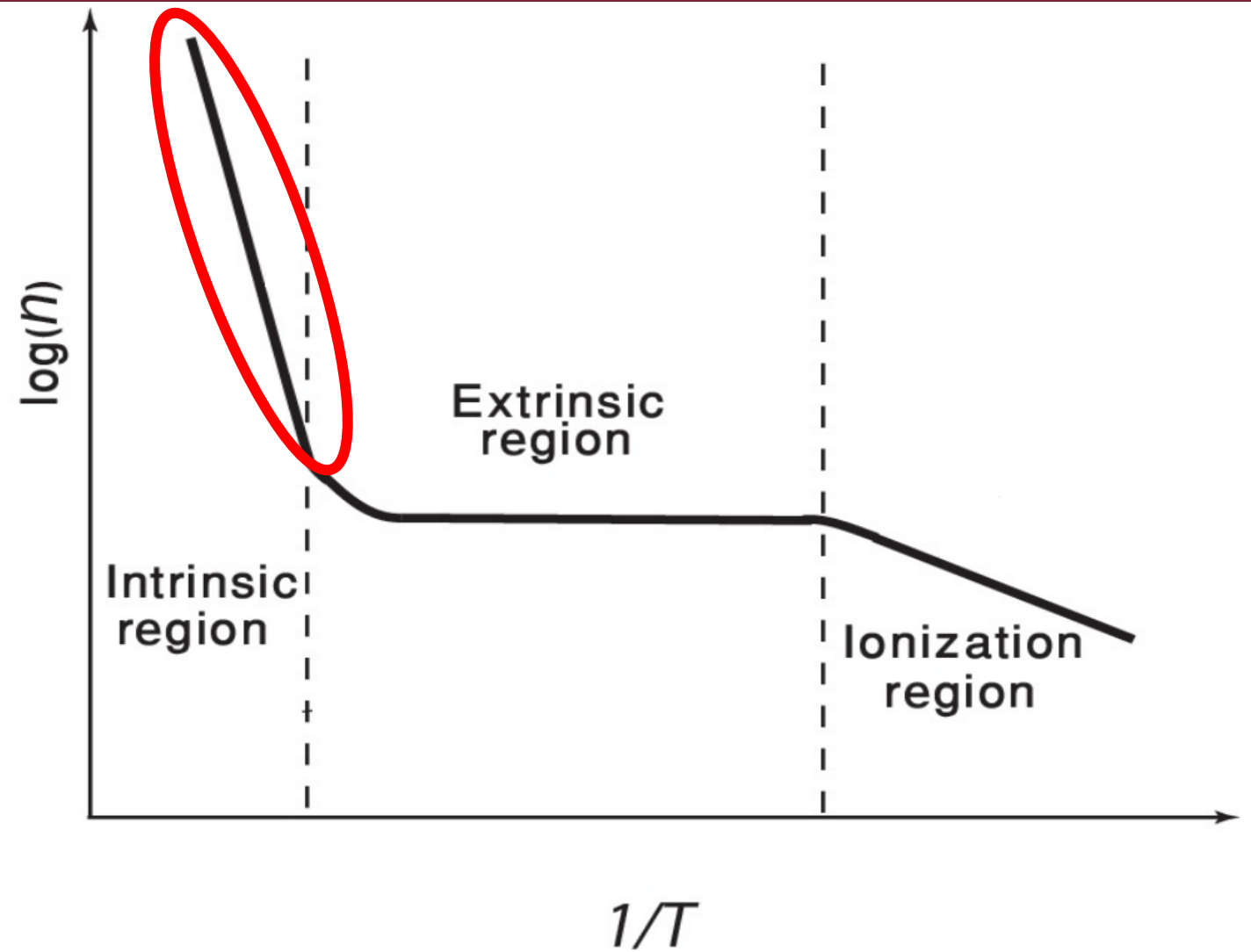
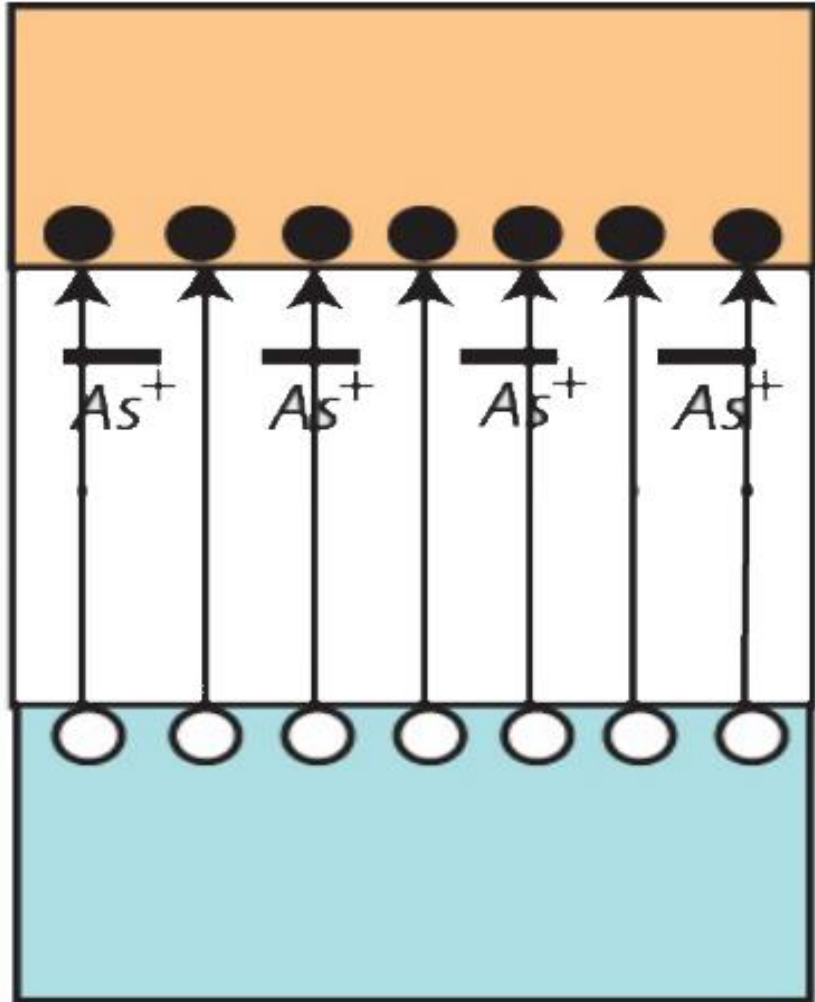
Vezetési karakterisztika



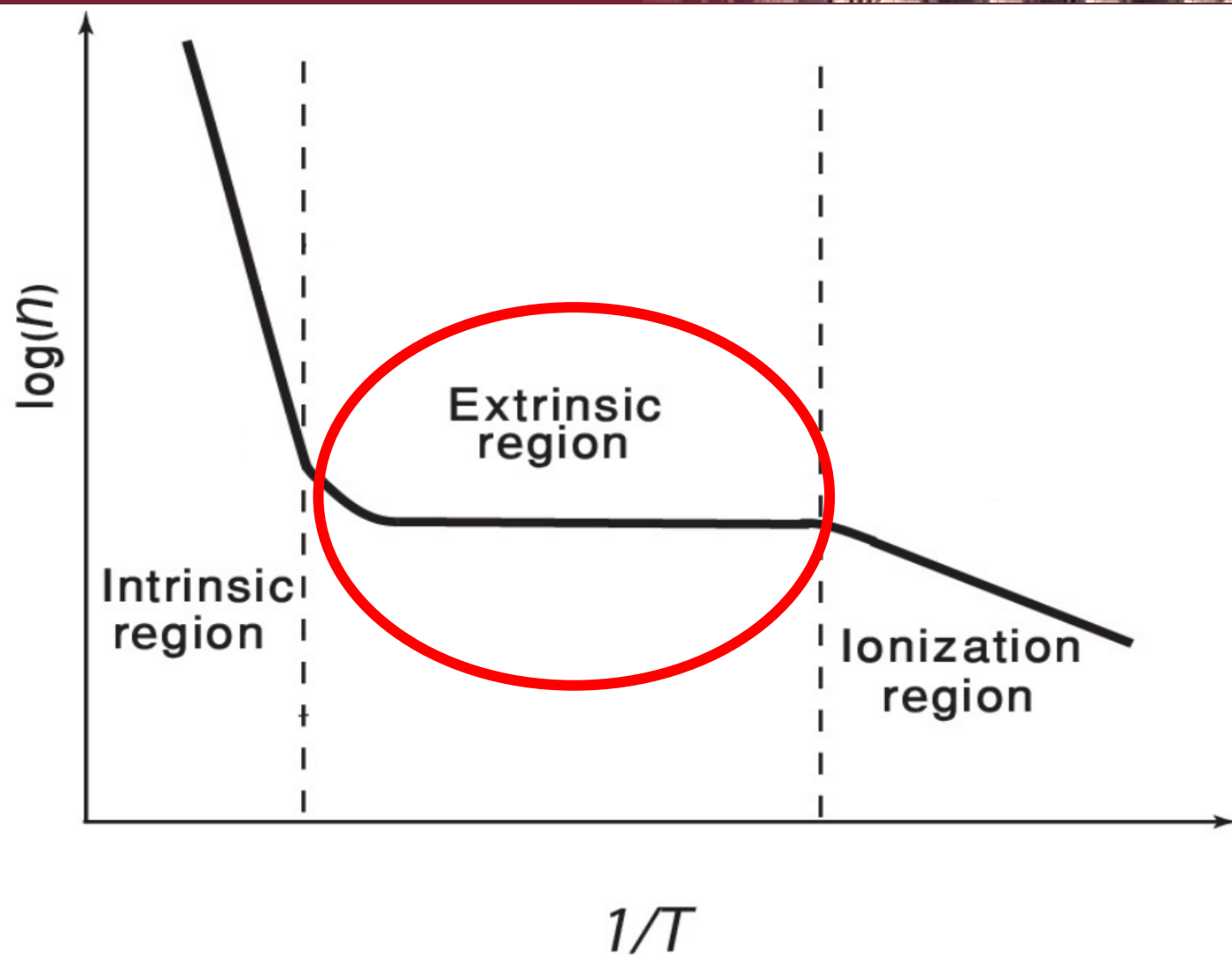
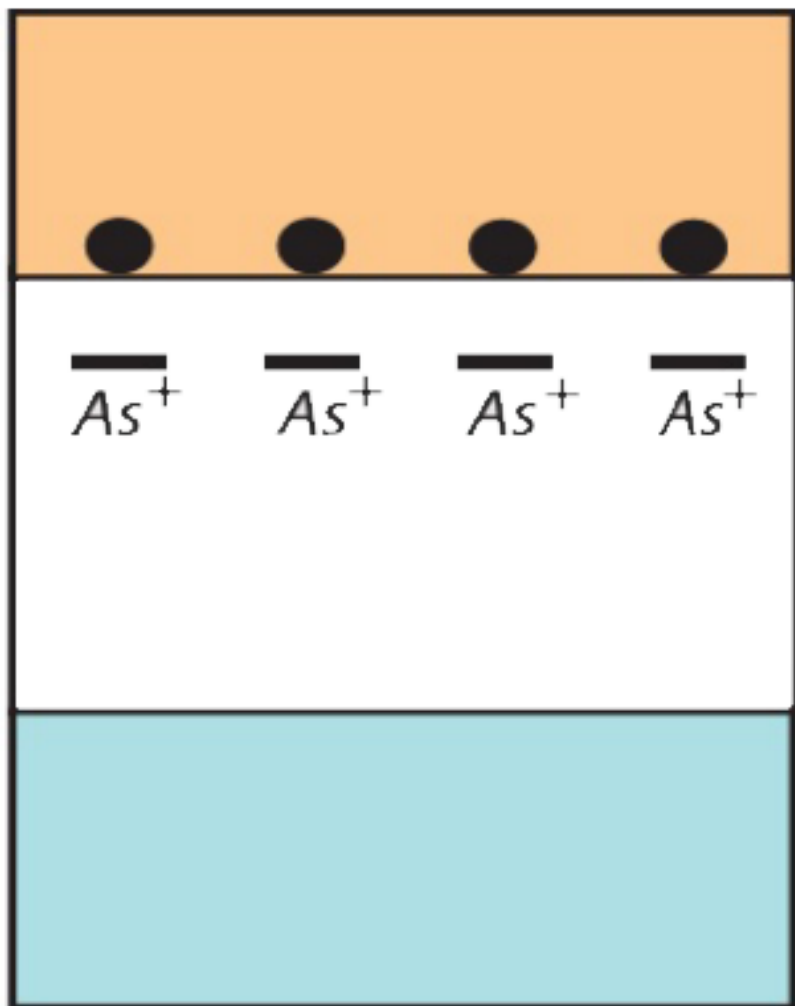
Vezetési karakterisztika



