Yarim o'tkazgichlar

Reja:

1.O'tkazgichlar, dielektriklar vayarimo'tkazgichlar
2.Yarimo'tkazgichlarning xususiy o'tkazuvchanligi
3.Aralashmali o'tkazuvchanlik
4.Yarimo'tkazgichlarning eletr sxemalari: diod, tranzistorlar

Metallarda erkin elektronlar konsentrasiyasi juda katta

(10^{22} -10^{23} sm^{-3}). Shu sababli ularning elketr qarshiligi kichkina.

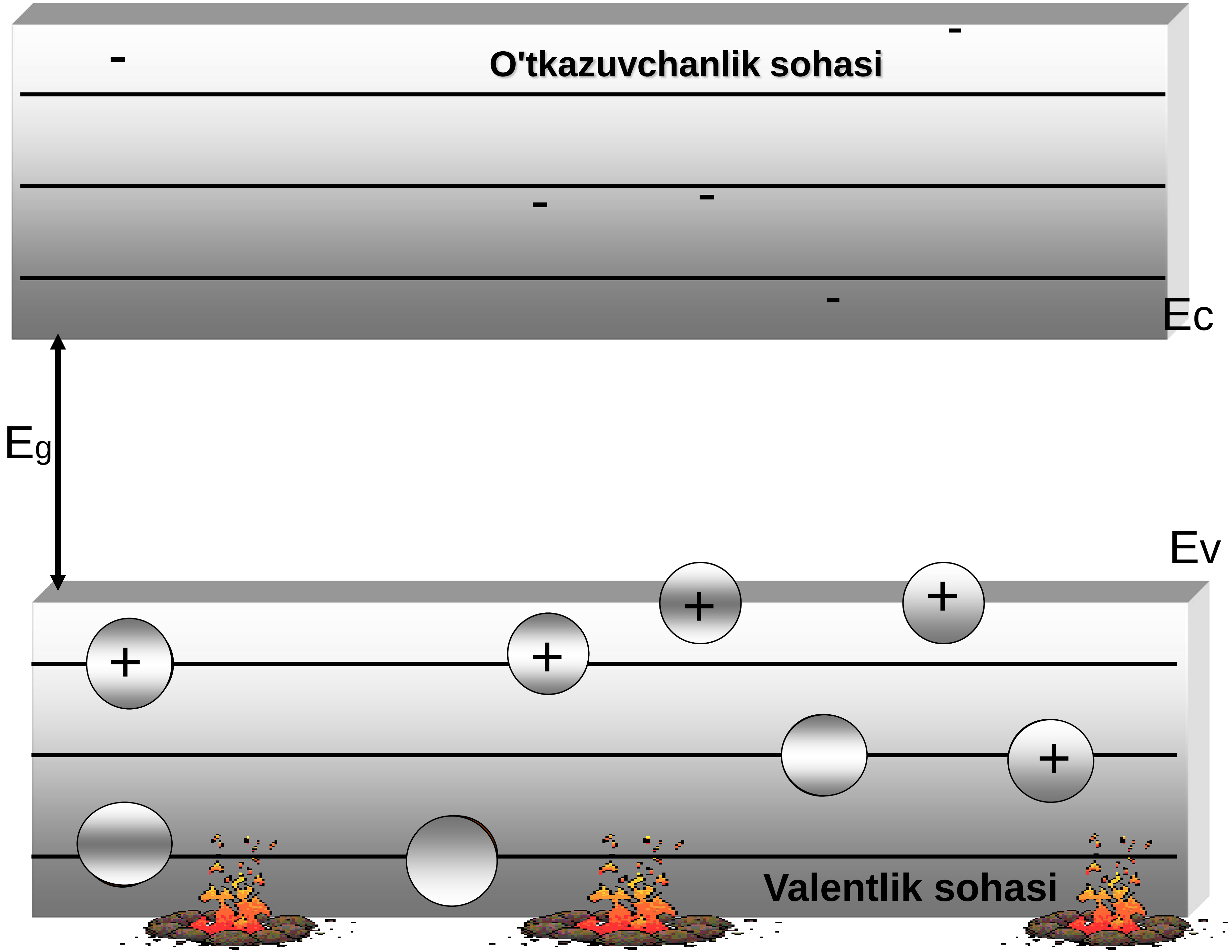
Dielektriklarda erkin elektronlar konsentrasiyasi kam (n≤ $10^{14} sm^{-3}$), ekektr qarshiligi esa juda katta. Elektr qarshiligi nisbatan yarim o'tkazgichlar metall va dielektriklar o'rtasida oraliq holatni egallaydi.

Metallardan farqli ravishda yarim o'tkazgichlarning solishtirma qarshiligi temperatura ortishi bilan kamayadi.

Yuqori darajada tozalangan kremniy tarkibida kirishmalarning atom ulushi.

Kirishmalar	Mumkin bo'lgan miqdori, *%*
Al	$1 \cdot 10^{-7}$
B	$1 \cdot 10^{-7}$
H	$1 \cdot 10^{-3}$
Fe	$1 \cdot 10^{-7}$
O	$1 \cdot 10^{-7}$
Mg	$1 \cdot 10^{-7}$
Mn	$1 \cdot 10^{-7}$
Cu	$1 \cdot 10^{-8}$
Pb	$1 \cdot 10^{-7}$
Ag	$1 \cdot 10^{-7}$
P	$1 \cdot 10^{-8}$
Zn	$1 \cdot 10^{-8}$

Kimyoviy jihatdan toza yarim o'tkazgichlar xususiy yarim o'tkazgichlar deb ataladi. Ularga bir qator kimyoviy toza elementlar (germaniy-**Ge,** kremniy-**Si,** selen-**Se,** tellur-**Te**) va kimyoviy birikmalar (galliy arsenidi– **GaAs**, indiy arsenidi-**InAs**, indiy antimonidi - **InSb**,Karbid kremniy-**SiC** va xokazolar) kiradi.

