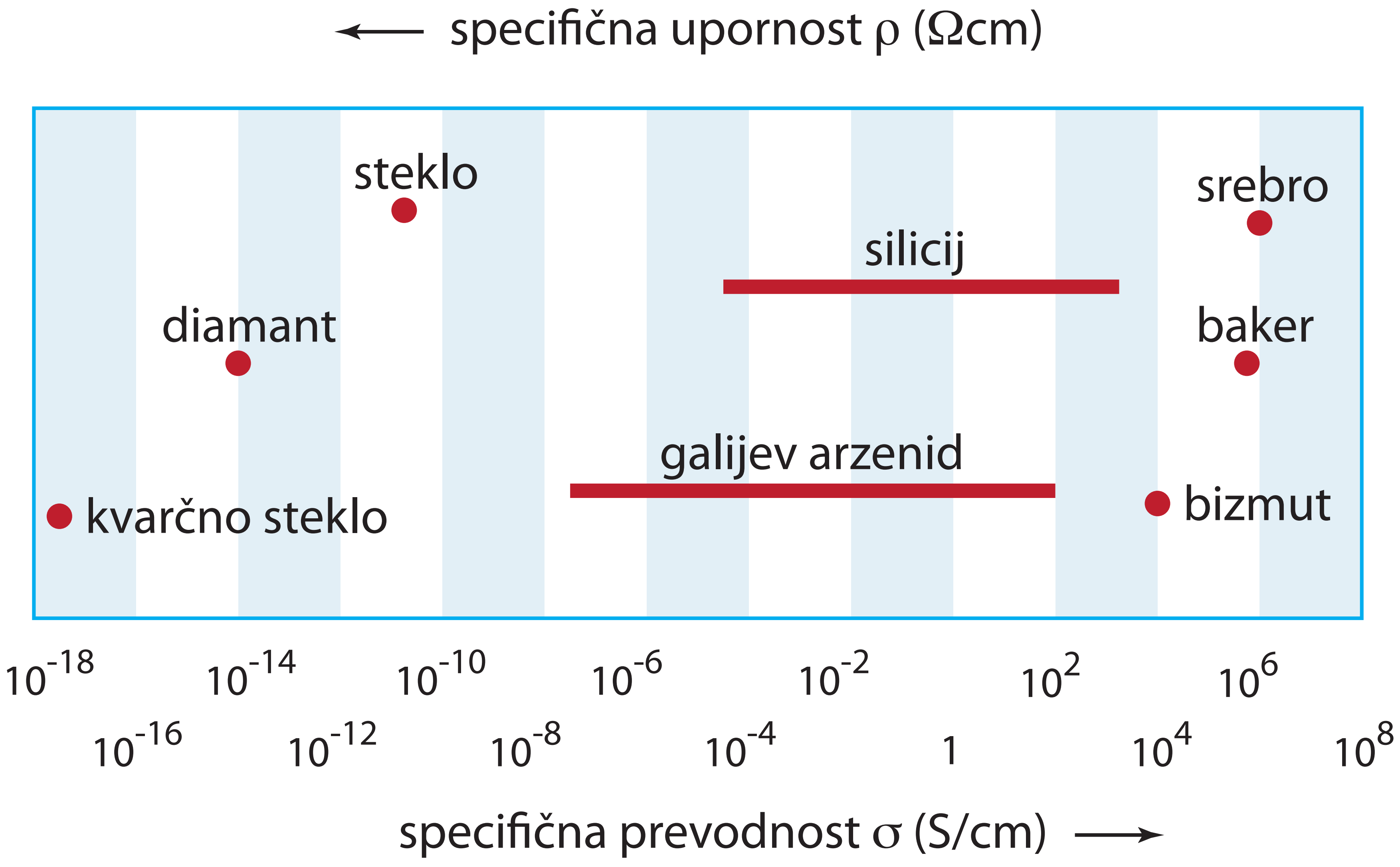
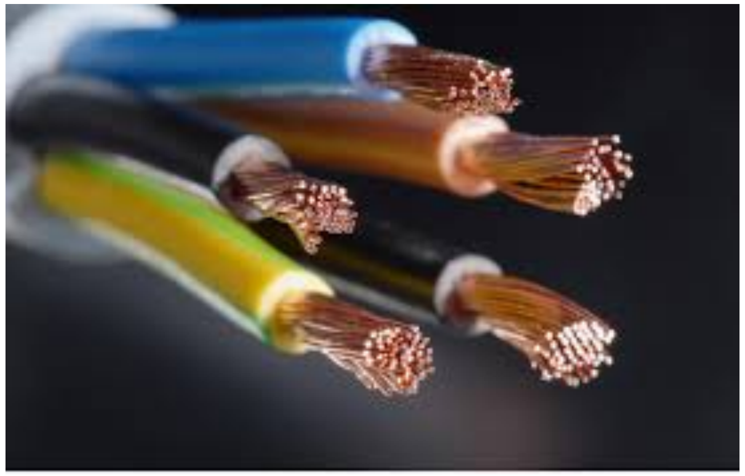
DOBRI IN SLABI ELEKTRIČNI PREVODNIKI