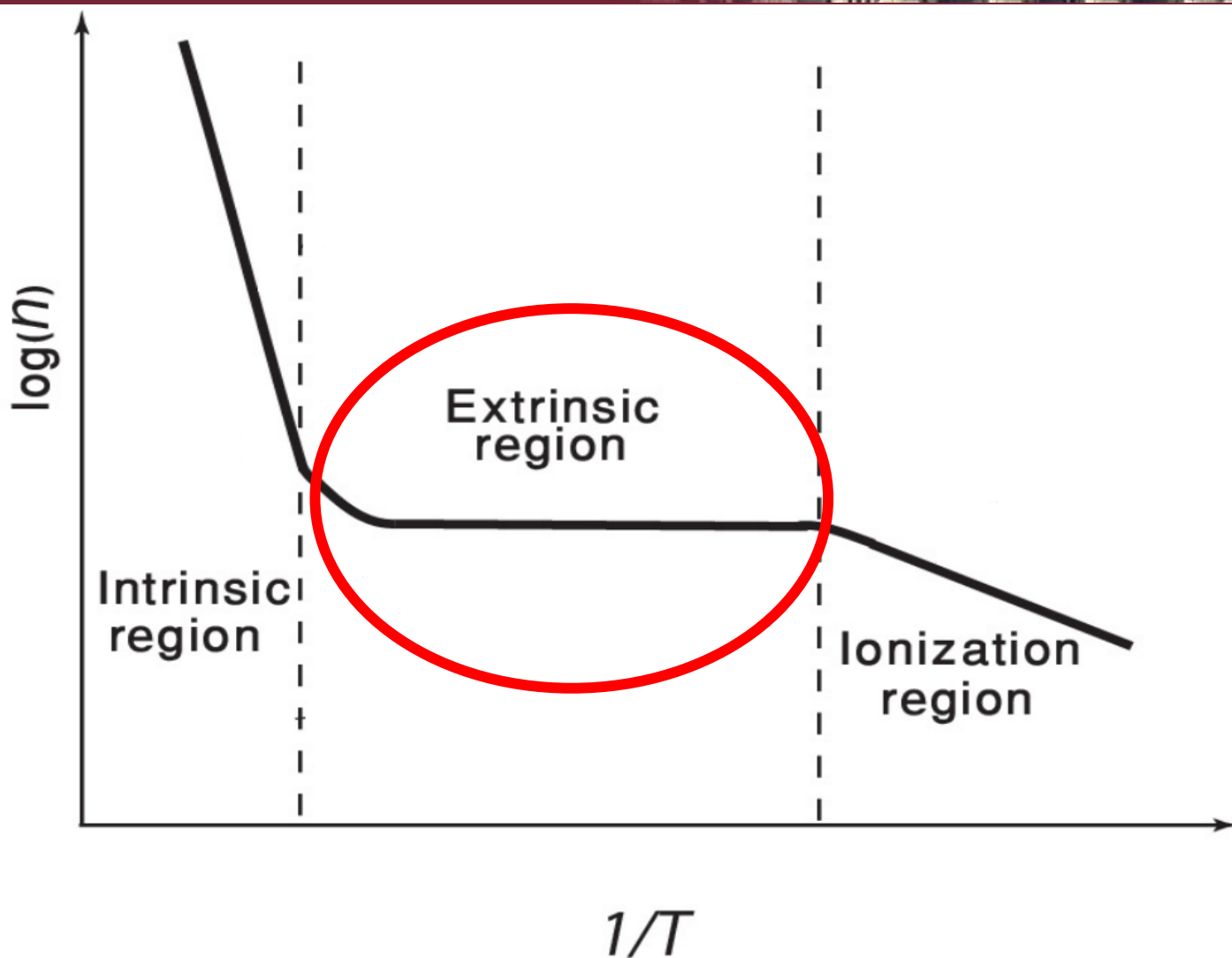
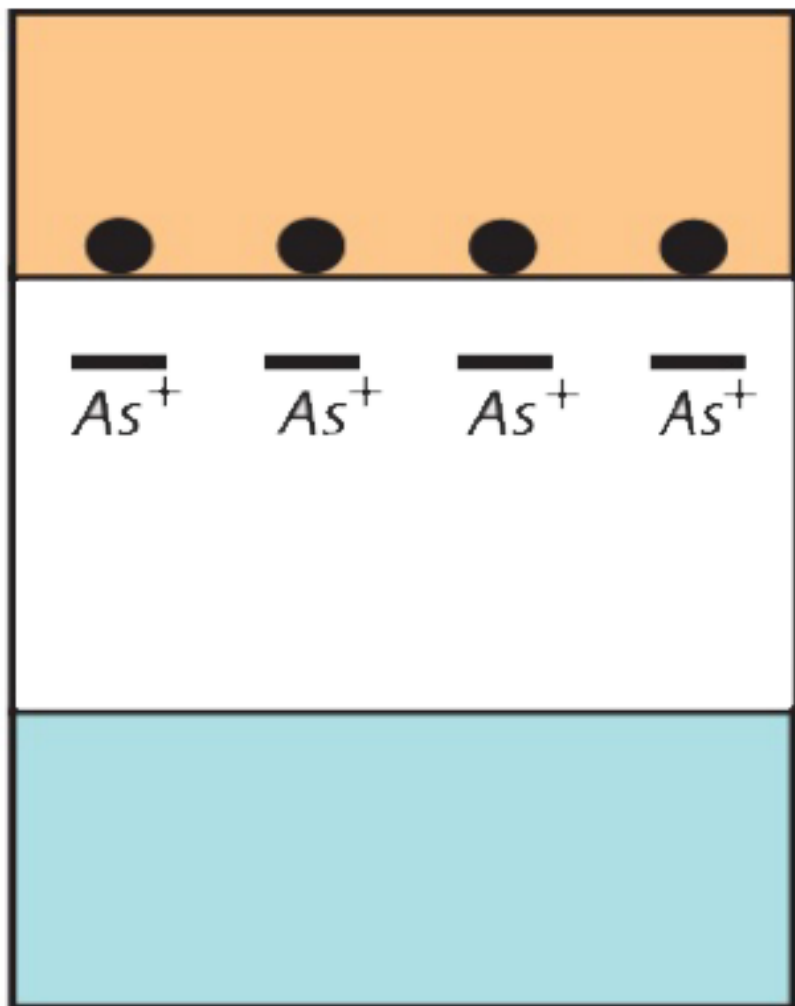
Vezetési karakterisztika