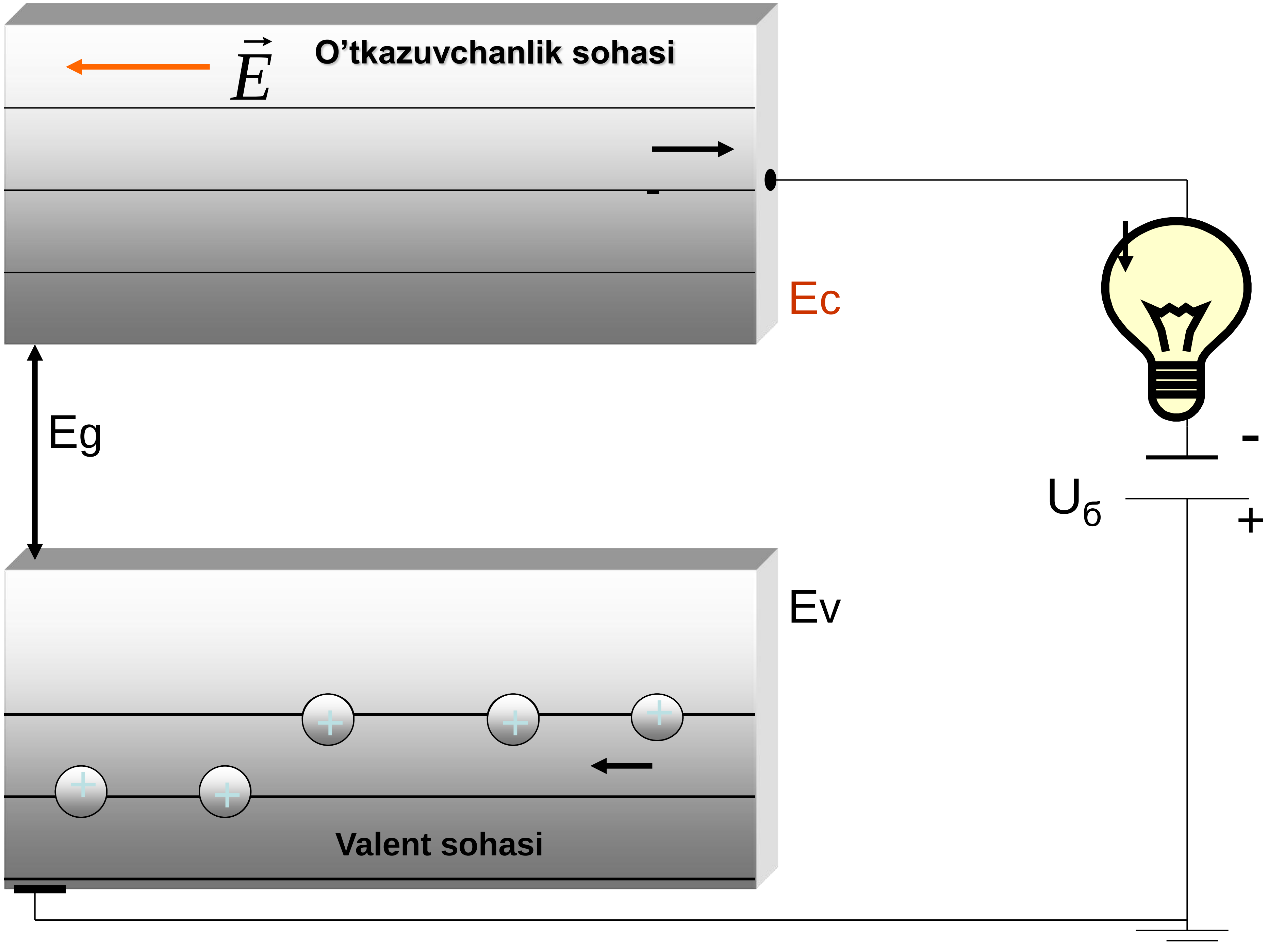

O'tkazuvchanlik sohasi
Ec
Eg
Ev
Valentlik sohasi

Taqiqlangan soha kengligi Eq=0.66 eV. **Germaniy** uchun uy temperaturasida t=250 C, o’tkazuvchanlik sohasidagi elektron gaz kontsentratsiyasi ni≈10 19 m-3, solishtirma qarshiligi ρi=0.48 Om m ga teng bo’ladi.

Taqiqlangan sohaning kengligi Eq=5.2 eV ga teng bo’lgan **olmos** uy temperaturasida t=250 C o’tkazuvchanlik sohasida elektronlar kontsentratsiyasi ni≈107 m-3 ga, solishtirma qarshiligi ρi=10 8 Om m ga teng bo’ladi.

Ammo temperatura 600 K ga teng bo’lishi bilan elektron gazning kontsentratsiyasi olmosda bir necha tartibga ortadi, solishtirma qarshiligi esa 0,5Om m ga teng bo’ladi.

- **Yuqoridagilardan quyidagi ikkita muhim xulosa kelib chiqadi:**
- **1. Yarim o’tkazgichlarning o’tkazuvchanligi valent sohadagi elektronlarga o’tkazuvchanlik sohasiga o’tish uchun yetarli bo’lgan energiyani beruvchi tashqi kuchlar ta’sirida paydo bo’ladi. SHuning uchun yarim o’tkazgichlar o’tkazuvchanligi qo’zg’atilgan o’tkazuvchanlikdan iboratdir;**
- **2. Qattiq jismlarni yarimo’tkazgichlar va dielektriklarga bo’linishi ma’lum bir hisobda shartli xarakterga egadir. O’y haroratida dielektrik xususiyatiga ega bo’lgan olmos yuqori temperaturalarda sezilarli o’tkazuvchanlikka ega bo’lib, yarim o’tkazgich xususiyatini oladi.**



$\vec{E}$
O’tkazuvchanlik sohasi
Ec
Eg
Ev
Valent sohasi
-
$U_б$
+

$$\vec{I} = q\vec{v}_S, \qquad (1)$$

Yarim-o’tkazgichlar				Effektiv massalar	
				Elektronmn	Kovak mp
Indiy Antimonidi	0.17	1.41022	6 10-5	0.015m	0.18m
Germaniy	0.66	3 1019	0.48	0.56m	0.59m
Kremniy	1.12	1016	2 103	1.08m	0.37m

Erkin zaryad tashuvchilar kontsenratsiyasining Fermi sathi holatiga bog'liqligi

- Yarim o'tkazgichlarda erkin zaryad tashuvchi gazning xususiyatlarini belgilovchi asosiy parametrlardan biri μ- kimyoviy potentsialdir. Bu iborani elektron va kovakli gaz uchun oddiygina qilib **Fermi sathi** deyiladi.
- Bizga ma'lumki metallarda Fermi sathi o'tkazuvchanlik sohasidagi elektronlar bilan to'lgan oxirgi energetik sathdir. T=0 K da Fermi sathidan pastdagi hamma energetik sathlar elektronlar bilan tulgan, undan yuqoridagi energetik sathlarning barchasi bo'shdir. Metallarda elektron gazning kontsentratsiyasi o'tkazuvchanlik sohasidagi xolatlar soni bilan bir xil bo'ladi, shuning uchun bu gaz aynigan gaz hisoblanadi va elektronlarning xolatlar buyicha taqsimlanishi Fermi Dirak kvant statistikasi bilan ifodalanadi. Bunday gazdagi elektronlarning kontsentratsiyasi temperaturaga deyarli bog'liq emas.

E
o'tkazuvchanlik sohasi
Eю
E+dE
0
Ec
Eg
μ
μ
μ'
valent sohasi
Ev

Yuqoridagi rasmda xususiy yarim o'tkazgich keltirilgani sababli elektron gazi aynimagan bo'lganligi uchun Maksvell-Boltsman taqsimotiga asoslanib **dE** energiya oralig'idagi egallagan **dn**- elektronlar kontsentratsiyasini hisoblashga harakat qilamiz:

$$N(E)dE = f(E)g(E)dE \qquad \textbf{\textit{(2)}}$$

$$f_{М.Б.}(E) = e^{\frac{\mu - E}{kT}} \qquad \textbf{\textit{(3)}}$$

$$f_{М.Б.}(E) = \frac{N}{V}\left(\frac{h^2}{2\pi mkT}\right)^{\frac{3}{2}} e^{-\frac{E}{kT}} \qquad \textbf{\textit{(4)}}$$

$$g(E)dE = \frac{4\pi V}{h^3}(2m)^{\frac{3}{2}}\sqrt{E}\,dE \qquad \textbf{\textit{(5)}}$$

$$dn = \frac{4\pi}{h^3}(2m)^{\frac{3}{2}} e^{\frac{\mu - E}{kT}}\sqrt{E}\,dE \qquad \textbf{\textit{(6)}}$$

$$-E_g = \mu + \mu' \qquad \mu' = -(E_g + \mu) \qquad (7)$$

$$n = 4\pi\left(\frac{2m_n}{h^2}\right)^{\frac{3}{2}} e^{\frac{\mu}{kT}} \int_0^{E_{ю}} e^{-\frac{E}{kT}} \sqrt{E}\,dE \qquad (8)$$

E ortishi bilan $e^{-\frac{E}{kT}}$ funktsiyasi juda tez kamayib borishini e'tiborga olib integrallash chegarasini **0** dan ∞ gacha deb olish mumkin.

$$n = 4\pi\left(\frac{2m_n}{h^2}\right)^{\frac{3}{2}} e^{\frac{\mu}{kT}} \int_0^{\infty} e^{-\frac{E}{kT}} \sqrt{E}\,dE \qquad (9)$$

$$n = 2\left(\frac{2\pi m_n kT}{h^2}\right)^{\frac{3}{2}} e^{\frac{\mu}{kT}} \qquad (10)$$

$$p = 2\left(\frac{2\pi m_p kT}{h^2}\right)^{\frac{3}{2}} e^{\frac{-(E_g+\mu)}{kT}} \qquad (11)$$

(10) va (11) ifodalarda mn va mp elektron va kovaklarning effektiv massalaridir.

$$np = n_i\, p_i = 4\left(\frac{2\pi kT}{h^2}\right)^3 (m_n m_p)^{\frac{3}{2}} e^{-\frac{E_g}{kT}} \qquad (12)$$

$$n_i = p_i \qquad (13)$$

$$2\left(\frac{2\pi m_n kT}{h^2}\right)^{\frac{3}{2}} e^{\frac{\mu}{kT}} = 2\left(\frac{2\pi m_p kT}{h^2}\right)^{\frac{3}{2}} e^{-\frac{E_g+\mu}{kT}}$$