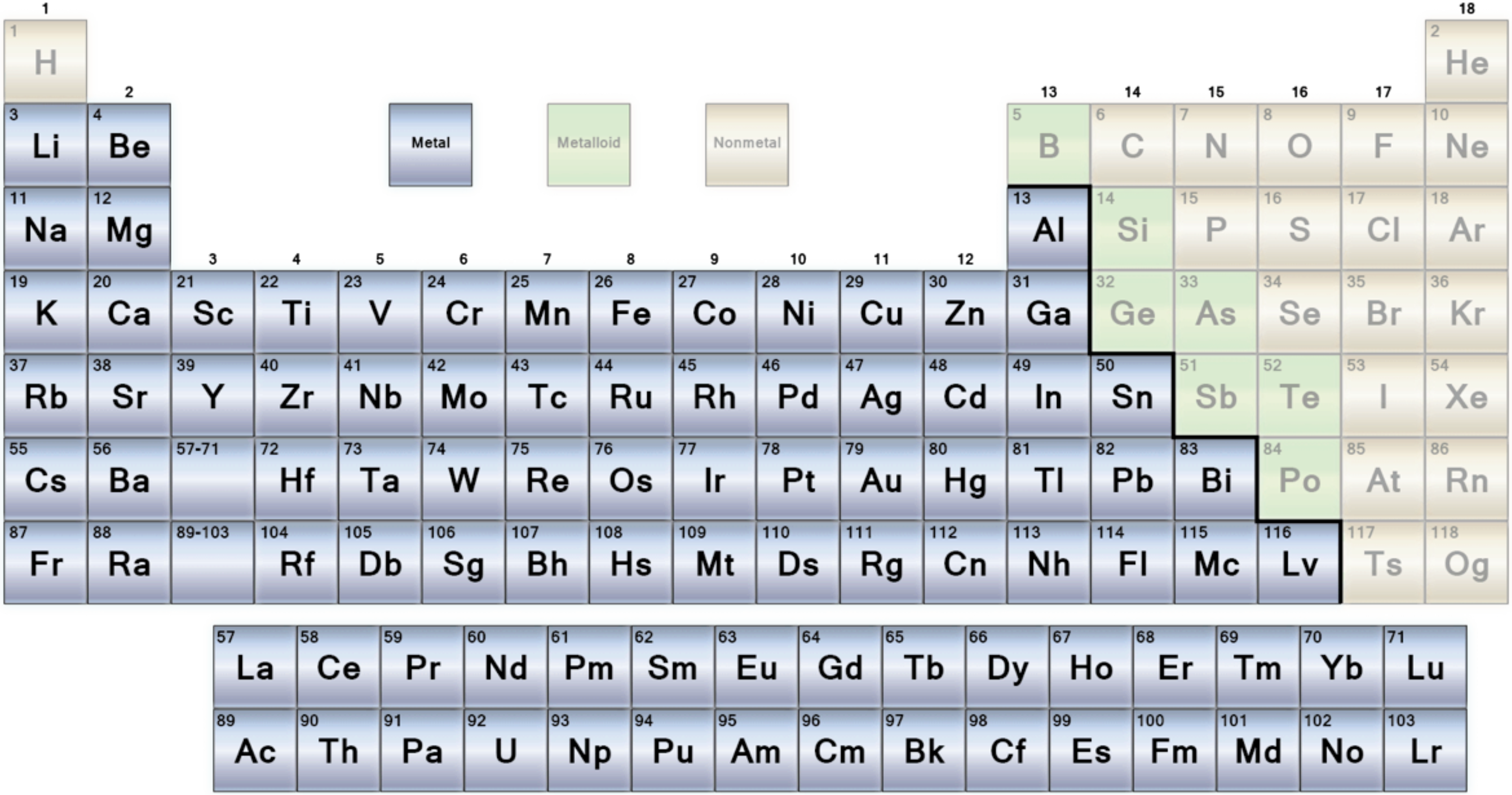


izolatorji polprevodniki prevodniki



KOVINE

Dobri električni prevodniki.
Upornost narašča z naraščajočo temperaturo.



Metal

Metalloid

Nonmetal

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

COMPOSITIONS OF DIFFERENT ALLOYS

Alloys are materials composed of a mixture of elements including at least one metal, used as they often have superior properties to component elements. This table shows the main elements found in a number of different alloys, and their common uses. Compositions can vary in cases, and this is merely an overview.

KEY

Composition & trace elements

● Metal ● Non-metal

Major elements are given with percentages. Minor elements are given without percentages.

Alloy uses

ELEMENTS KEY

Ag	Silver	Mn	Manganese
Al	Aluminium	Mo	Molybdenum
As	Arsenic	Nd	Neodymium
Au	Gold	Ni	Nickel
Bi	Bismuth	P	Phosphorus
C	Carbon	Pb	Lead
Ce	Cerium	Pd	Palladium
Cr	Chromium	Pt	Platinum
Cu	Copper	Sb	Antimony
Fe	Iron	Si	Silicon
Ge	Germanium	Sn	Tin
Hg	Mercury	Ti	Titanium
La	Lanthanum	V	Vanadium
Mg	Magnesium	Zn	Zinc

AMALGAM

Hg MIN 45% MAX 55% · Ag MIN 22% MAX 32%

Sn MIN 12% MAX 30% · Cu MIN 12% MAX 24%

In older dental fillings, mining

BRASS

Cu MIN 65% MAX 90% · Zn MIN 10% MAX 35%

Pb

Older compositions contained lead, but no longer used due to toxicity.

Decoration, plumbing, instruments

BRONZE

Cu MIN 78% MAX 95% · Sn MIN 5% MAX 22%

Al Mn Ni Zn As P Si

Instruments, guitar strings, medals

CAST IRON

Fe MIN 96% MAX 98% · C MIN 2% MAX 4%

Si

Similar in composition to steel, which has a lower carbon content.

Metal structures & bridges

CUPRONICKEL

Cu MIN 70% MAX 90% · Ni MIN 10% MAX 30%

Mn Fe

Highly resistant to corrosion in seawater.

Coinage, marine engineering

GREEN GOLD

Au 75% · Ag MIN 6% MAX 25% · Cu

Archaically known as electrum. Appears as greenish-yellow, rather than green.

Core of Nobel prize medals

MAGNALIUM

Al MIN 50% MAX 95% · Mg MIN 5% MAX 50%

Cu Ni Sn

Creates crackling effects in fireworks

Aircraft and car parts, fireworks

MISCHMETAL

Ce 50% · La 25% · Nd 15%

Range of rare earth elements also present. Mixed with iron oxide to harden for flints.

Cigarette lighter flints

NICHROME

Ni MIN 60% MAX 80% · Cr MIN 15% MAX 20%

Fe Mn Si

Can be used for coils of electronic cigarettes.