Vezetési karakterisztika

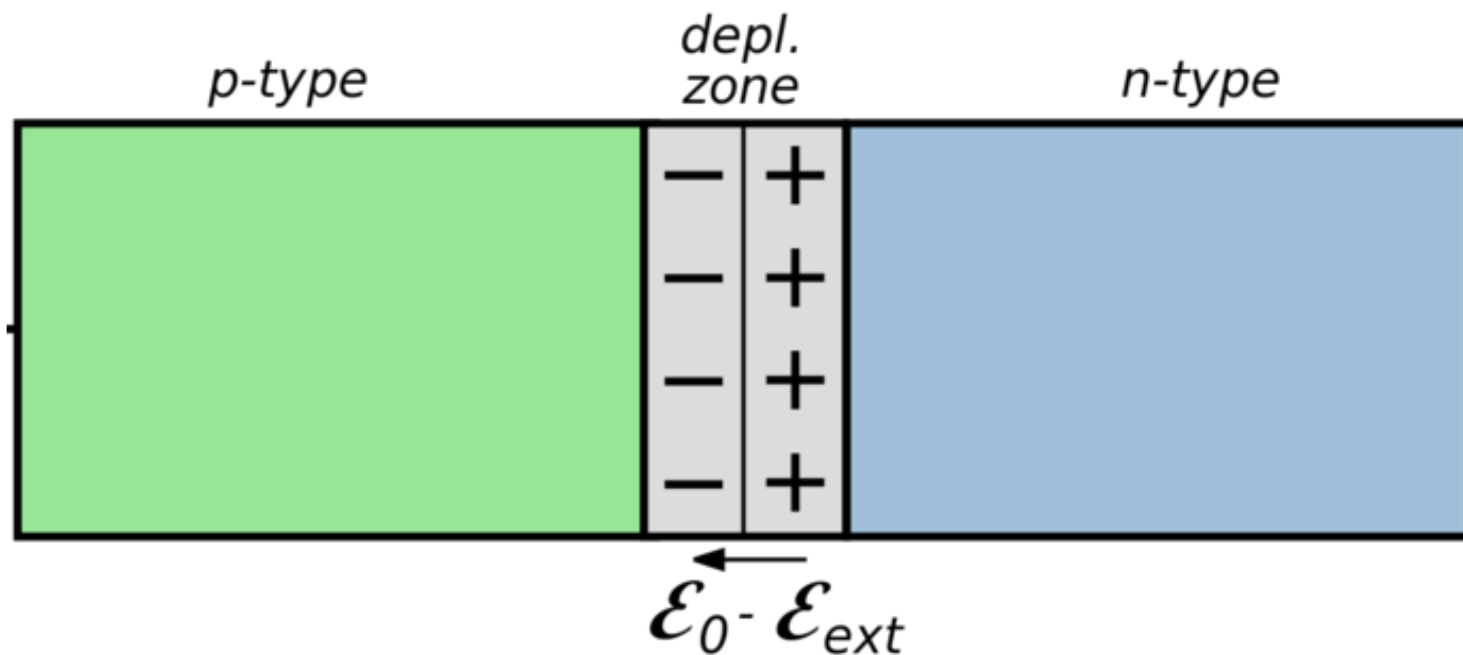


Vezetési karakterisztika

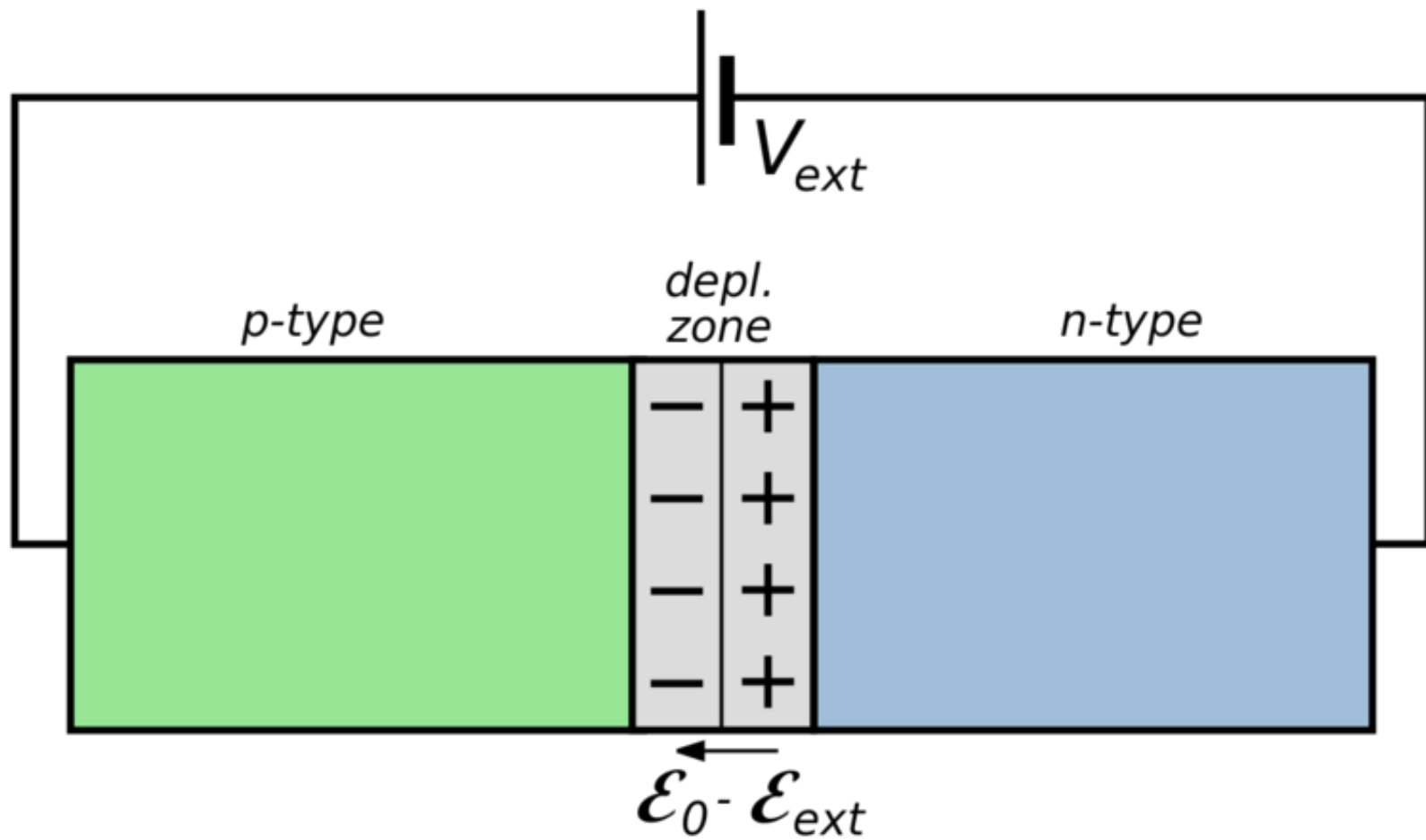


- 250K – 350K (-50°C – 100°C)!!
- Dópolással kontrollálható!!

- Rekombináció
- Kiürítési réteg
- Beépített elektromos tér



PN átmenet



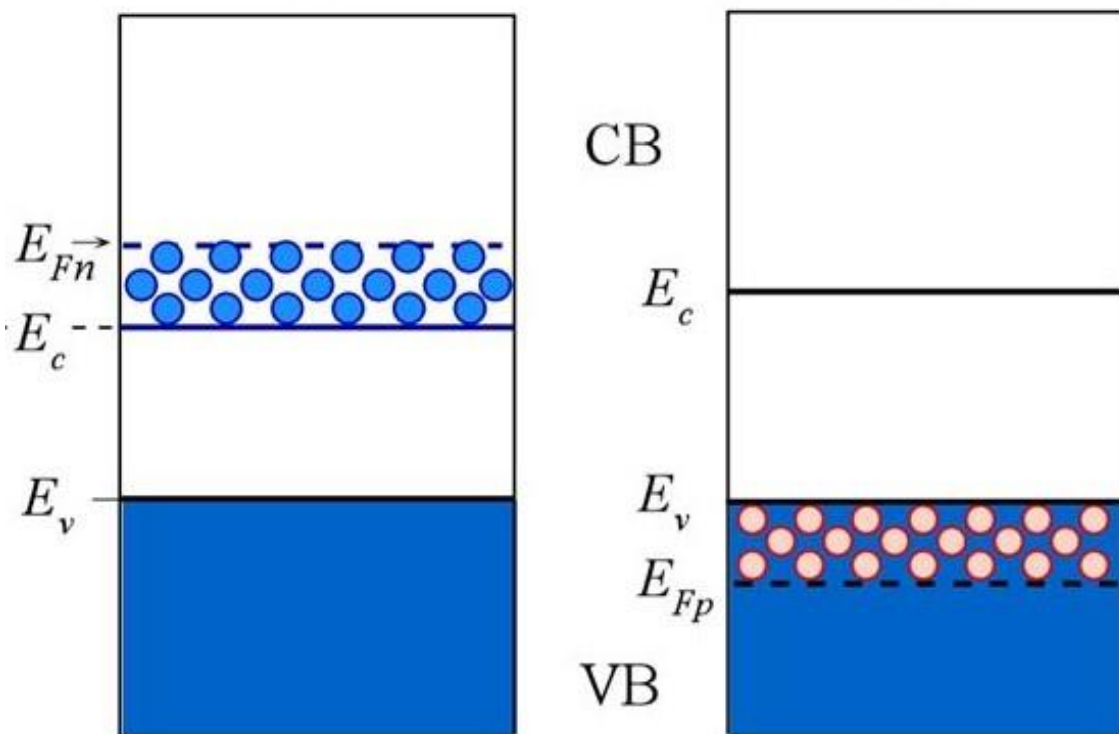
- Rekombináció
- Kiürítési réteg
- Beépített elektromos tér
- Külső elektromos tér