Bu ifodani μ ga nisbatan yechib, xususiy yarim o'tkazgichning Fermi sathining holatini aniqlaymiz:

$$\mu = -\frac{E_g}{2} + \frac{3}{4} kT \ln \frac{m_p}{m_n}$$

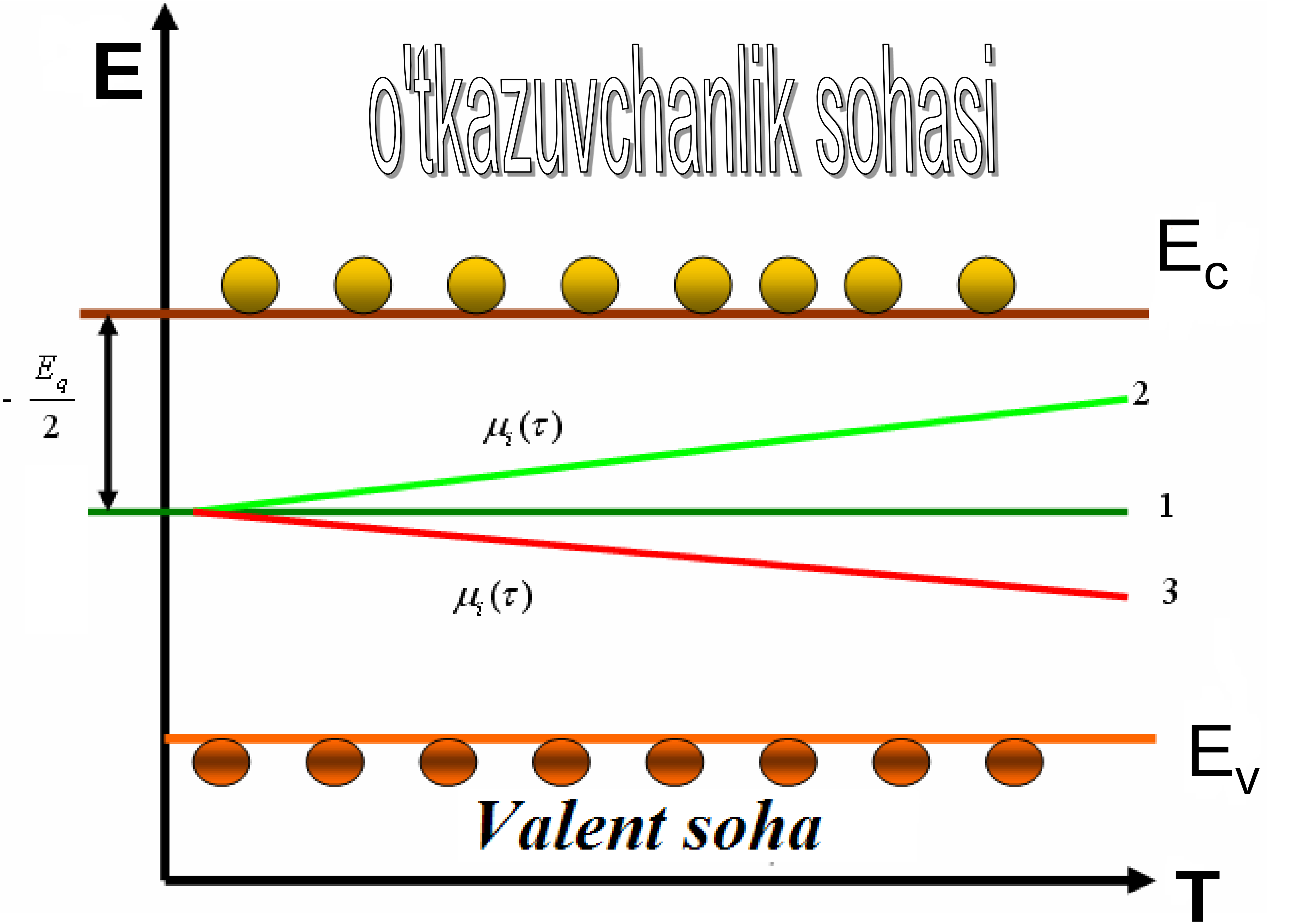
T=0 K bo'lgan xolda $\mu = -\frac{E_g}{2}$ ga teng, Fermi sathi taqiqlangan sohaning qoq o'rtasida joylashadi.

Fermi sathining qiymatini (10) va (11) ifodalarga qo'ysak, xususiy yarim o'tkazgichlardagi elektron va kovaklar kontsentratsiyasini aniklashimiz mumkin:

$$n_i = p_i = 2\left(\frac{2\pi\sqrt{m_n m_p}kT}{h^2}\right)^{\frac{3}{2}} e^{-\frac{E_g}{2kT}} \qquad (15)$$

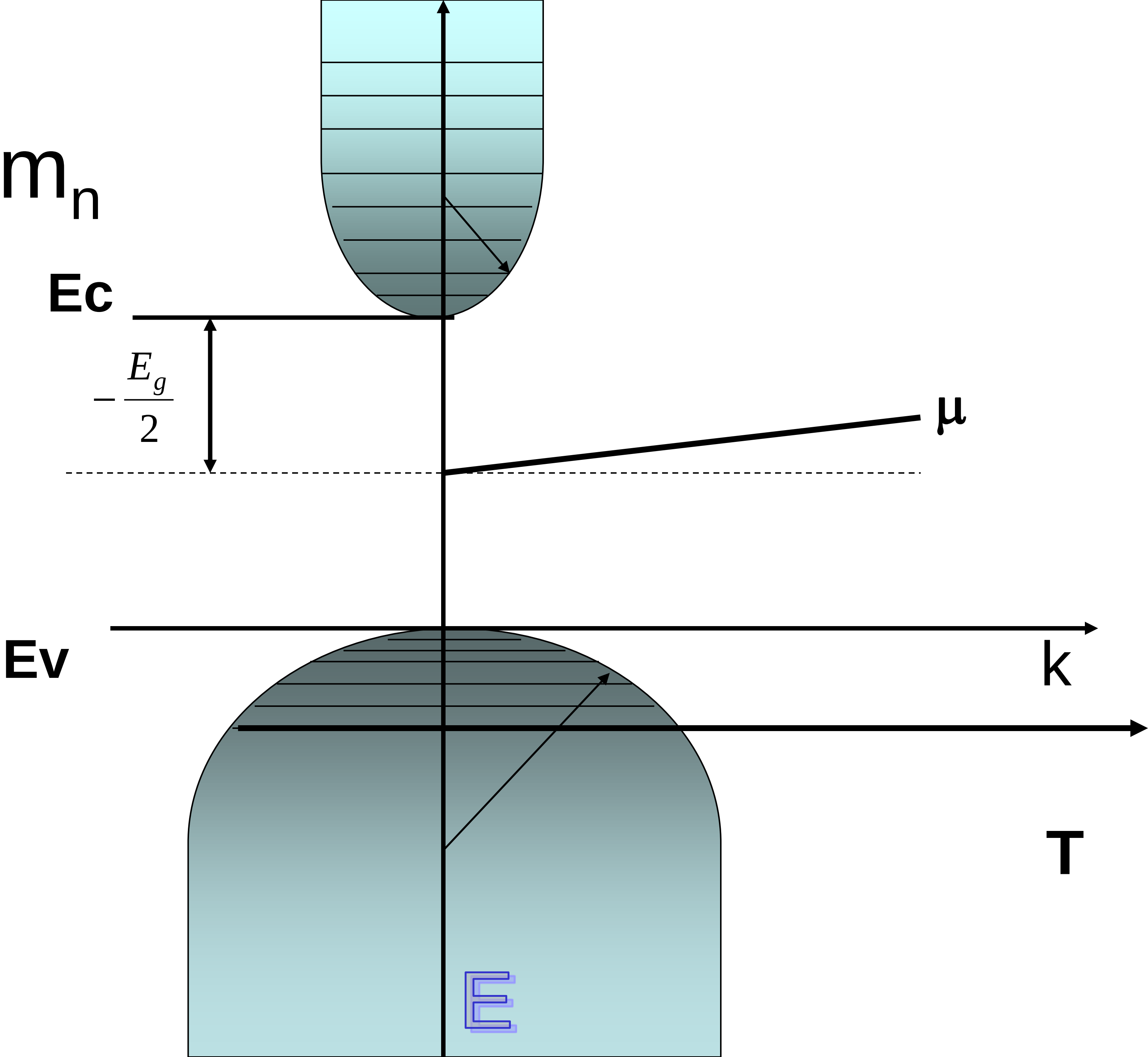
Ular taqiqlangan soha kengligi va temperaturaga bog'liqdir. Xususiy yarim o'tkazgichlarda belgilangan biror **T** temperatura uchun elektron va kovak kontsentratsiyasining ko'paytmasi o'zgarmas kattalikdir