Electric heaters, foam cutters

NITINOL

Ni MIN 50% MAX 55% · Ti MIN 45% MAX 50%

Shape memory alloy; if deformed, its original shape is recovered on heating.

Glasses frames

NORDIC GOLD

Cu 89% · Al 5% · Zn 5%

Sn 1%

Despite the name, doesn't contain any gold.

10, 20 and 50 cent Euro coins

PEWTER

Sn MIN 85% MAX 99% · Cu Sb Bi

Compositions used to commonly contain lead, but no longer do due to toxicity.

Decorative plates & vases

SOLDER

Sn 90% · Ag 5% · Cu 5%

Solder compositions previously contained lead, now discouraged due to toxicity.

Joining electrical components

STEEL

Fe MIN 50% MAX 99% · C MIN 0.1% MAX 2.5%

Cr Mn V Mo

Stainless steel: ~12% chromium

Structures, cutlery, car bodies, rails

STERLING SILVER

Ag 92.5% · Cu Pt Ge Zn

Must contain 92.5% silver; remainder is other metals, usually copper.

Cutlery, jewelry, musical instruments

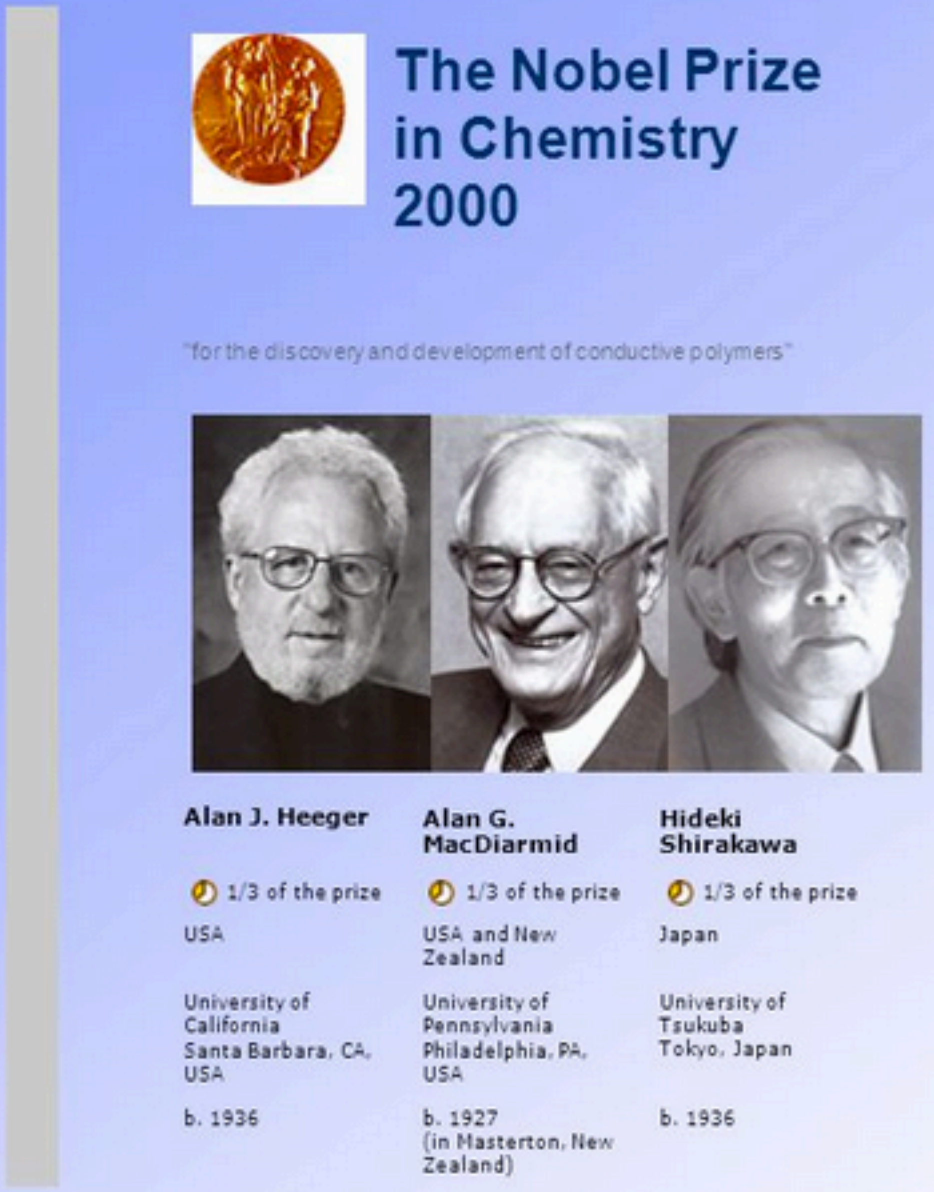
WHITE GOLD

Au 75% · Pd 10% · Ni 10%

Zn 5%

Often plated with rhodium to enhance whiteness.