Esaki dióda

Degenerált félvezető

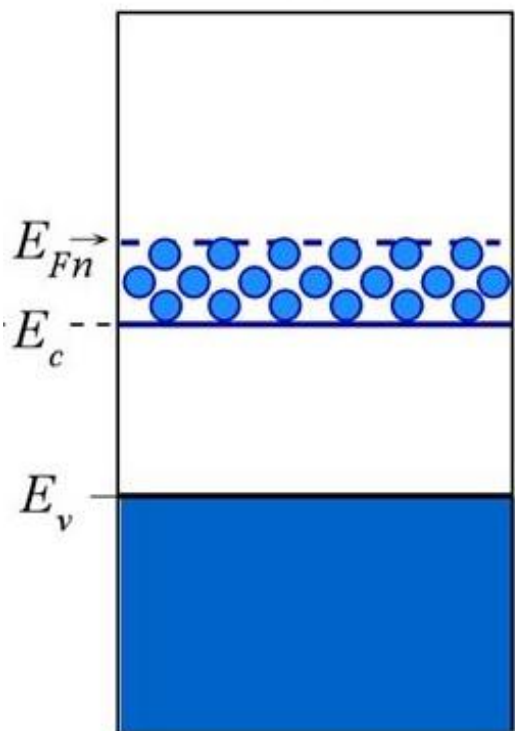
n-típusú

p-típusú

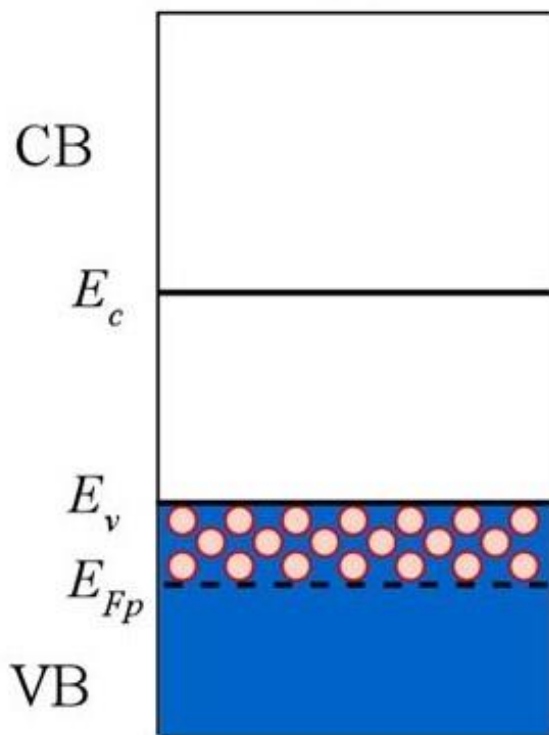


Degenerált félvezető

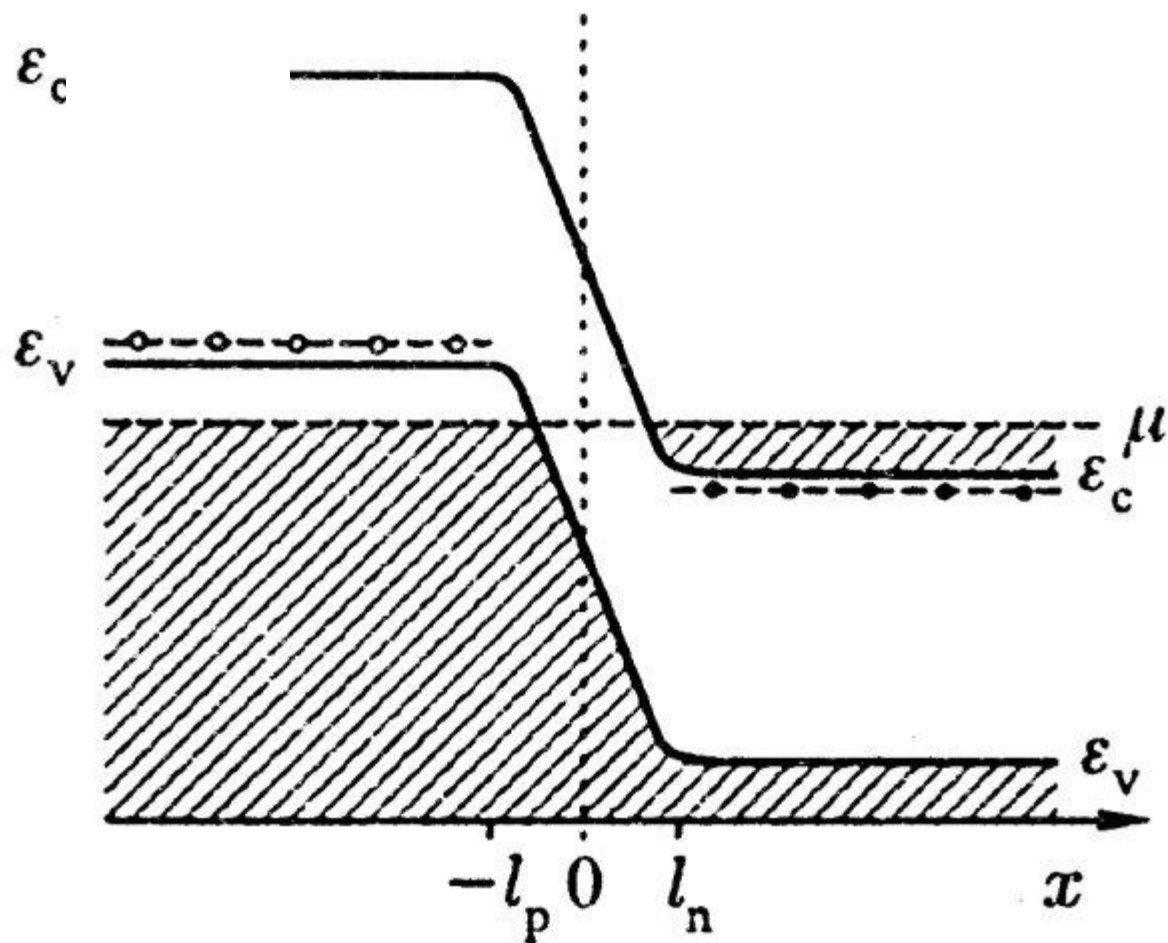
n-típusú



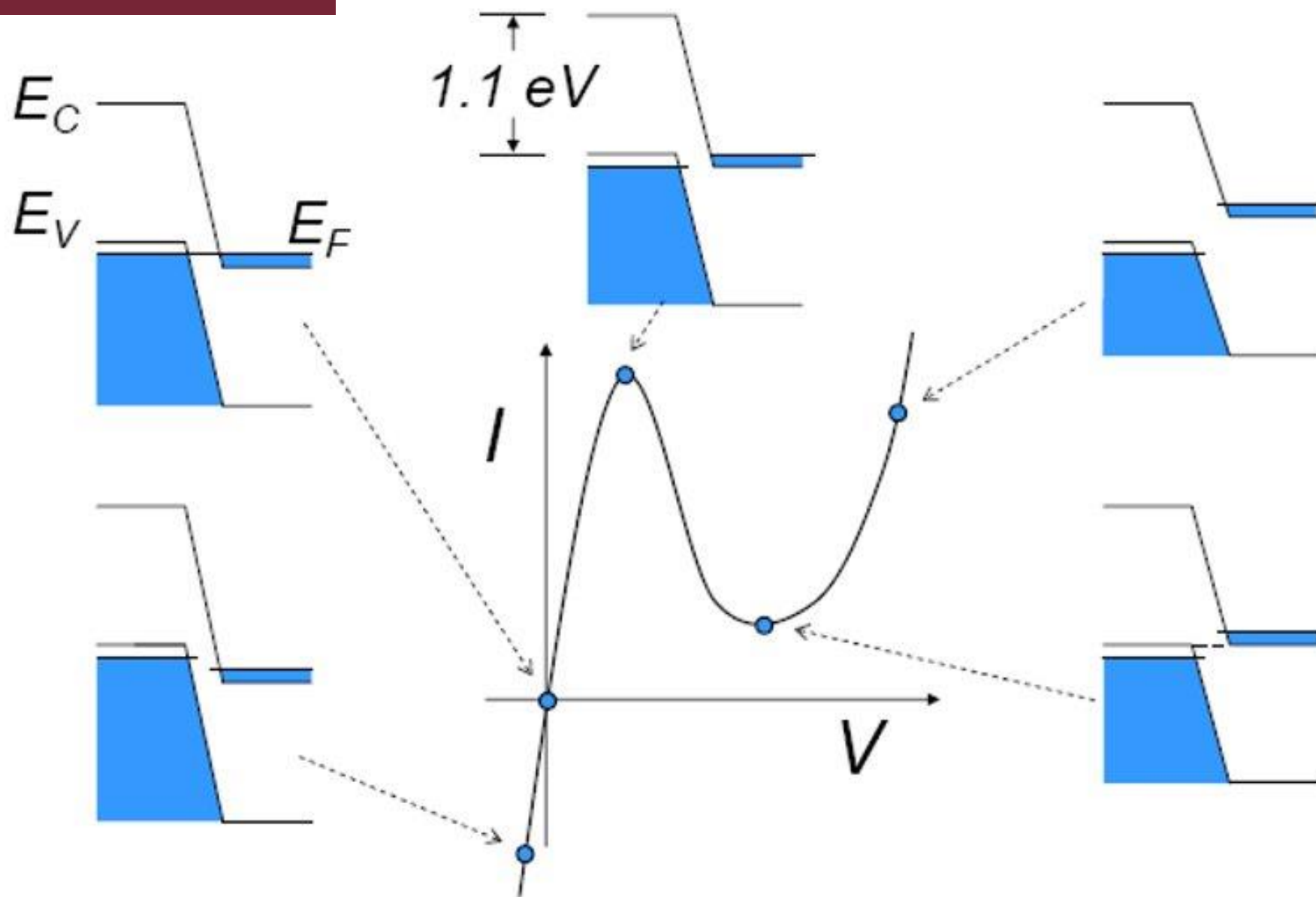
p-típusú



Sávszerkezet

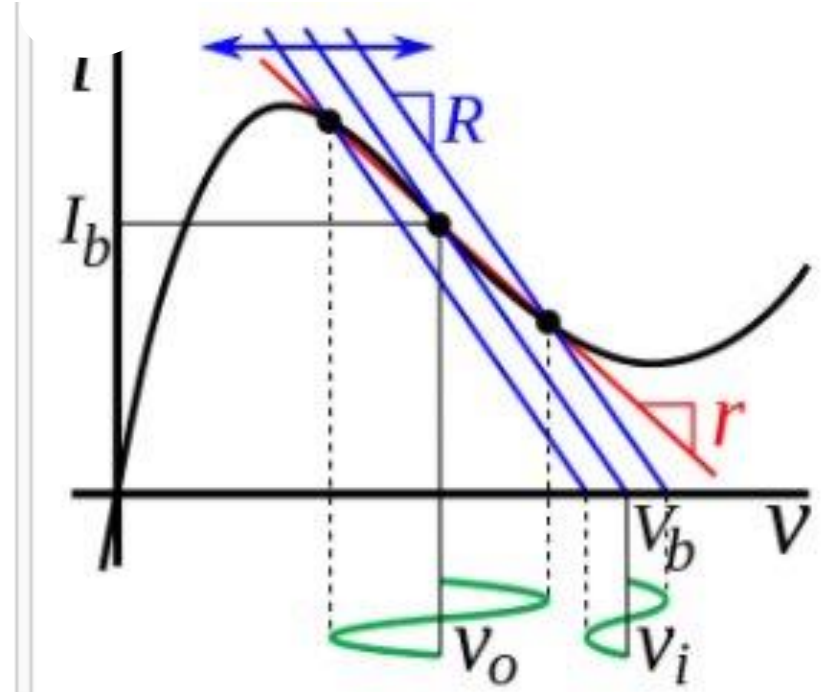
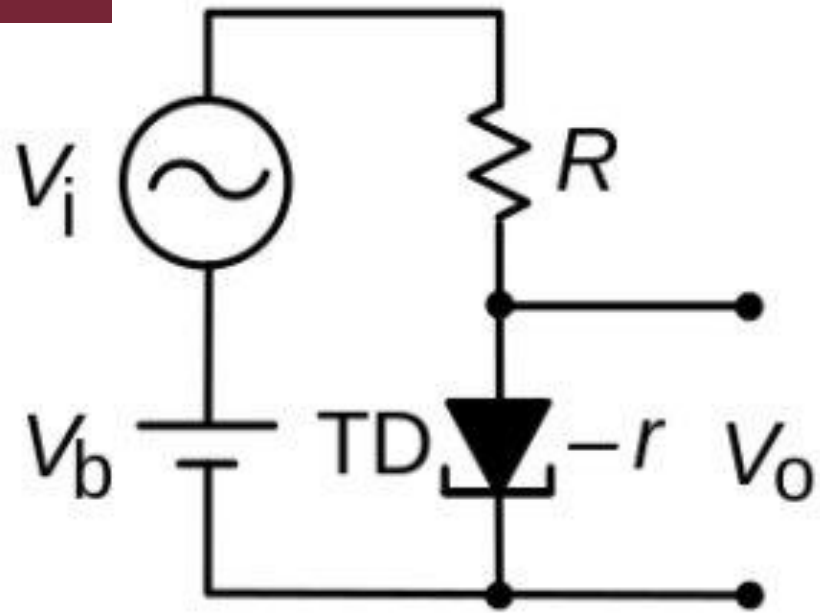