$$n_n \cdot n_p = n_i^2 \qquad (16)$$

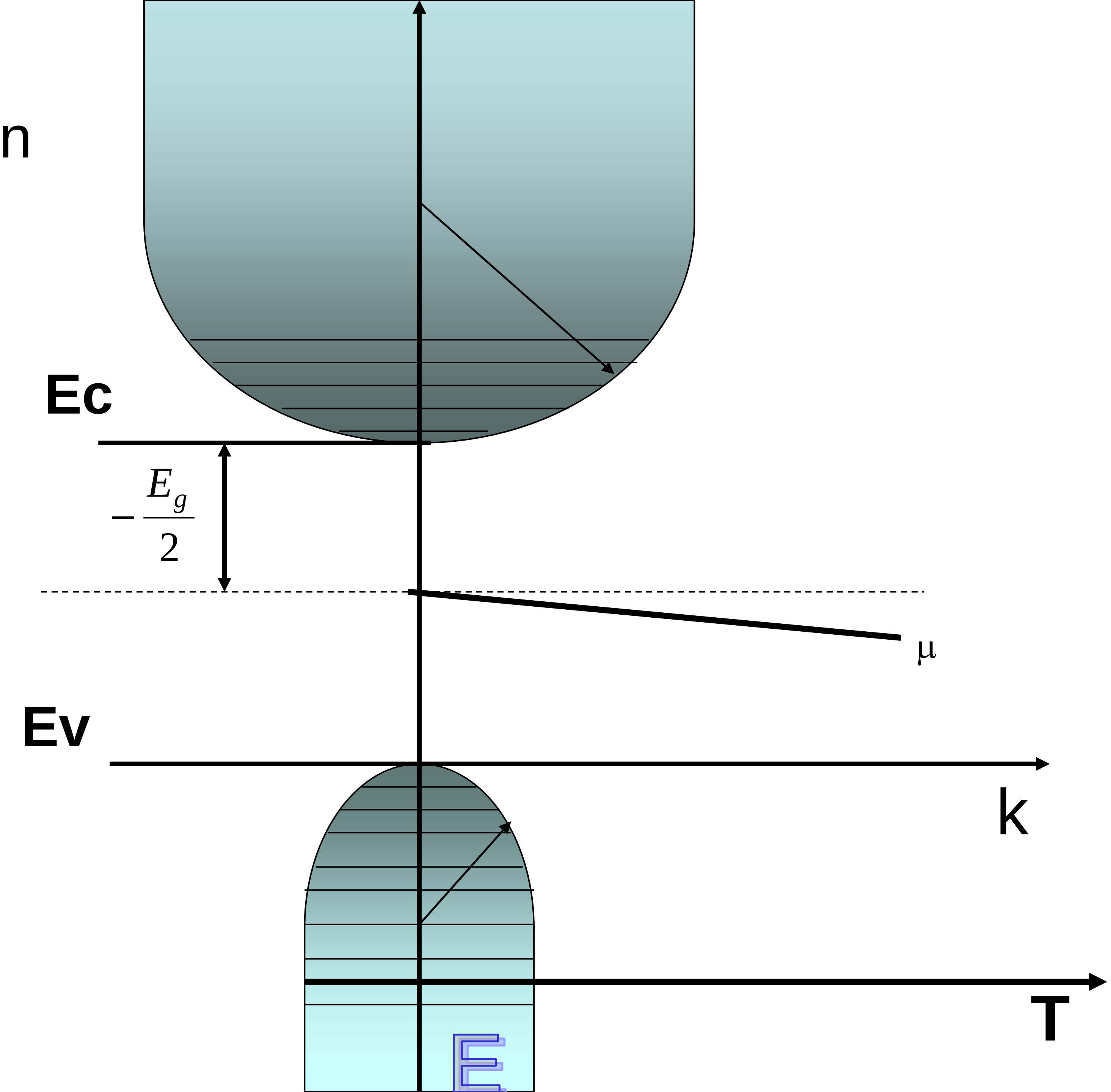


E
o'tkazuvchanlik sohasi
E_c
$-\frac{E_g}{2}$
$\mu_i(\tau)$
2
1
$\mu_i(\tau)$
3
E_v
Valent soha
T

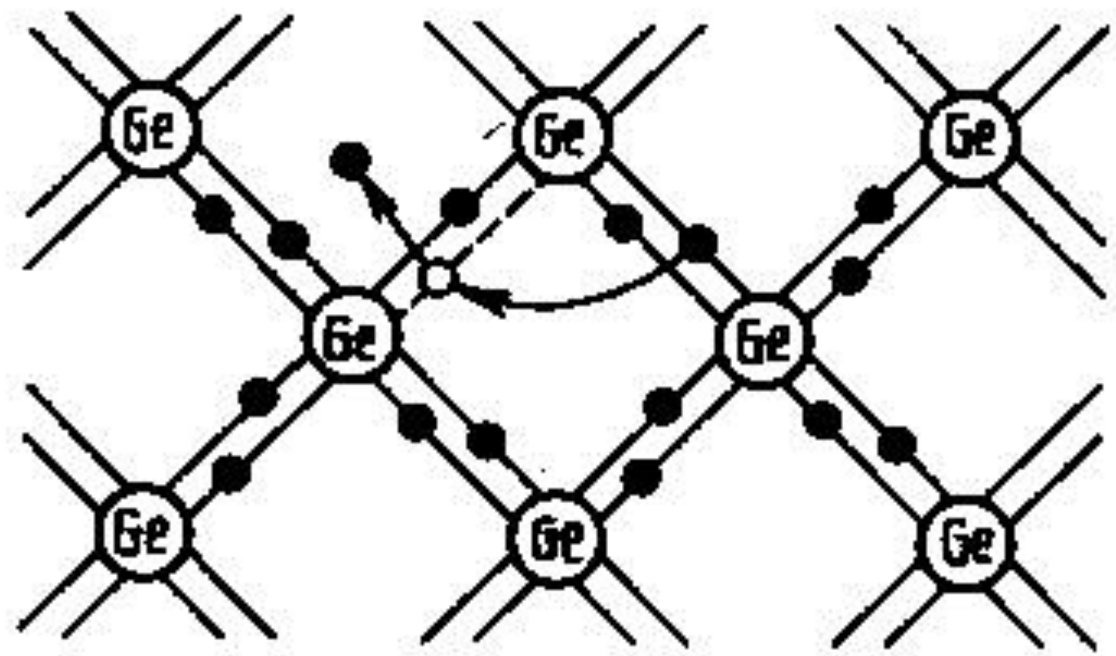
- $m_p > m_n$



- $m_p < m_n$



Germaniy kristalida atomlarning joylanishi



Xususiy yarim o’tkazgichlarning elektr o’tazuvchanligi

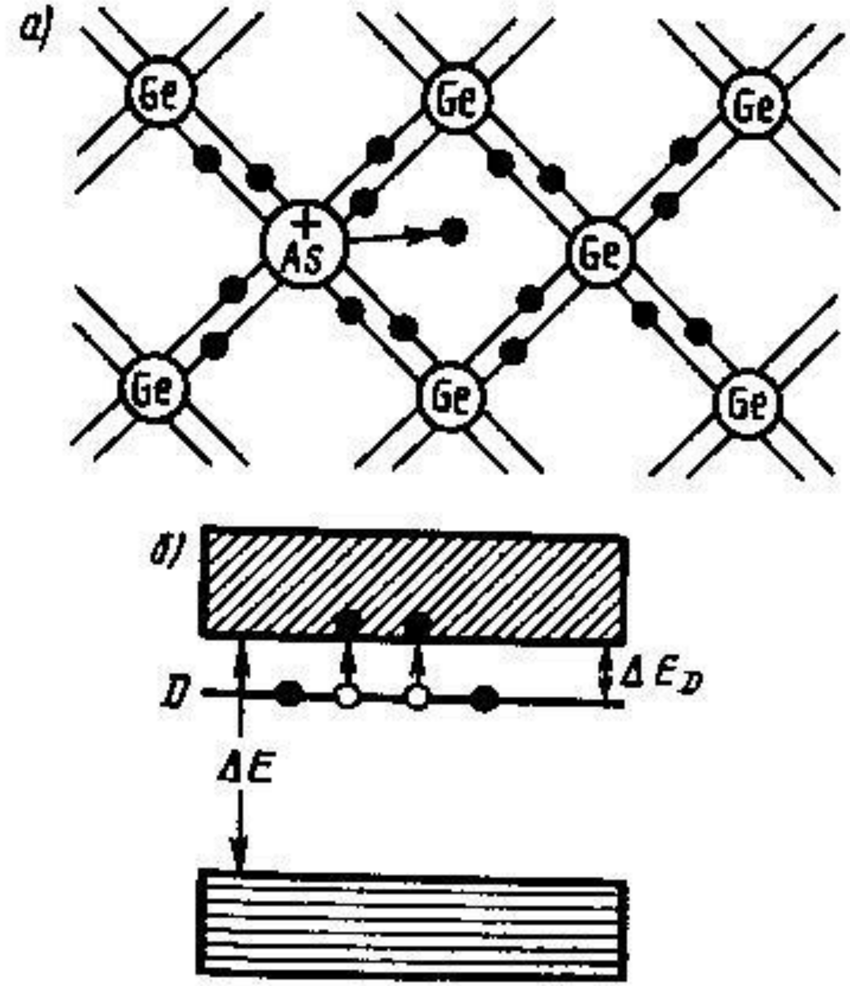
Kirishmalardan yuqori darajada tozalangan yarim o’tkazgichlar juda past bo’lmagan temperaturalarda, quyilgan tashqi elektr maydon ta’sirida o’zining xususiy zaryad tashuvchilari – elektronlar va kovaklarning yo’naltirilgan harakati hisobiga elektr o’tkazuvchanlikki ega bo’ladi. Ushbu elektr o’tkazuvchanlik yarim o’tkazgichlarning **xususiy o’tkazuvchanligi** deyiladi.