Jewelry



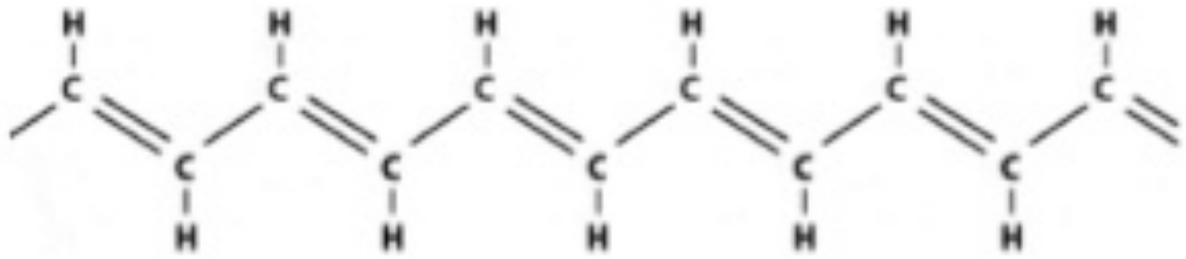
The Nobel Prize in Chemistry 2000

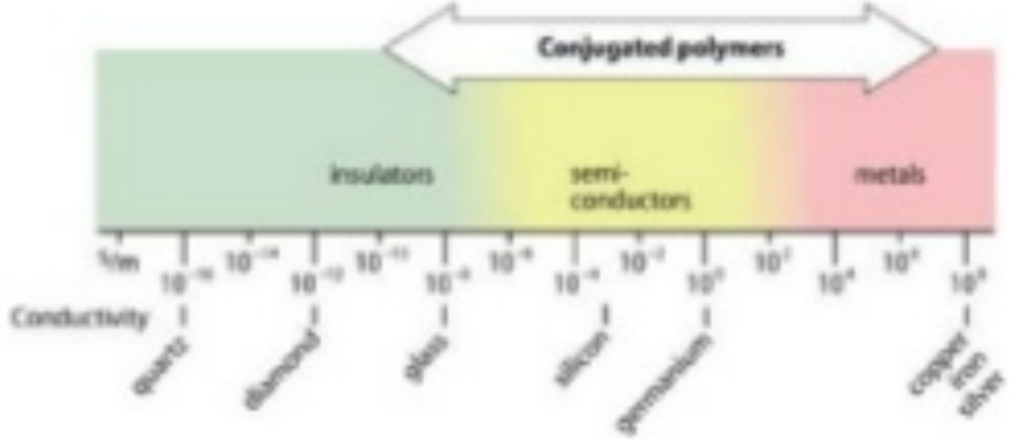
"for the discovery and development of conductive polymers"

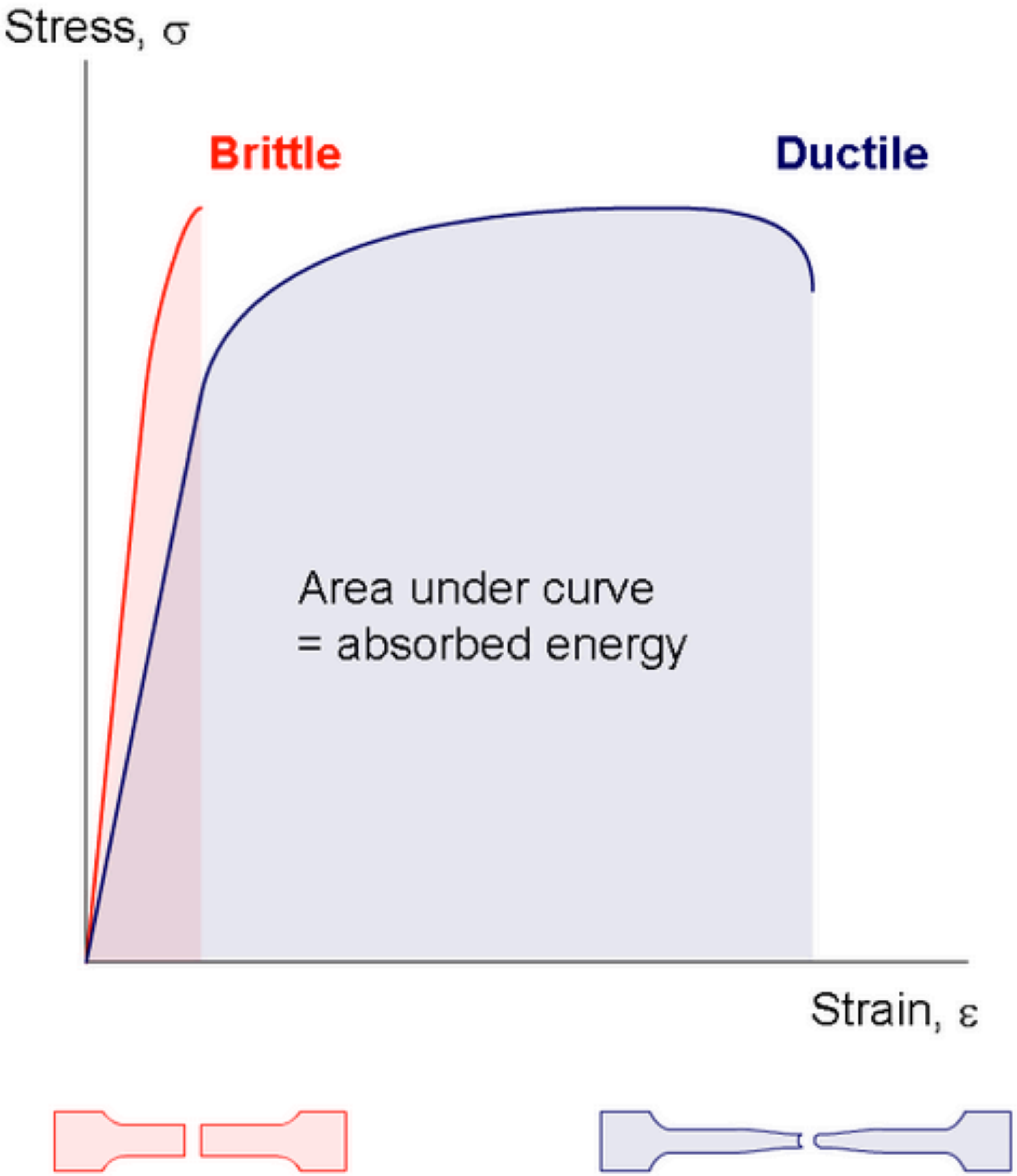
Alan J. Heeger	Alan G. MacDiarmid	Hideki Shirakawa
1/3 of the prize	1/3 of the prize	1/3 of the prize
USA	USA and New Zealand	Japan
University of California Santa Barbara, CA, USA	University of Pennsylvania Philadelphia, PA, USA	University of Tsukuba Tokyo, Japan
b. 1936	b. 1927 (in Masterton, New Zealand)	b. 1936

"for the discovery and developement of conductive polymers"

A new material class!