Esaki dióda



Esaki dióda

$$\Delta v / \Delta i = -r$$



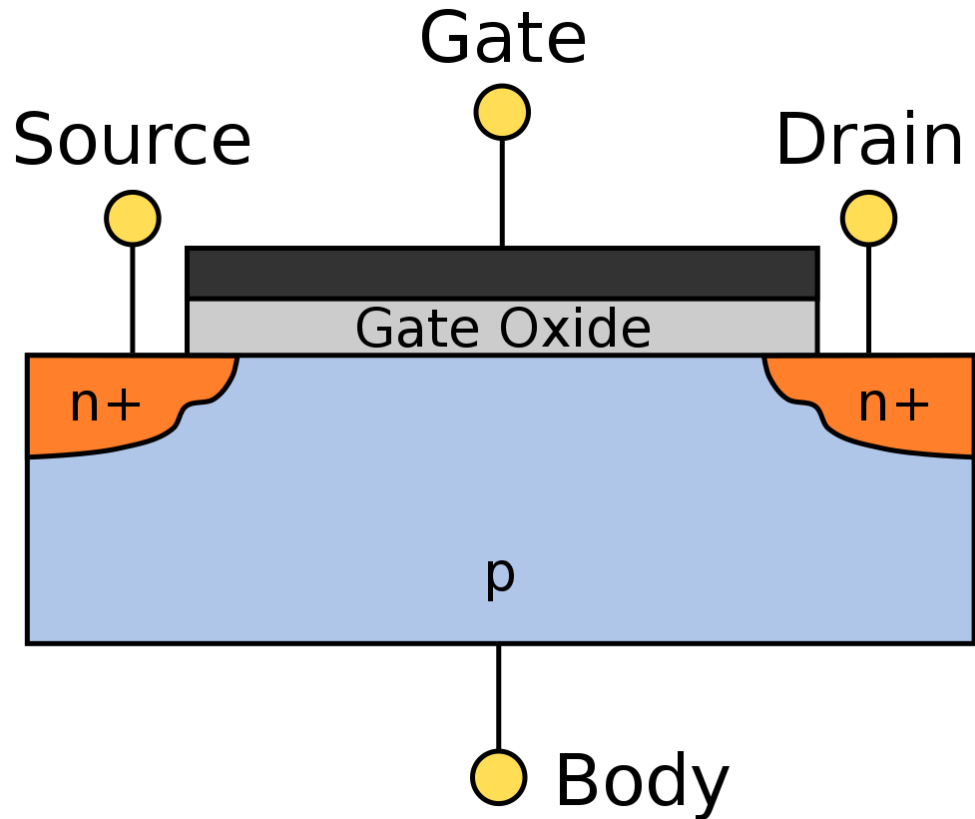
- Erősítő áramkör
- V_i AC jel, ezt erősítem
- V_b DC feszültség

$$v_o = \frac{-r}{R - r} v_i = \frac{r}{r - R} v_i$$

voltage gain

$$G_v = \frac{r}{r - R}$$

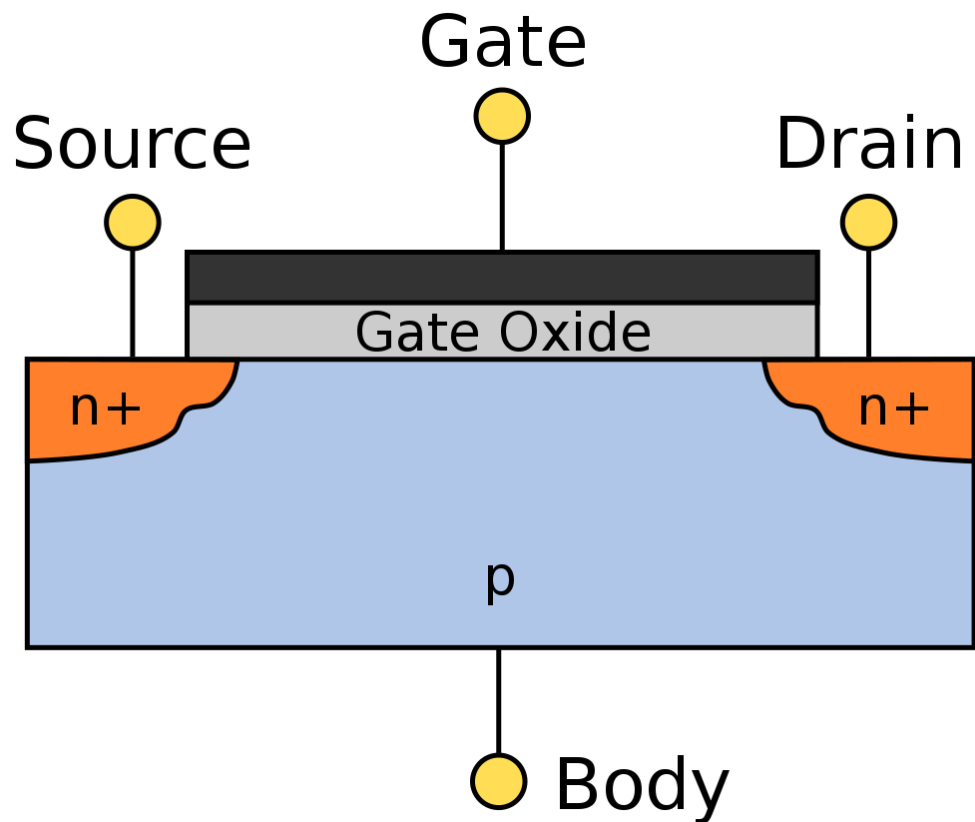
Tranzisztor (FET)



$V_{\text{kapu}} > 0$ → áram folyik

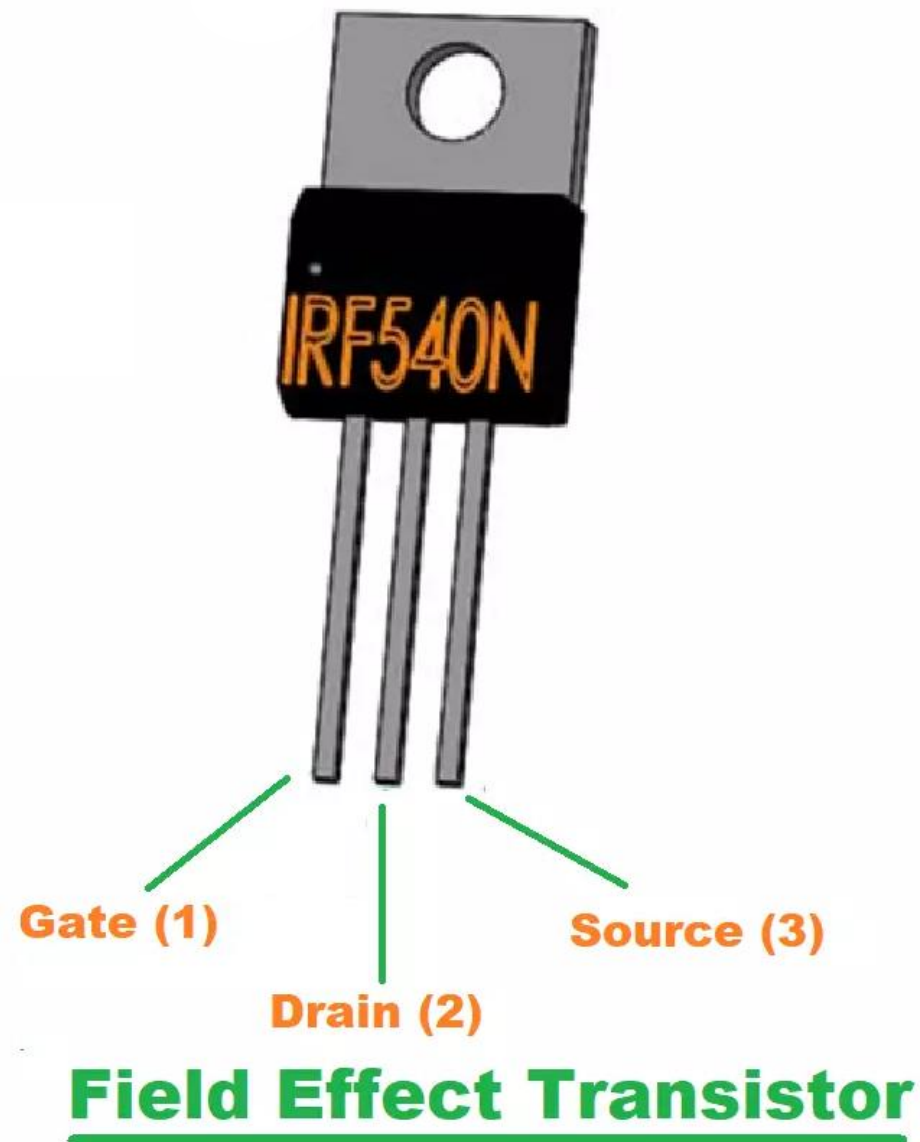
$V_{\text{kapu}} \leq 0$ → nem folyik áram

Tranzisztor (FET)