$$n_i = p_i$$

sharti bajarilganligi uchun xususiy yarim o’tkazgichning o’tkazuvchanligi quyidagiga teng bo’ladi:

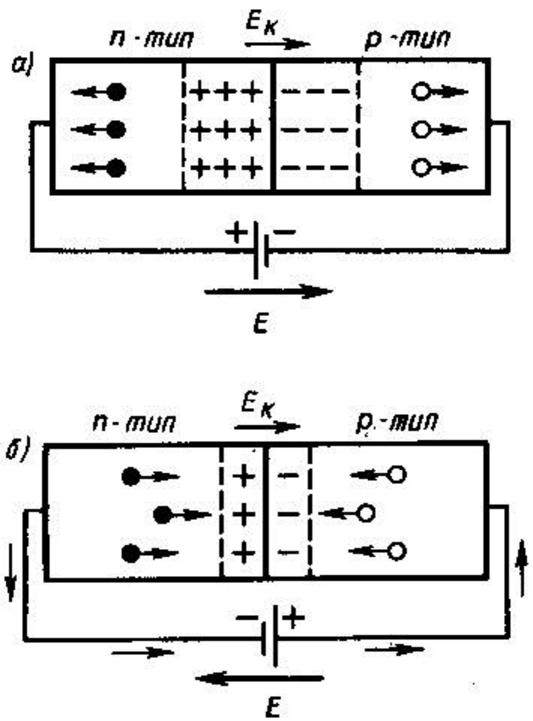
$$\sigma_i = \sigma_n + \sigma_p = qn_i(u_n + u_p) \quad (17)$$

Aralashmali o'tkazuvchanlik

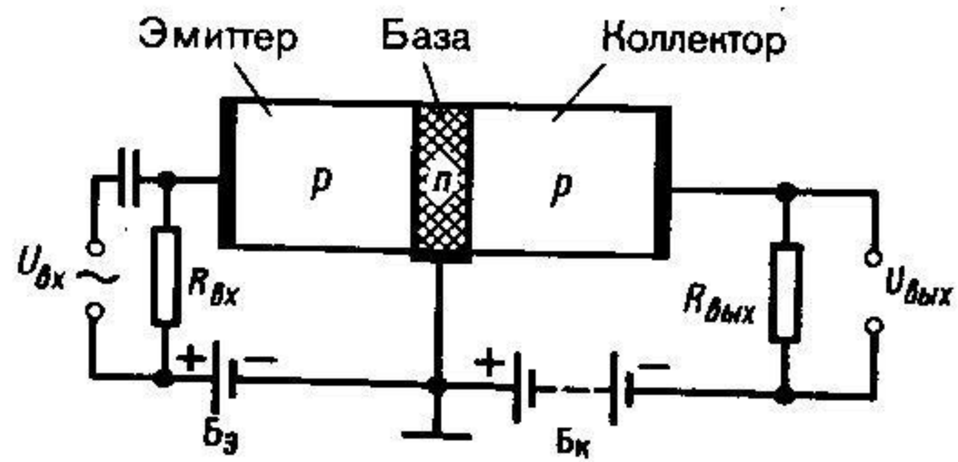


а)

б)

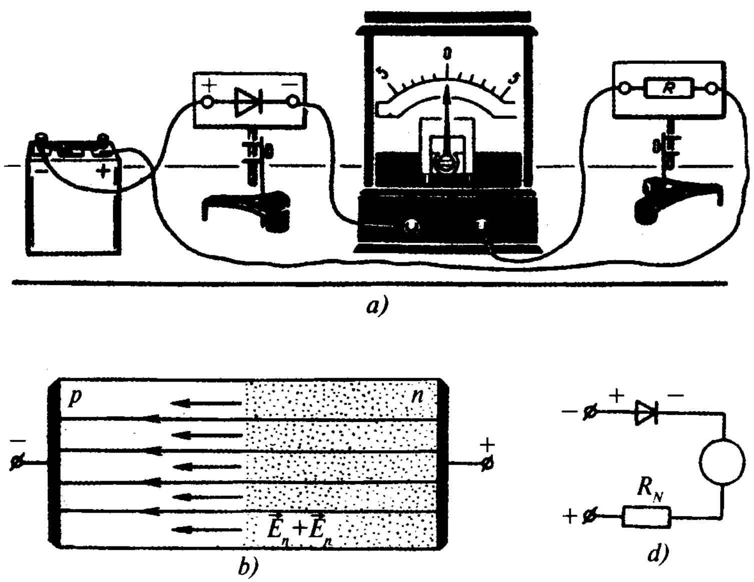


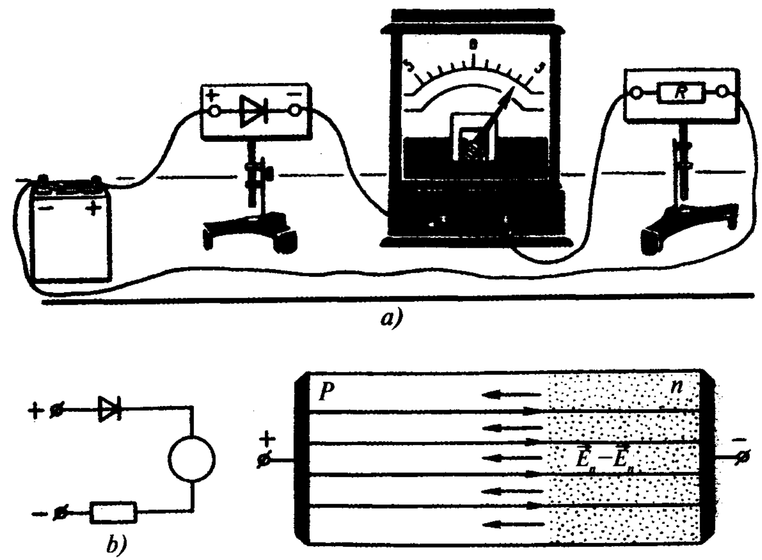
а)
n - тип
Eк
p - тип
E
б)
n - тип
Eк
p - тип
E



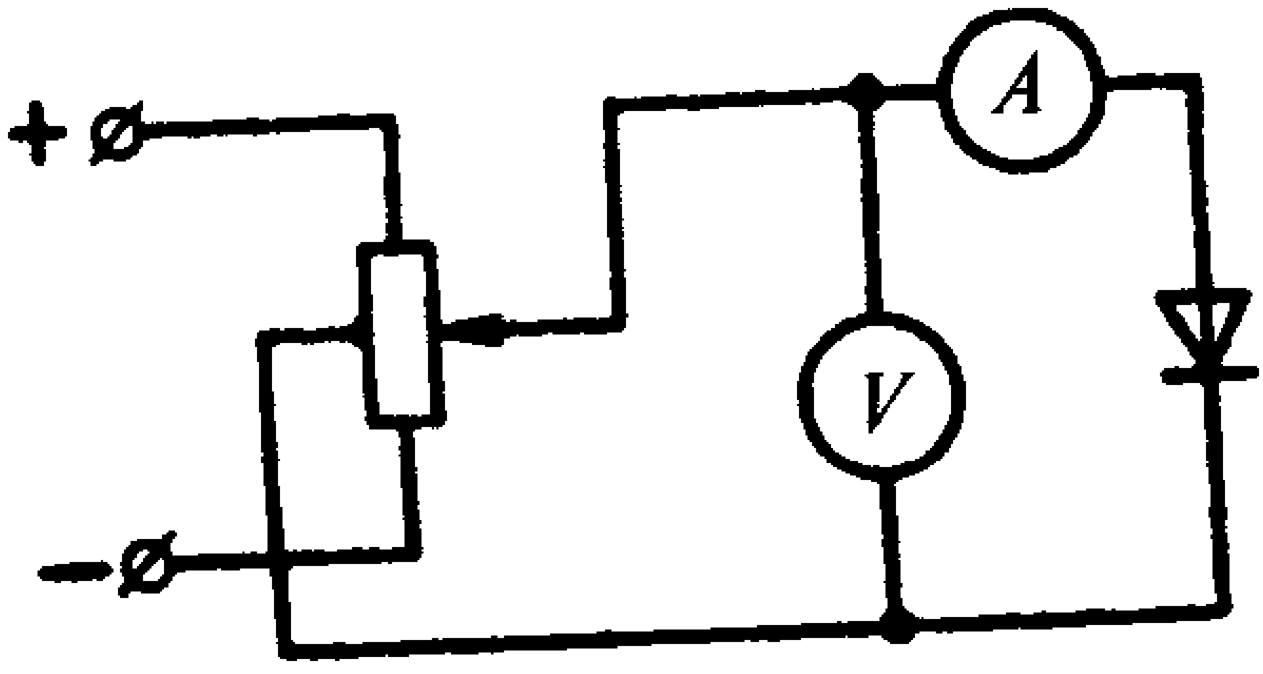
Эмиттер
База
Коллектор
p
n
p
Uвх
Rвх
Rвых
Uвых
Бэ
Бк