Stress, σ
Brittle
Ductile
Area under curve
= absorbed energy
Strain, ε


Al


Fe


Ca


Na

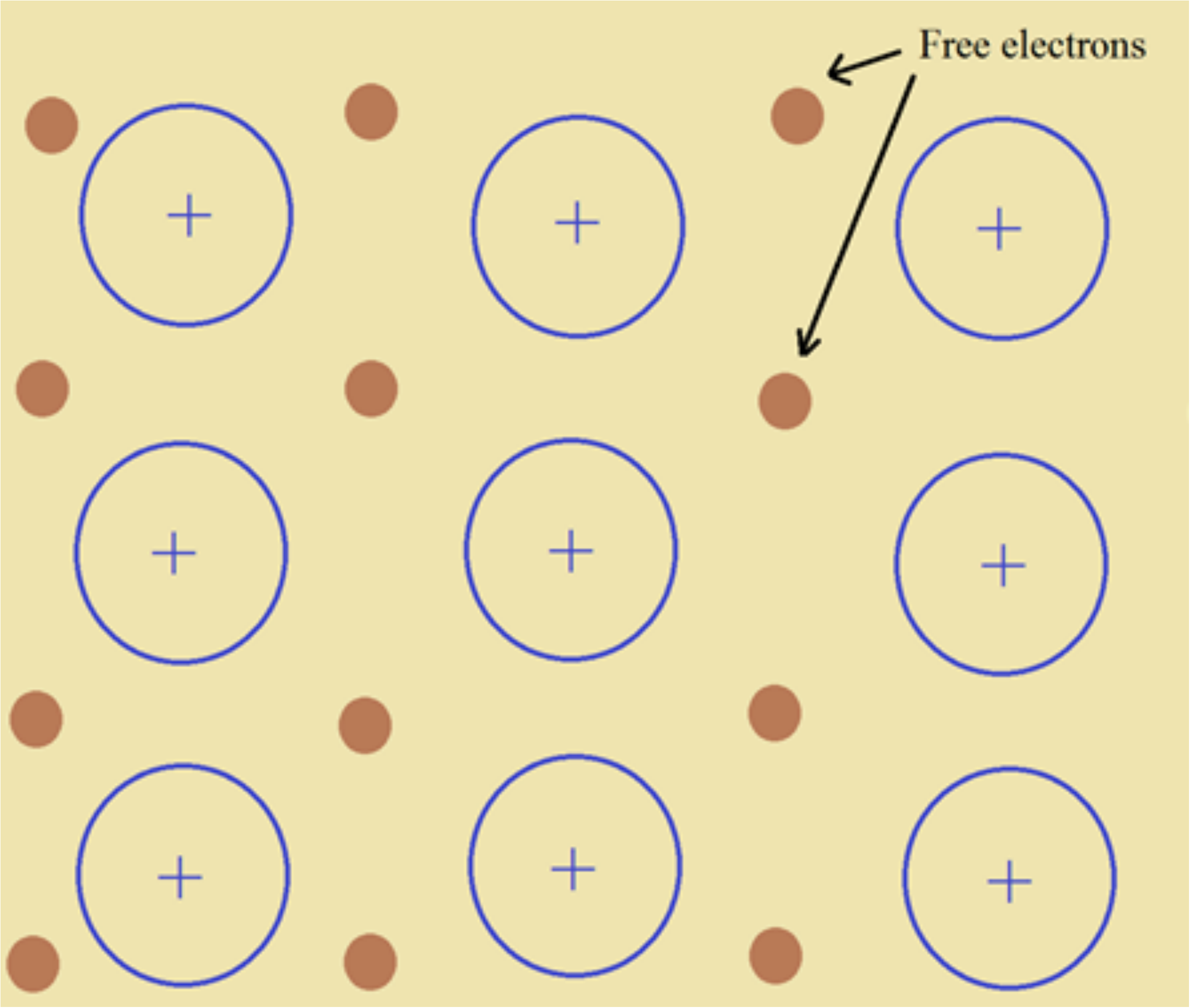

K


Mg


Au


Pt

1. Kaj je model prostih elektronov? Katere snovi dobro opisuje?



- Upoštevamo samo valenčne elektrone.
- Zanemarimo interakcije (med pari elektronov, med elektroni in ioni).

Elektroni se prosto gibajo, kot plin.

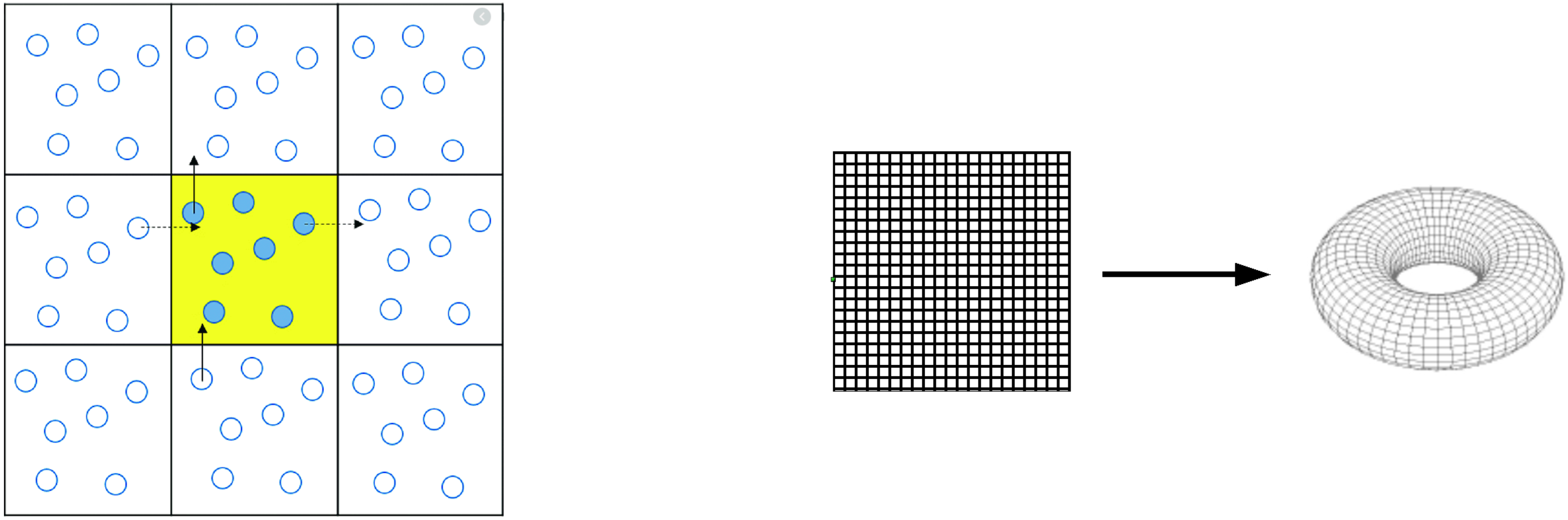
$$\psi = \frac{1}{\sqrt{V}} e^{i\mathbf{k}\cdot\mathbf{r}}$$