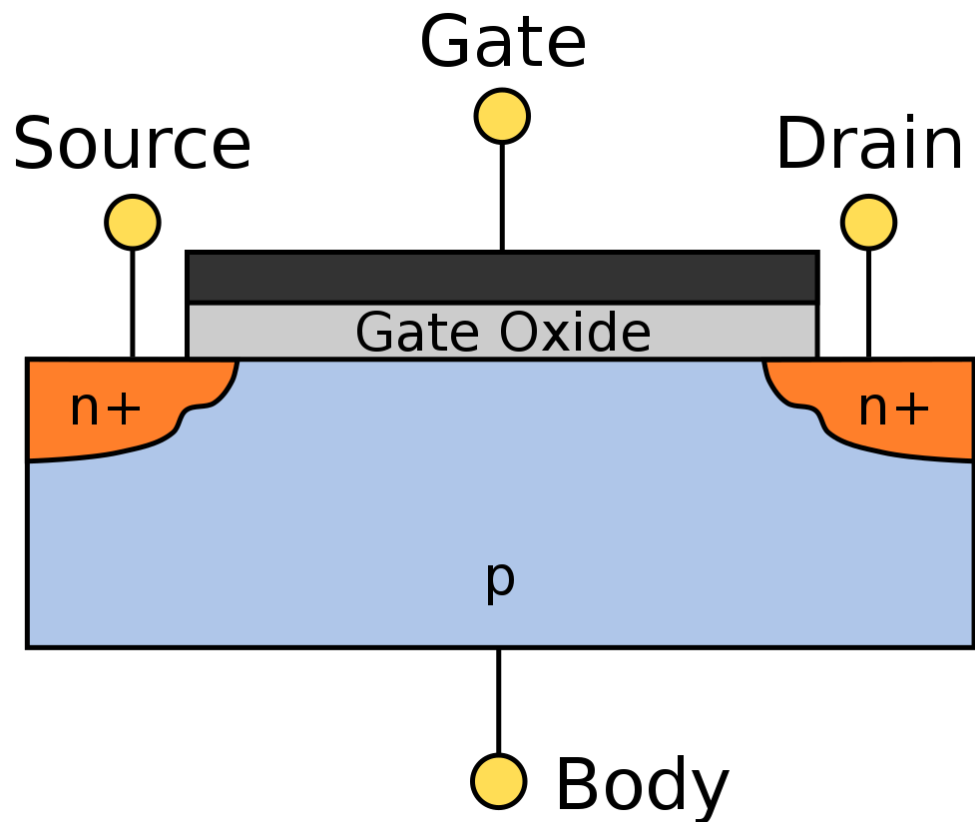


$V_{\text{kapu}} > 0$ → áram folyik

$V_{\text{kapu}} \leq 0$ → nem folyik áram

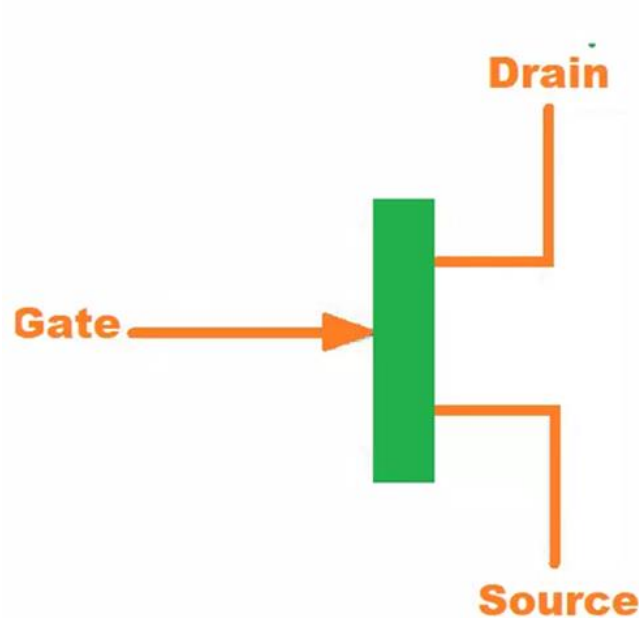


Tranzisztor (FET)

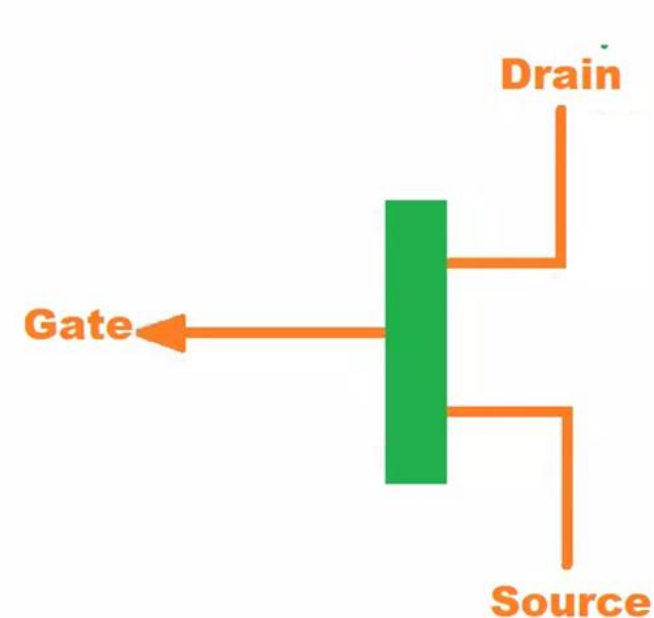


$V_{\text{kapu}} > 0$  áram folyik

$V_{\text{kapu}} \leq 0$  nem folyik áram



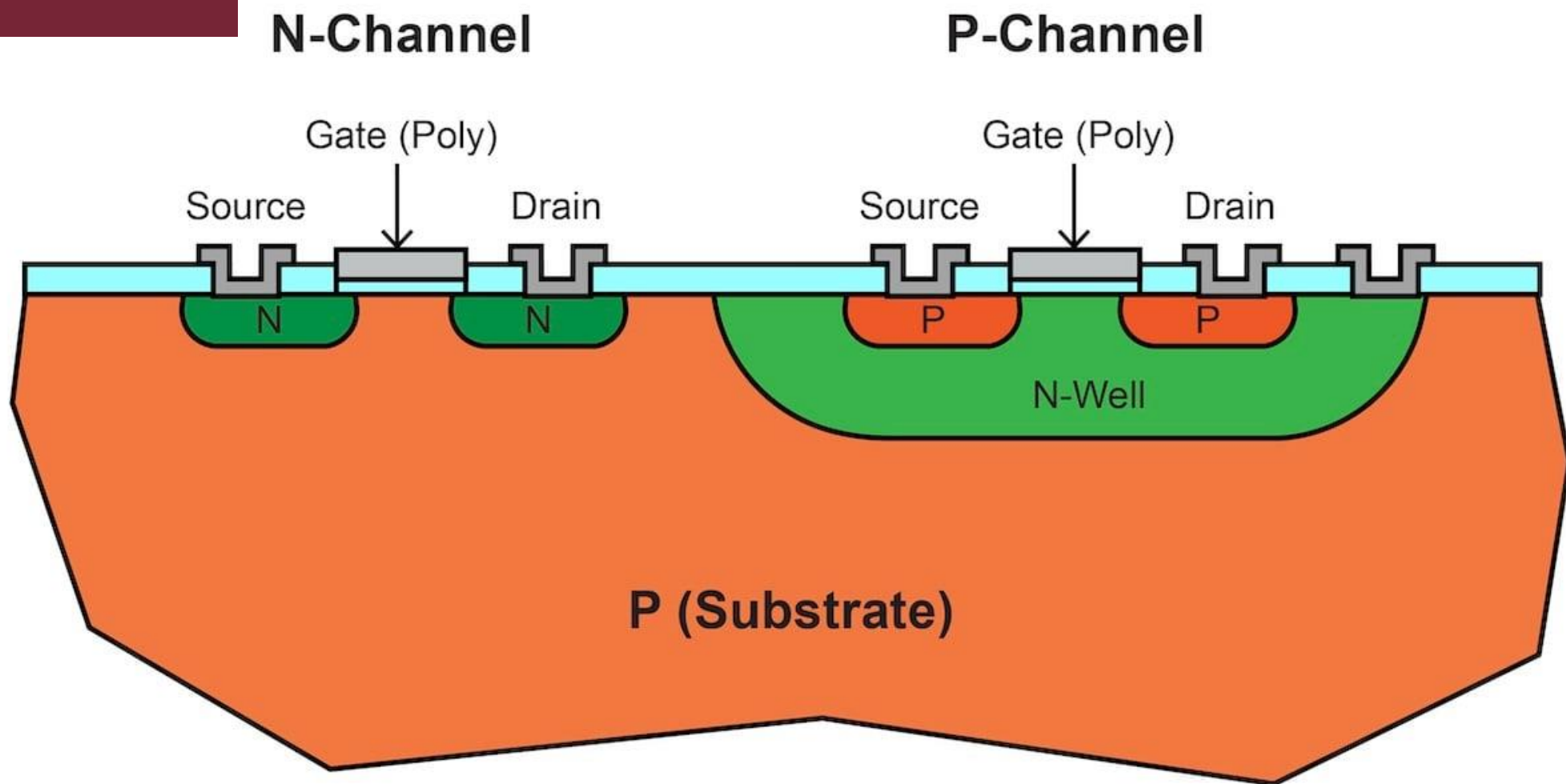
N-Channel



P-Channel

Symbol of Field Effect transistor

NMOS és PMOS



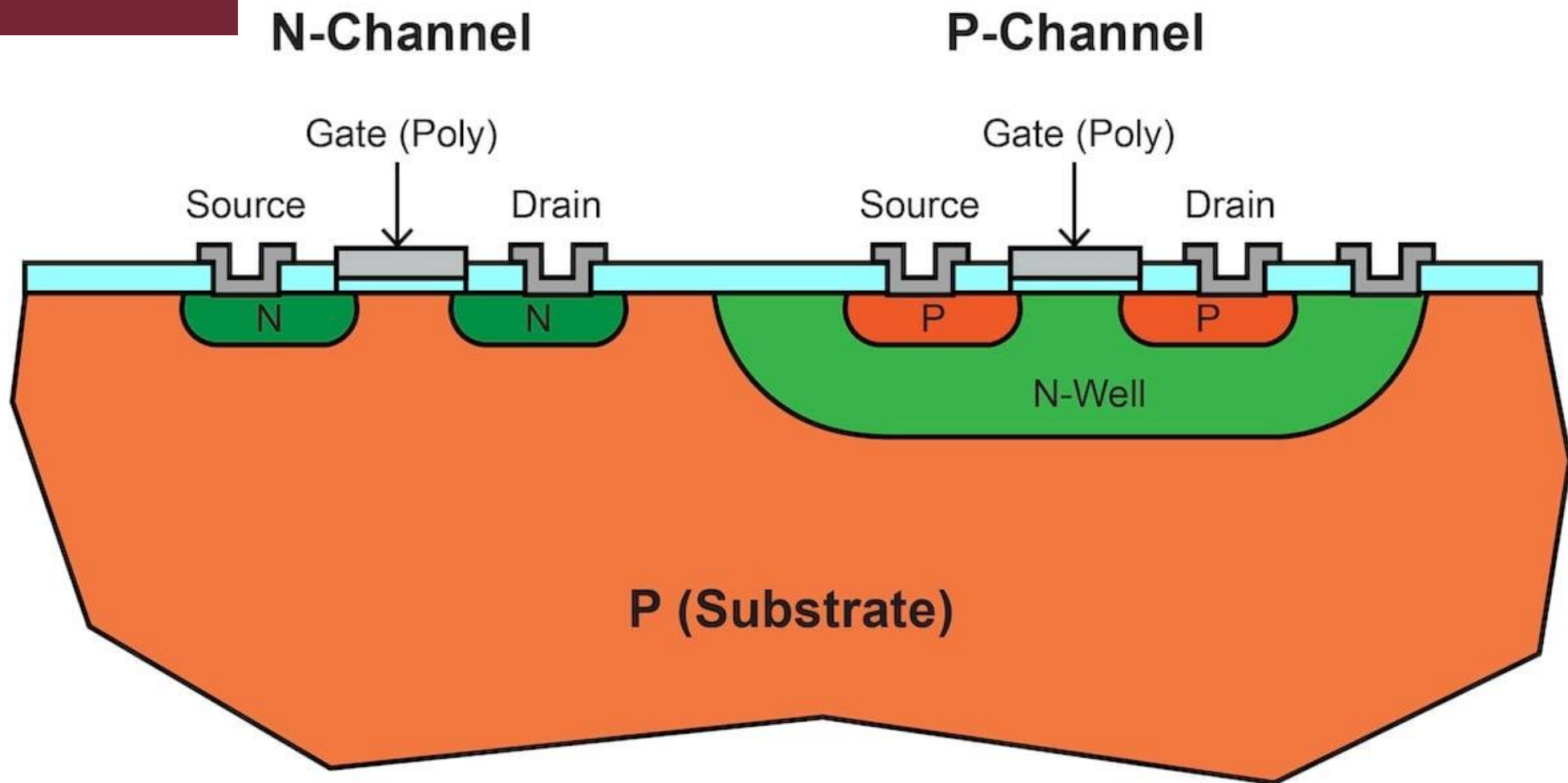
NMOS és PMOS

NMOS:

- N csatorna
- $V_{\text{kapu}} > 0$ nyit

PMOS:

- P csatorna
- $V_{\text{kapu}} < 0$ nyit



Tranzisztor (FET)

Input

Output

A	B	AND	NAND
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

PMOS

A

B

Out

NMOS

A

B

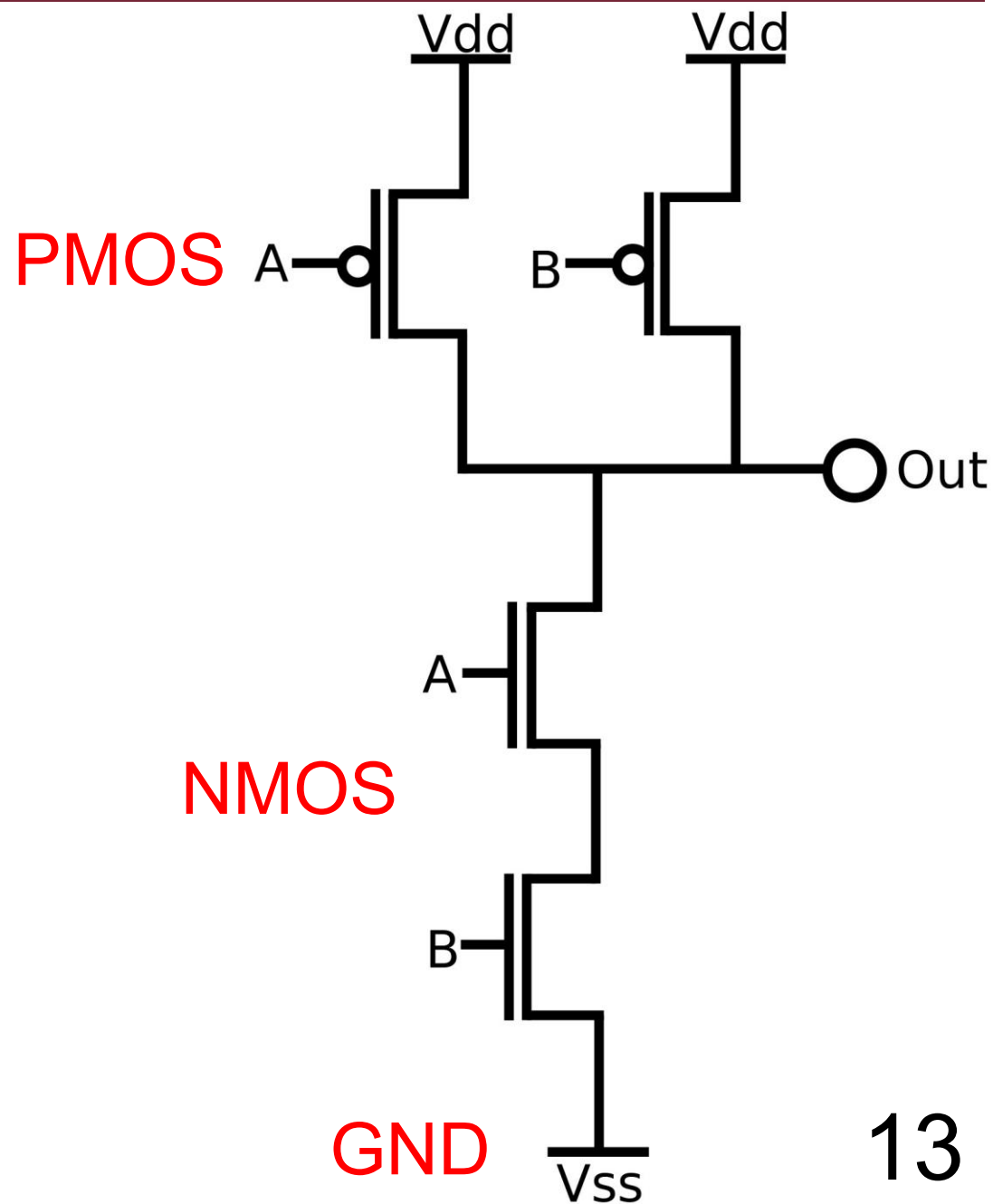
GND

Vss

Tranzisztor (FET)

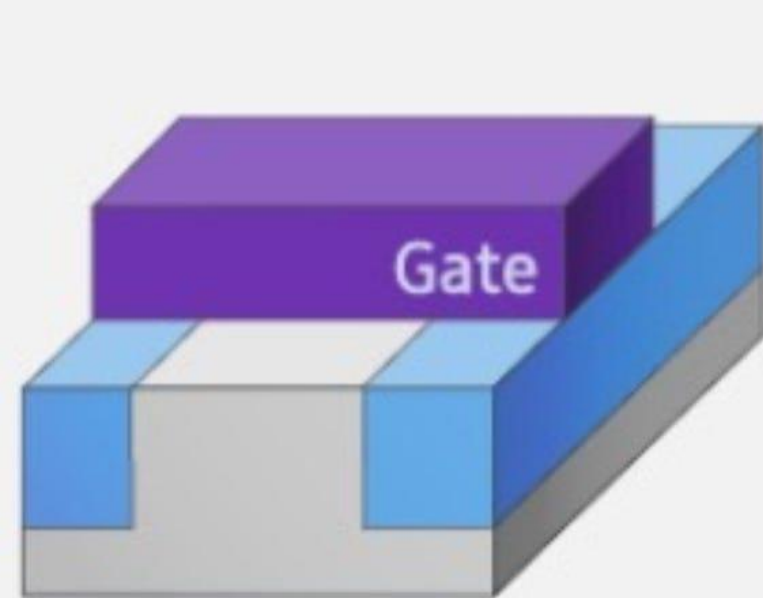
Input		Output	
A	B	AND	NAND
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

Nem folyik áram, feszültség
tárolja az információt!

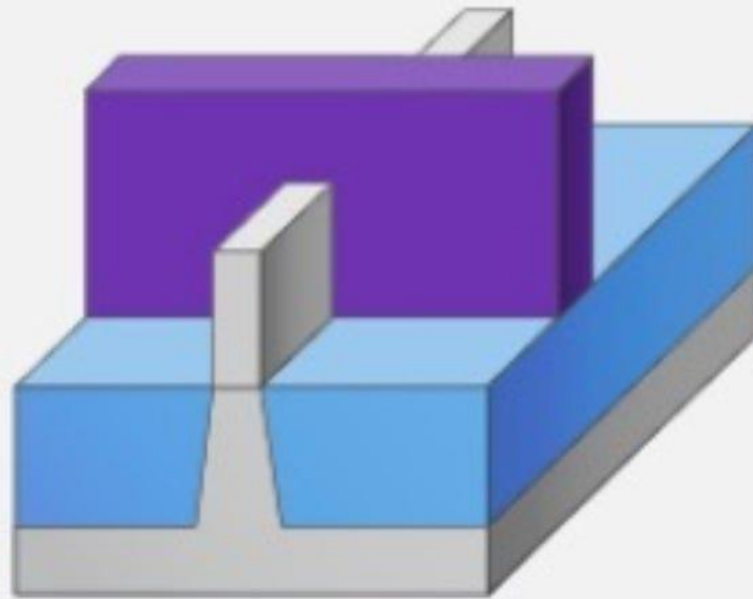


Tranzisztor (FET)

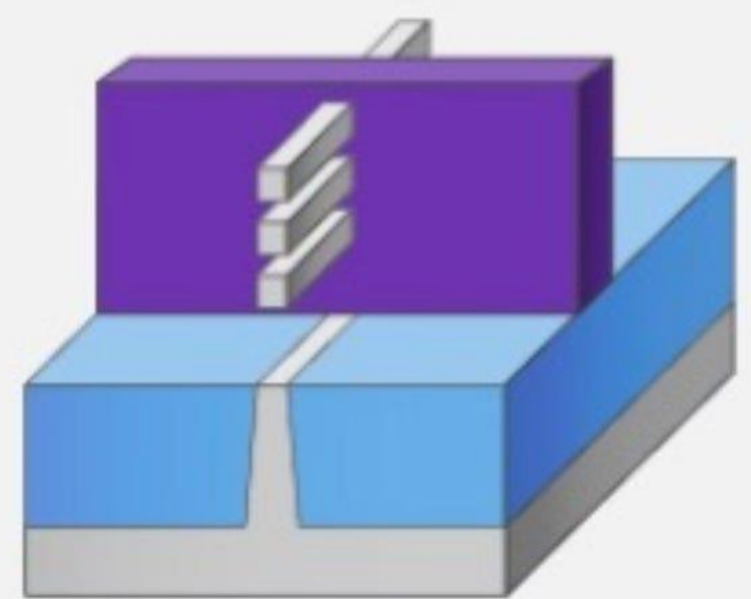
Többet és többet!