Yarim o'tkazgichni to'g'ri va teskari ulash

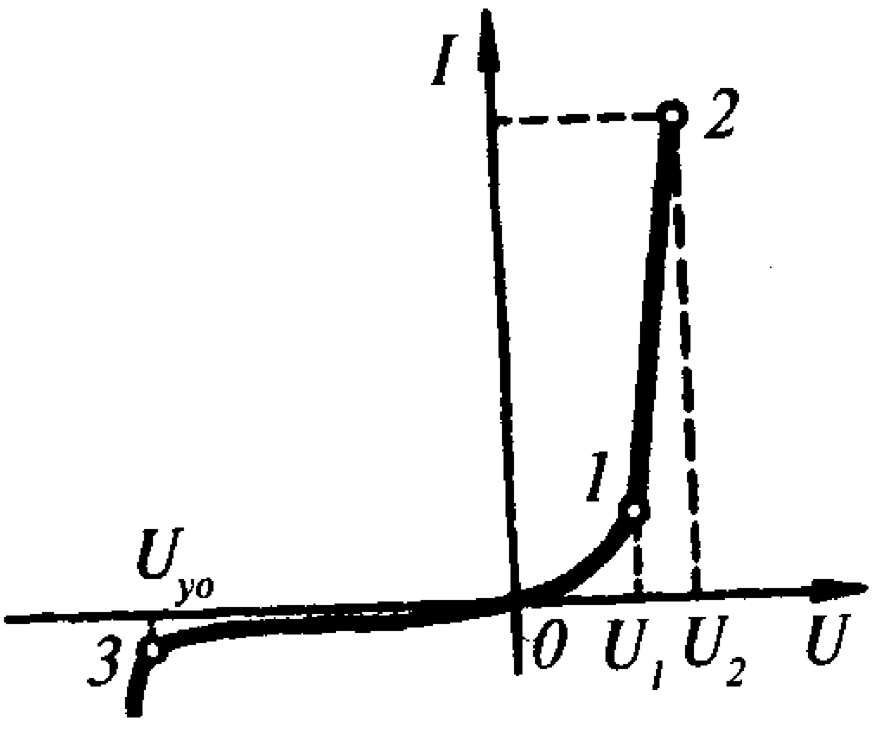




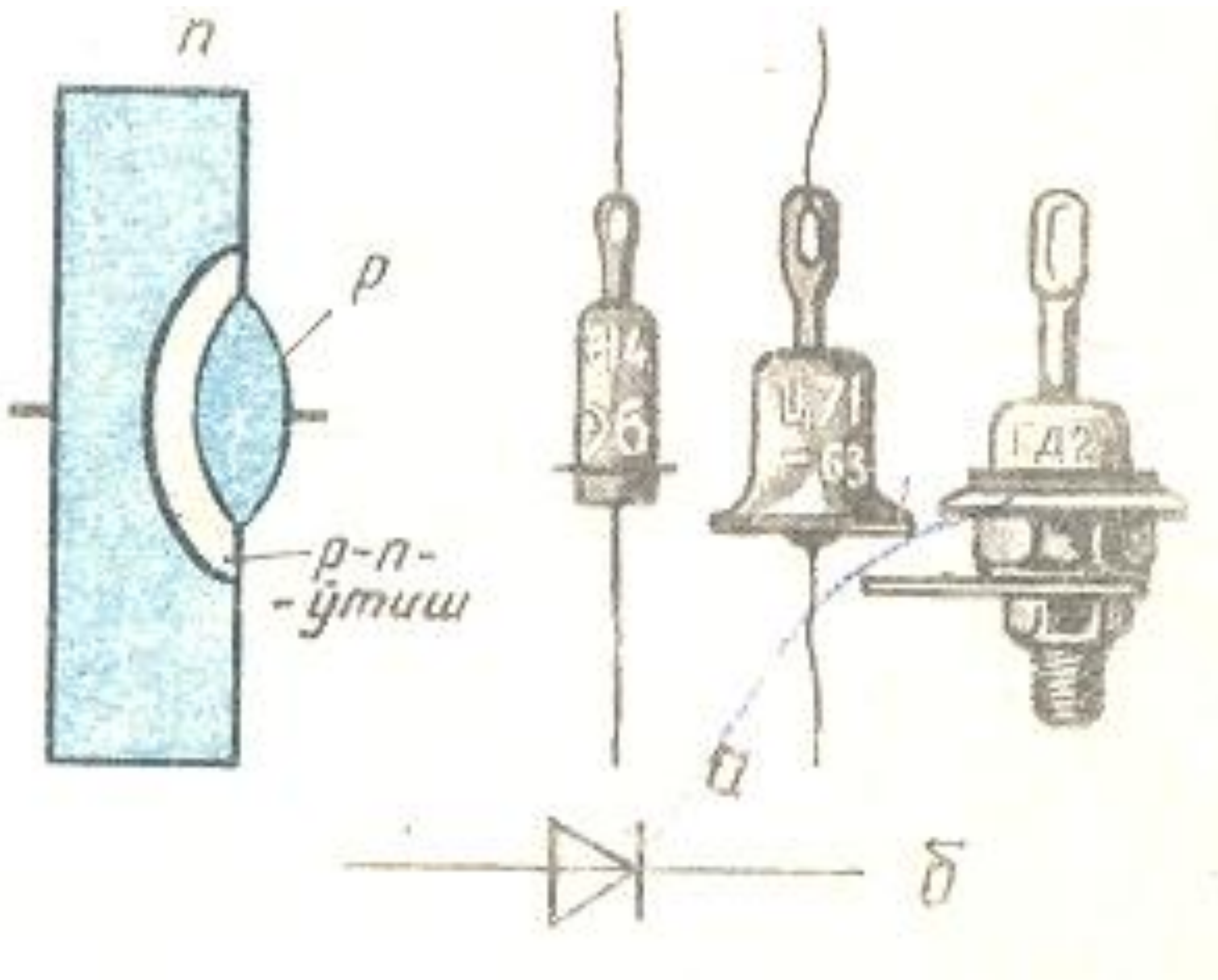
Diodning ulanish sxemasi



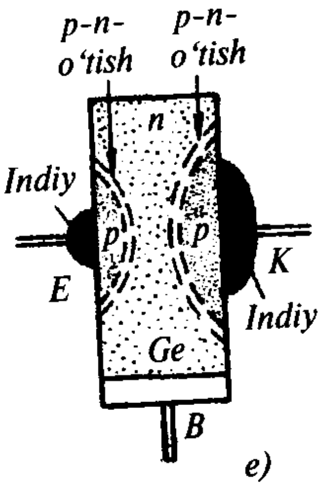
Volt –Amper xarakteristikasi

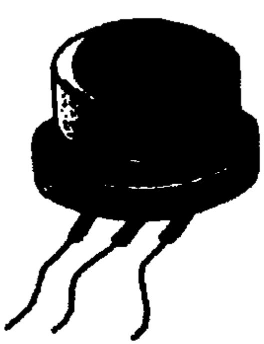