Trik: periodični robni pogoji

$$f(x,y,z) = f(x+l,y,z)$$

$$f(x,y,z) = f(x,y+l,z)$$

$$f(x,y,z) = f(x,y,z+l)$$



$$\psi = \frac{1}{\sqrt{V}} e^{i\mathbf{k}\cdot\mathbf{r}}$$

$$f(x, y, z) = f(x + l, y, z)$$

$$k_x\, l = 2\pi\, n_x$$

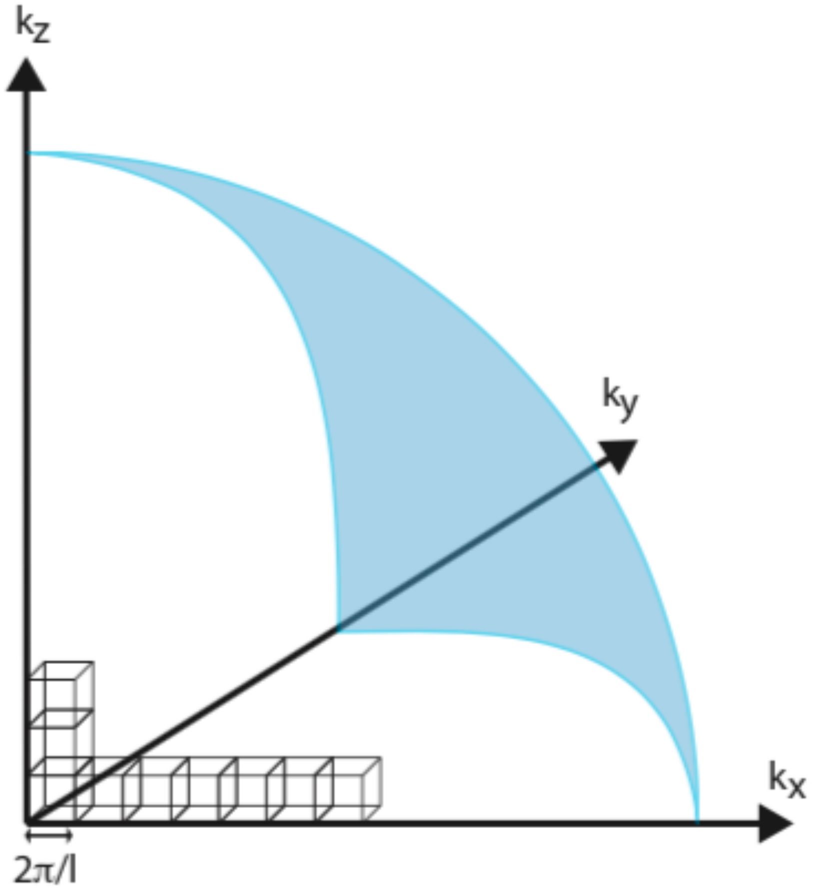
Množica točk z razmikom 2π/l.

V 3D: množica kock z volumnom $\left(\frac{2\pi}{l}\right)^3 = \frac{(2\pi)^3}{V}$

Pauli: po 1 elektron za vsak nabor kvantnih števil

$$n_x, n_y, n_z, m_s = \pm\frac{1}{2}$$

$$E = \frac{\hbar^2}{2m_e}\left(k_x^2 + k_y^2 + k_z^2\right) = \frac{\hbar^2 |\mathbf{k}|^2}{2m_e}$$



$$\frac{4\pi}{3}k_F^3 = \frac{N}{2}\frac{(2\pi)^3}{V}$$

$$k_F = (3\pi^2 n)^{1/3}$$

$$E_F = \frac{\hbar^2}{2m_e}k_F^2 = \frac{\hbar^2}{2m_e}\left(3\pi^2 n\right)^{2/3}$$

$$v_F = \frac{\hbar k_F}{m_e} = \frac{\hbar}{m_e}(3\pi^2 n)^{1/3}$$

Za baker je $n = 8{,}5 \times 10^{28}\,\mathrm{m}^{-3}$, od koder sledi $E_F = 7{,}0\,\mathrm{eV}$ in

$$v_F = 1{,}6 \times 10^6\,\mathrm{m/s} \approx 0{,}005c.$$

Table 2.1
FERMI ENERGIES, FERMI TEMPERATURES, FERMI WAVE VECTORS, AND FERMI VELOCITIES FOR REPRESENTATIVE METALS[a]