Planar FET



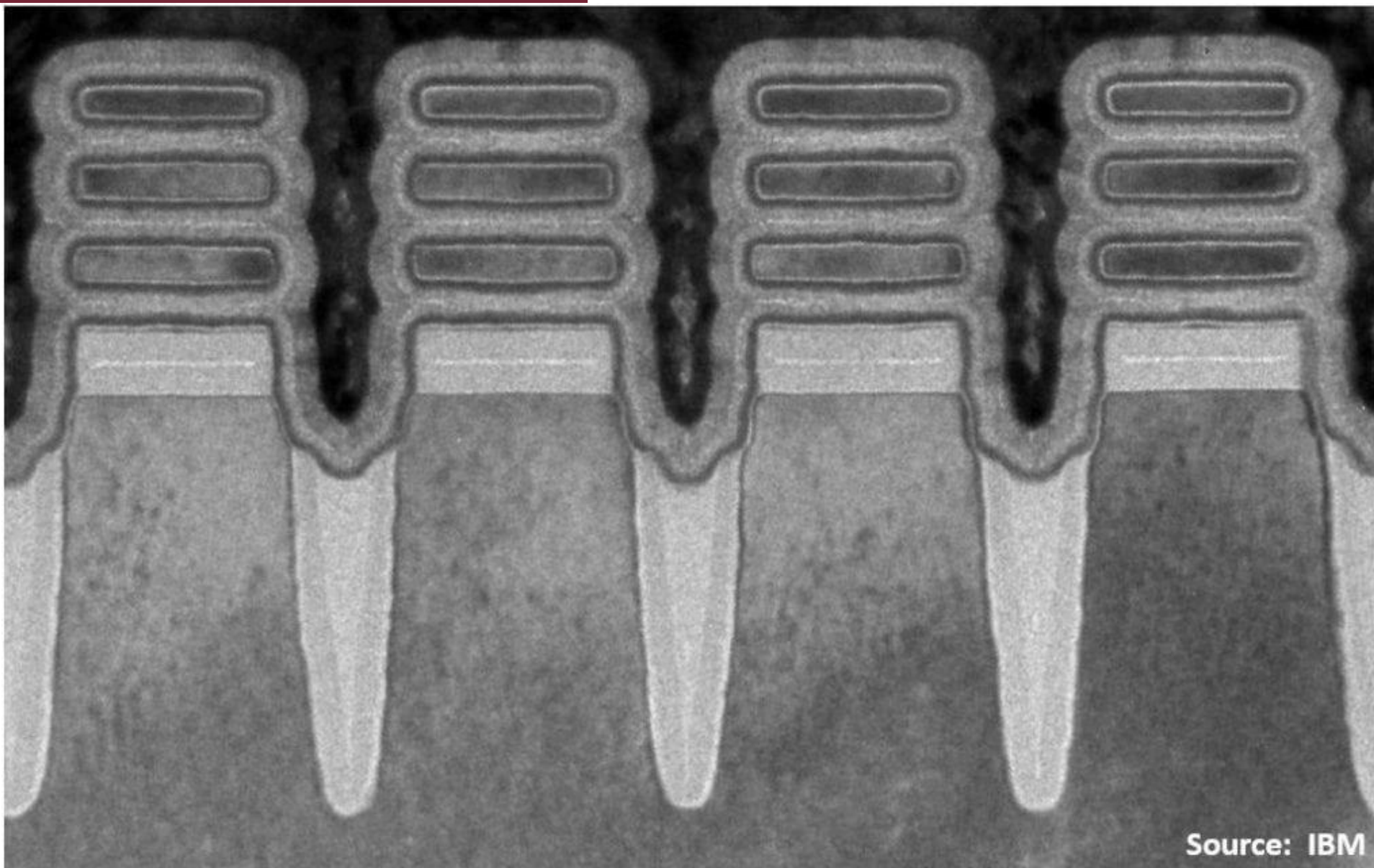
FinFET



GAAFET
(Nanowire)

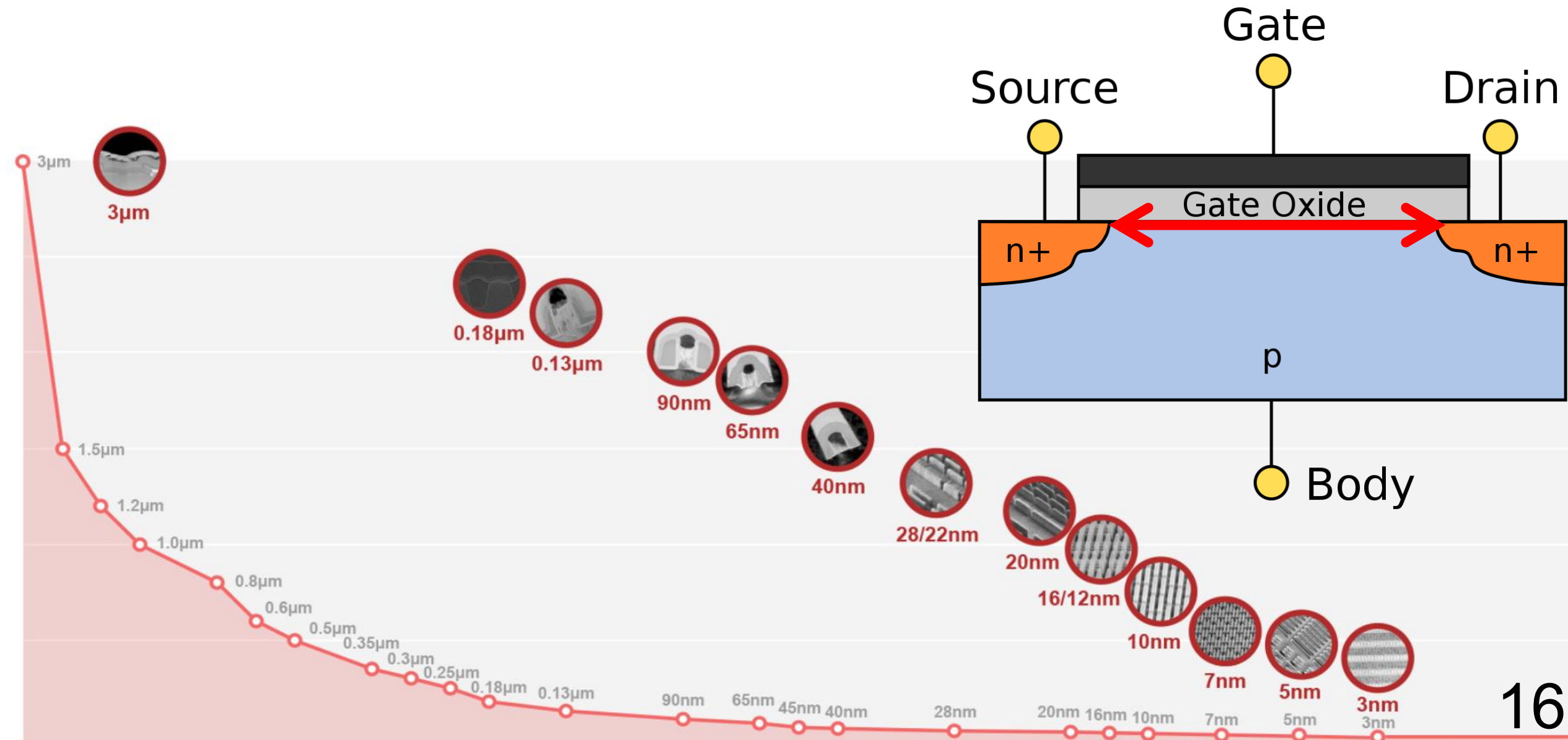
2011 Intel

2025 TSMC

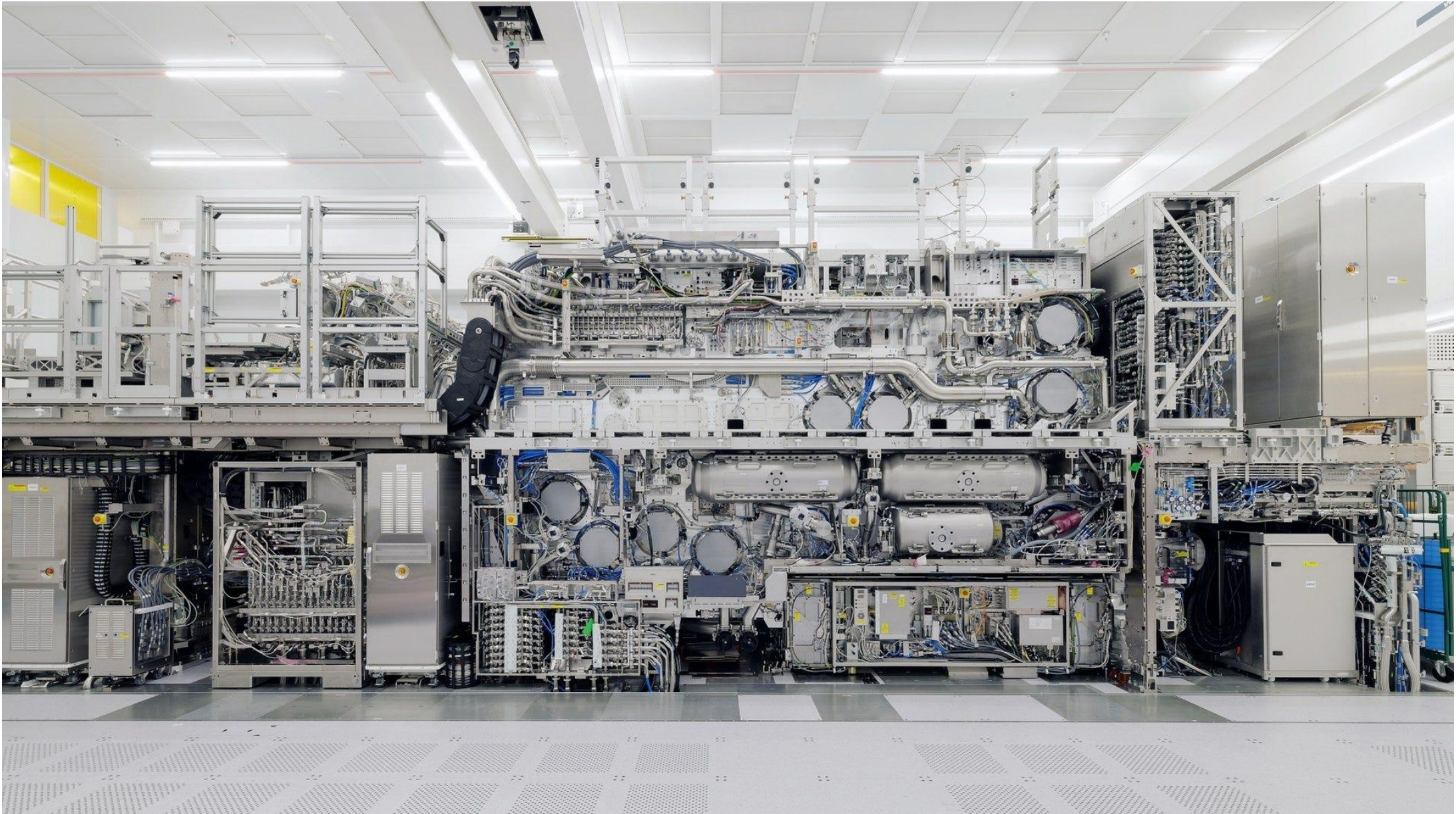


Tranzisztor (FET)

- 12 nm = 80 db atom



Tranzisztor (FET)



Tranzisztor (FET)

- El Capitan 30 MW, Gyöngyös 17 MW



Tranzisztor (FET)

- El Capitan 30 MW, Gyöngyös 17 MW



Merre tovább? Szupravezetés, kvantummechanika