Yarim o'tkazgichli diod ko'rinishi

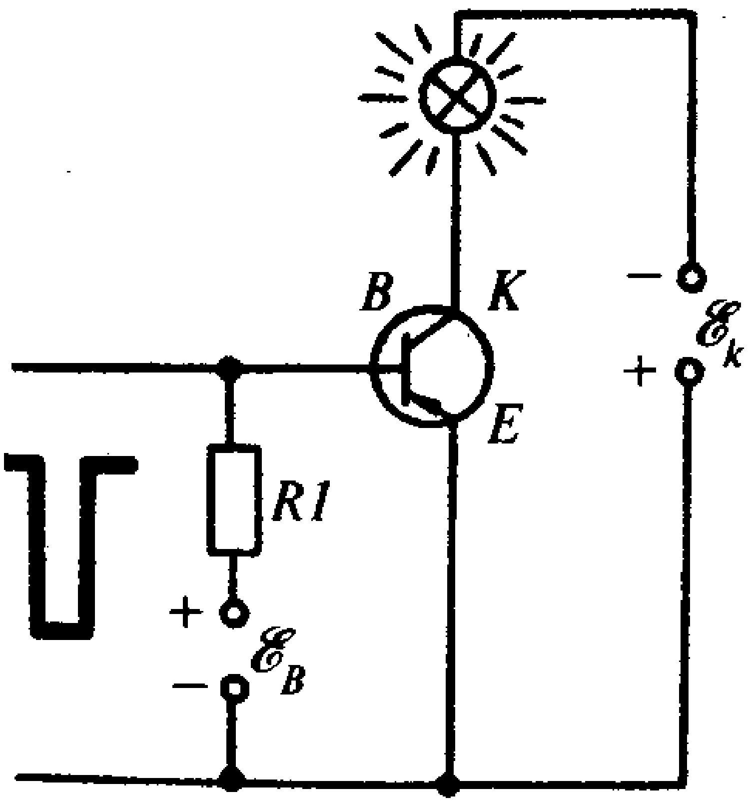


Tranzistorning ko'rinishi

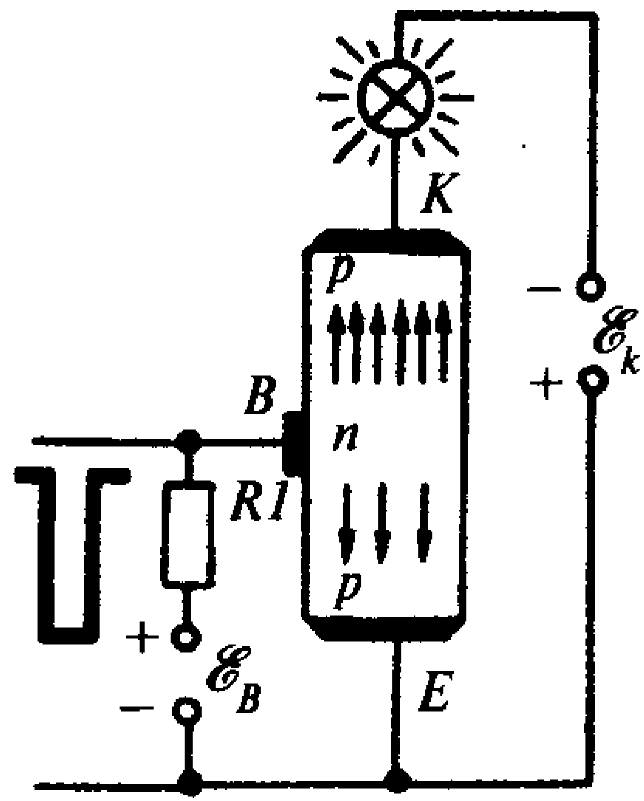




Tranzistorning ulanishi

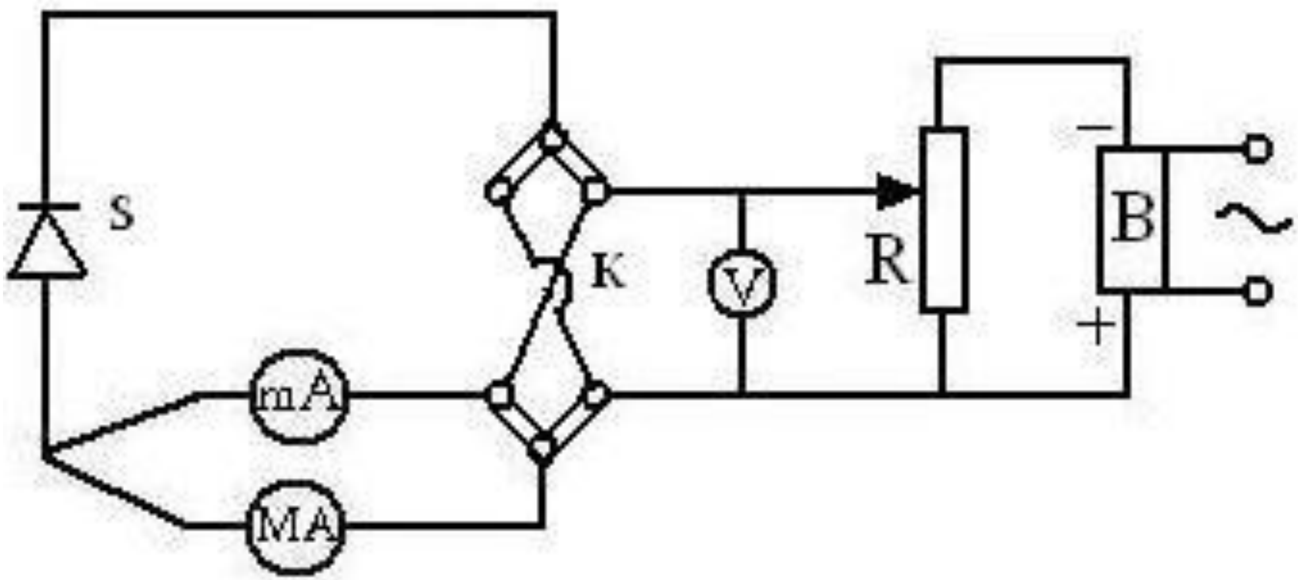


d)

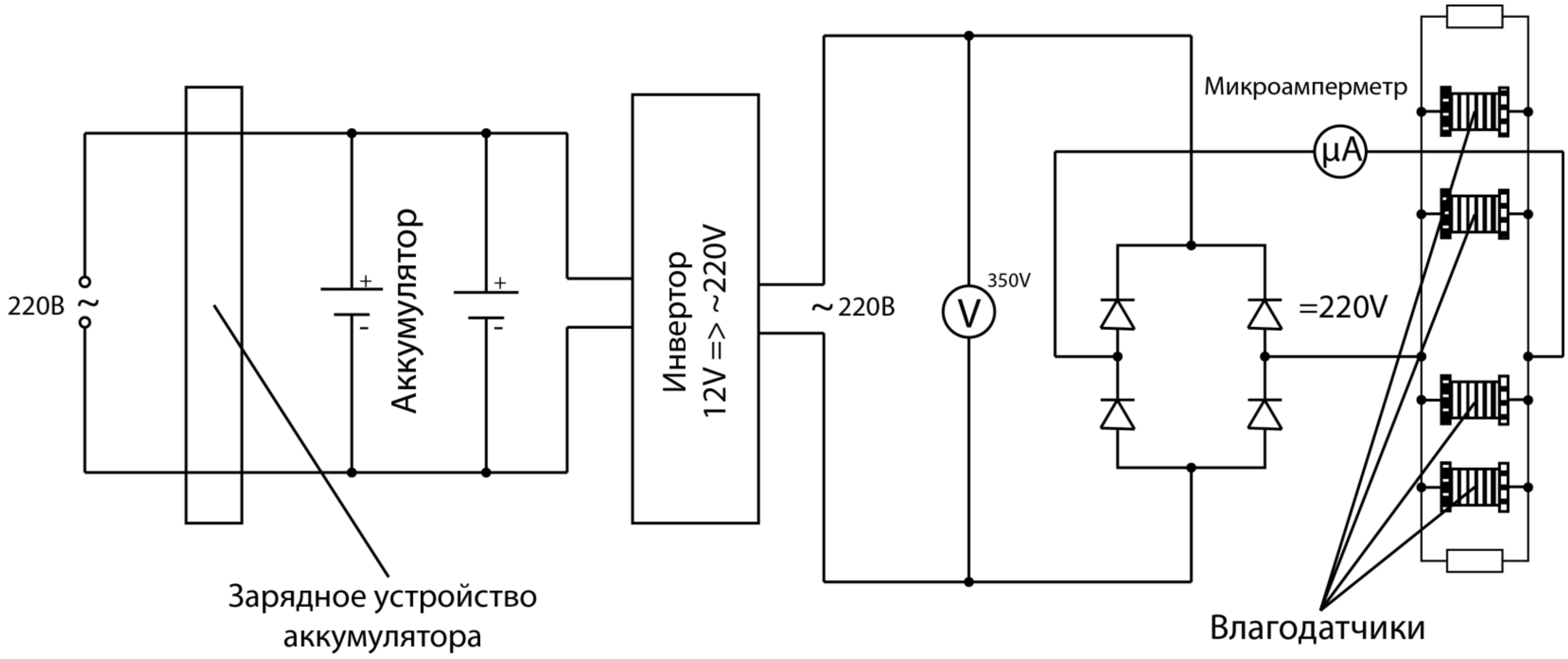


e)