ELEMENT	r_s/a_0	$\mathcal{E}_F$	T_F	k_F	v_F
Li	3.25	4.74 eV	5.51×10^4 K	$1.12 \times 10^8\ \text{cm}^{-1}$	1.29×10^8 cm/sec
Na	3.93	3.24	3.77	0.92	1.07
K	4.86	2.12	2.46	0.75	0.86
Rb	5.20	1.85	2.15	0.70	0.81
Cs	5.62	1.59	1.84	0.65	0.75
Cu	2.67	7.00	8.16	1.36	1.57
Ag	3.02	5.49	6.38	1.20	1.39
Au	3.01	5.53	6.42	1.21	1.40
Be	1.87	14.3	16.6	1.94	2.25
Mg	2.66	7.08	8.23	1.36	1.58
Ca	3.27	4.69	5.44	1.11	1.28
Sr	3.57	3.93	4.57	1.02	1.18
Ba	3.71	3.64	4.23	0.98	1.13
Nb	3.07	5.32	6.18	1.18	1.37
Fe	2.12	11.1	13.0	1.71	1.98
Mn	2.14	10.9	12.7	1.70	1.96
Zn	2.30	9.47	11.0	1.58	1.83
Cd	2.59	7.47	8.68	1.40	1.62
Hg	2.65	7.13	8.29	1.37	1.58
Al	2.07	11.7	13.6	1.75	2.03
Ga	2.19	10.4	12.1	1.66	1.92
In	2.41	8.63	10.0	1.51	1.74
Tl	2.48	8.15	9.46	1.46	1.69
Sn	2.22	10.2	11.8	1.64	1.90
Pb	2.30	9.47	11.0	1.58	1.83
Bi	2.25	9.90	11.5	1.61	1.87
Sb	2.14	10.9	12.7	1.70	1.96

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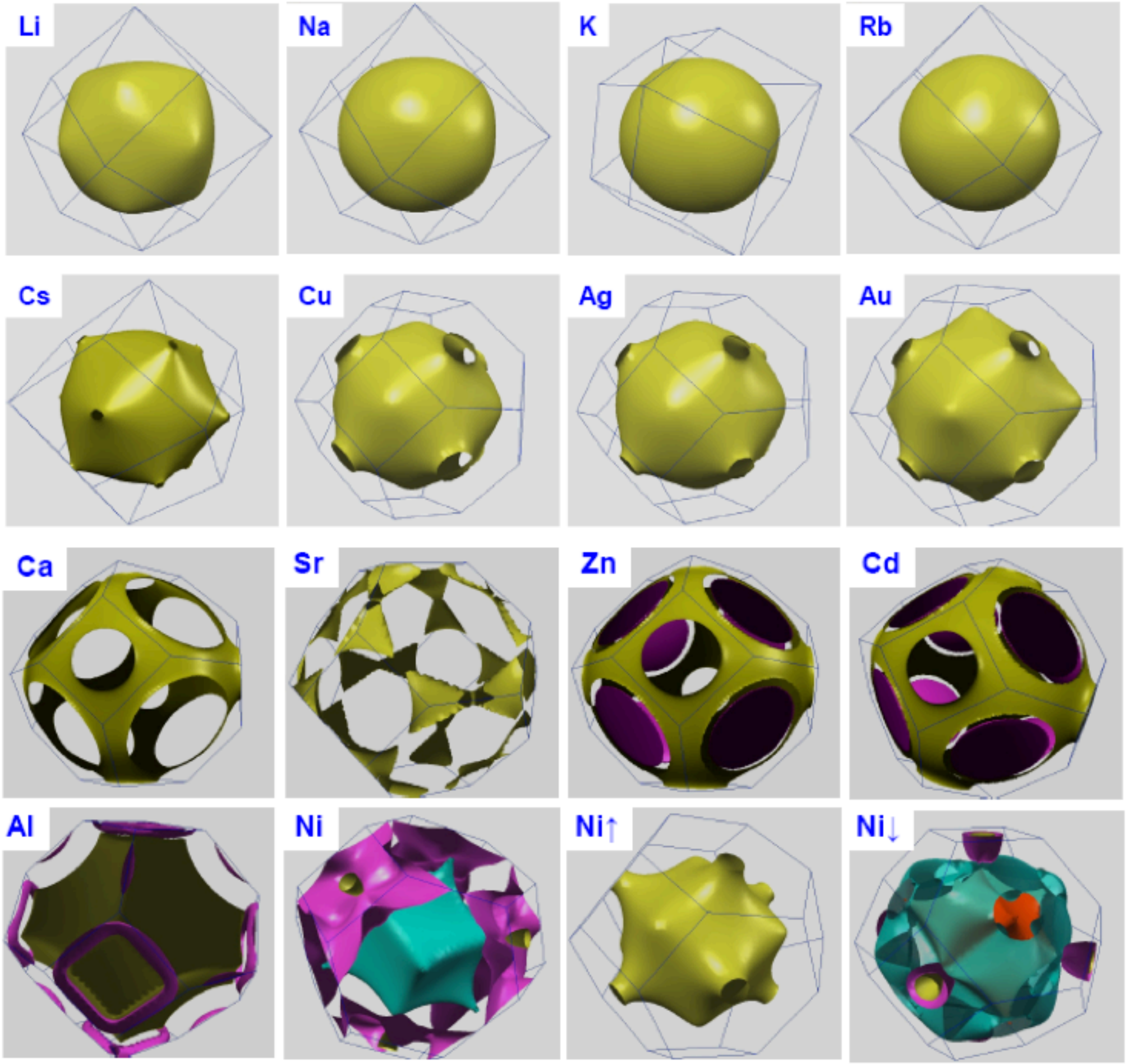
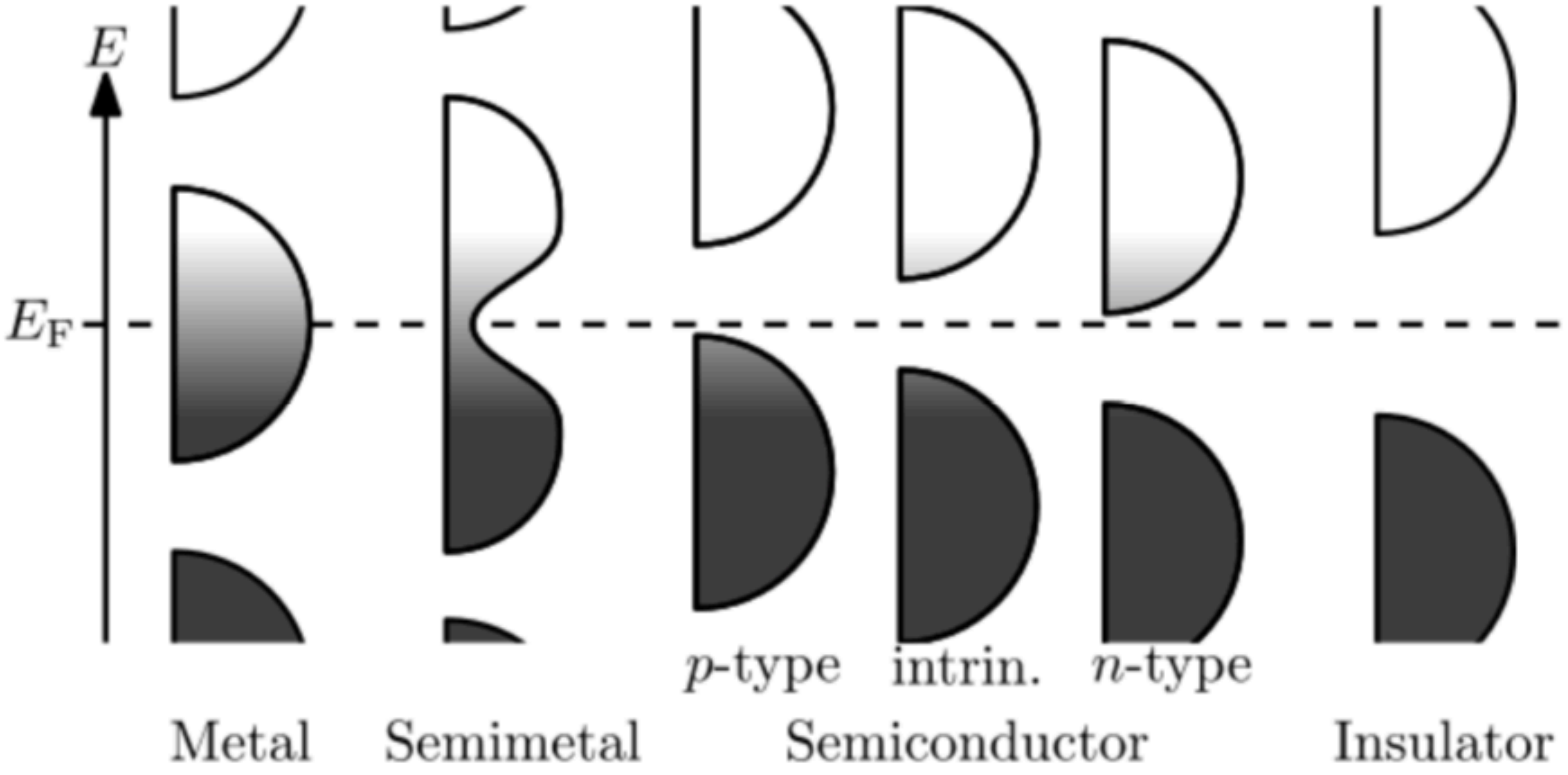
[a] The table entries are calculated from the values of r_s/a_0 given in Table 1.1 using $m = 9.11 \times 10^{-28}$ grams.