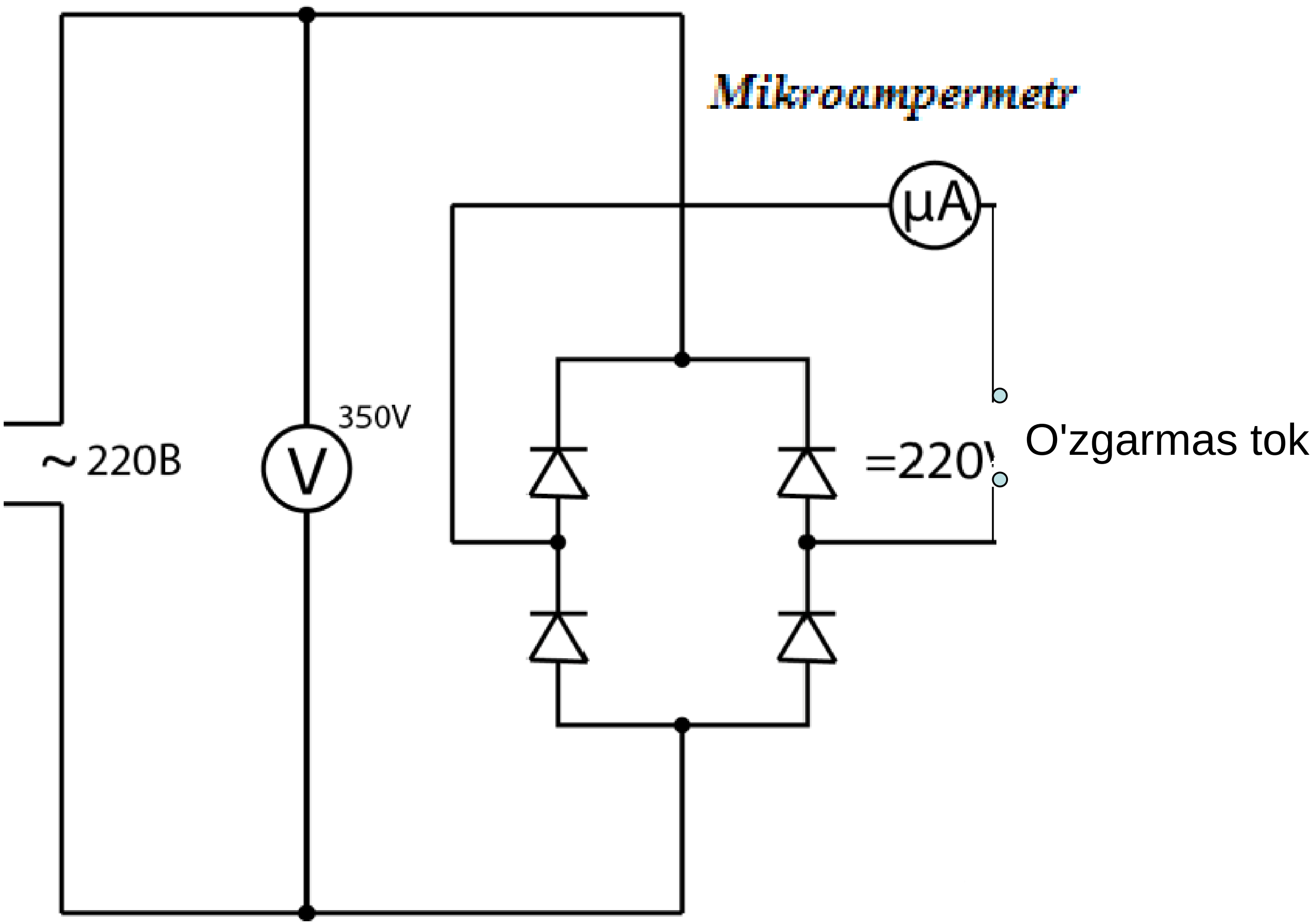
Diodni ulanish sxemasi



Diodni ulanish sxemasi



Diodni ulanish sxemasi



Aynimagan elektron gazi uchun

$$U \approx T^{-\frac{3}{2}}$$

shartni hisobga olib va (15) ifodadan foydalanib, xususiy yarim o'tkazgichning o'tkazuvchanligi uchun quyidagicha formulani hosil qilamiz:

$$\sigma = \sigma_0 e^{-\frac{E_g}{2kT}} \qquad (18)$$

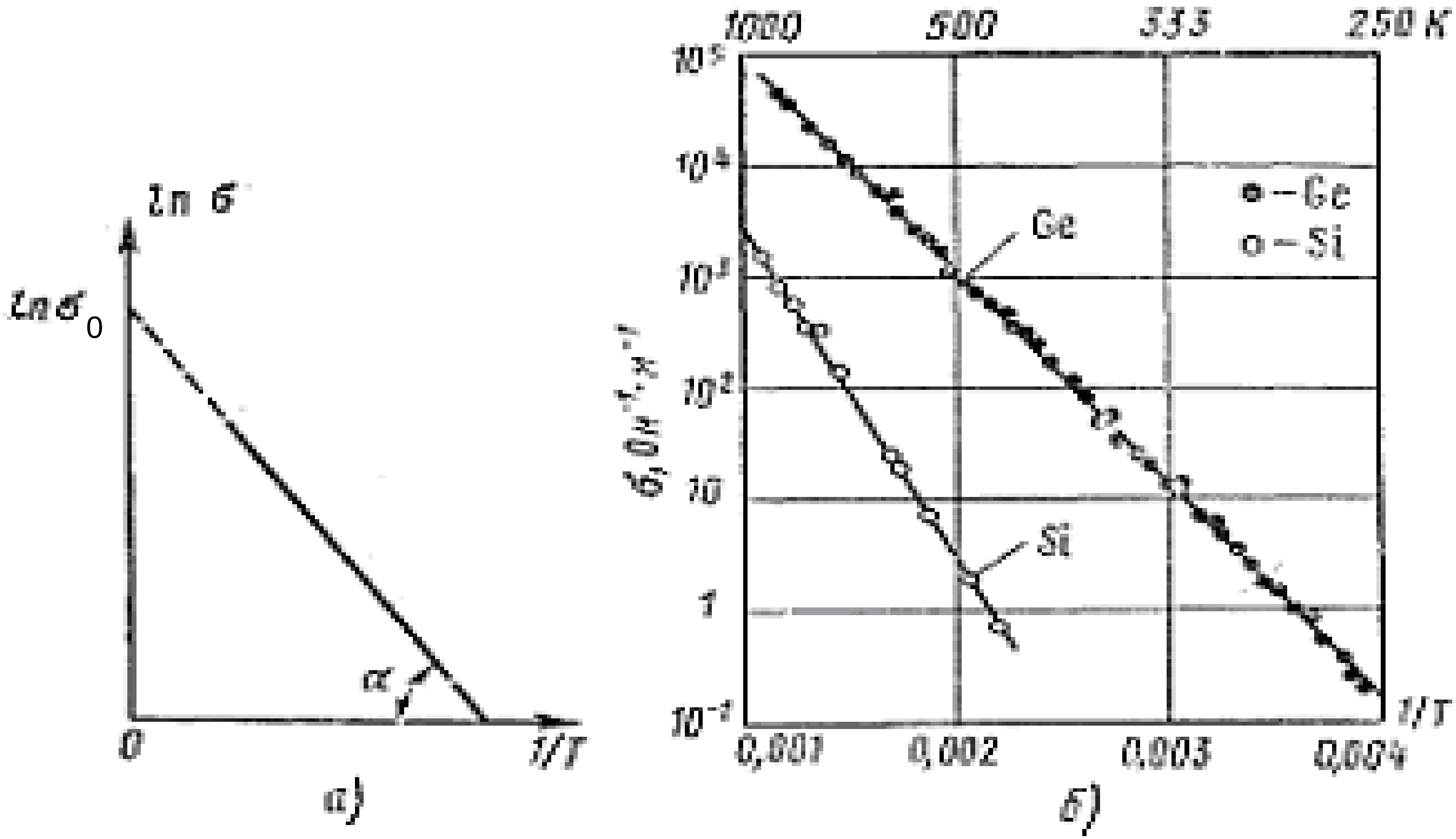
Bu ifodani yarim logarifmik masshtabda keltirish σ ning (T) ga qanday bog'liqligini yaqqol ko'rsatadi

$$\ln \sigma = \ln \sigma_0 - \frac{E_g}{2kT} \qquad (19)$$

Bu bog’lanish rasmda ko’rsatilgan. Bu to’g’ri chiziqni abtsissa o’qi bilan kesishda hosil qilgan α -burchakning tangensi

$$\frac{E_g}{2k}$$

ga tengdir. CHiziqning ordinata o’qi bilan kesishgan nuqtasi **σ0** doimiysini, α burchagi esa taqiqlangan soha kengligini **–(Eg)** ni topish imkonini beradi.



Amaliyotda xam aynan shu usul bilan taqiqlangan soha kengligi – Eg topiladi. SHu usul bilan tajribada kremniy va germaniylarning taqiqlangan soha kengligi aniqlangan bo’lib quyidagi qiymatlarga tengdir:

$$E_g\Big|_{Si} = 1.12 эB \qquad E_g\Big|_{Ge} = 0.75 эB$$

Ma’ruzani tayyorlashda foydalanilgan dasturlar, linklar va adabiyotlar

- Microsoft Power Point
- Savelev I. V. Kurs fiziki. M.: Nauka 1989 t.2
- Epifanov G.I. Fizika tverdogo tela. M. Visshaya shkola 1977.