Li
Na
K
Rb
Cs
Cu
Ag
Au
Ca
Sr
Zn
Cd
Al
Ni
Ni↑
Ni↓

2. Gostota stanj



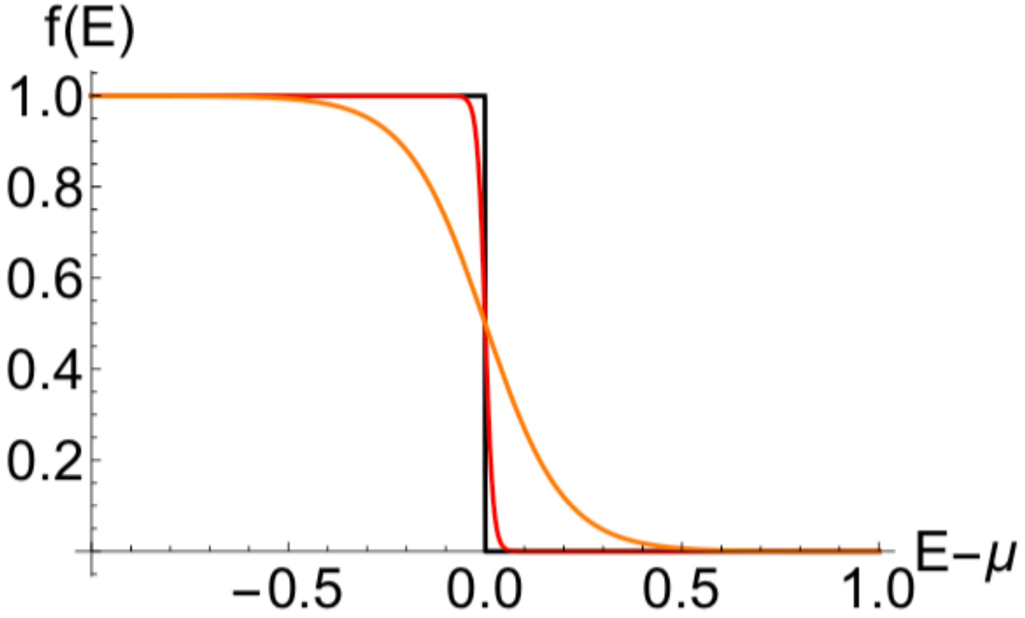
3. Kaj je Fermi-Diracova porazdelitev? V čem se fermioni razlikujejo od klasičnih delcev?

zasedbeno število: $f(E) = \dfrac{1}{1 + \mathrm{e}^{\frac{E-\mu}{k_B T}}}$ $\quad 0 \leq f(E) \leq 1$

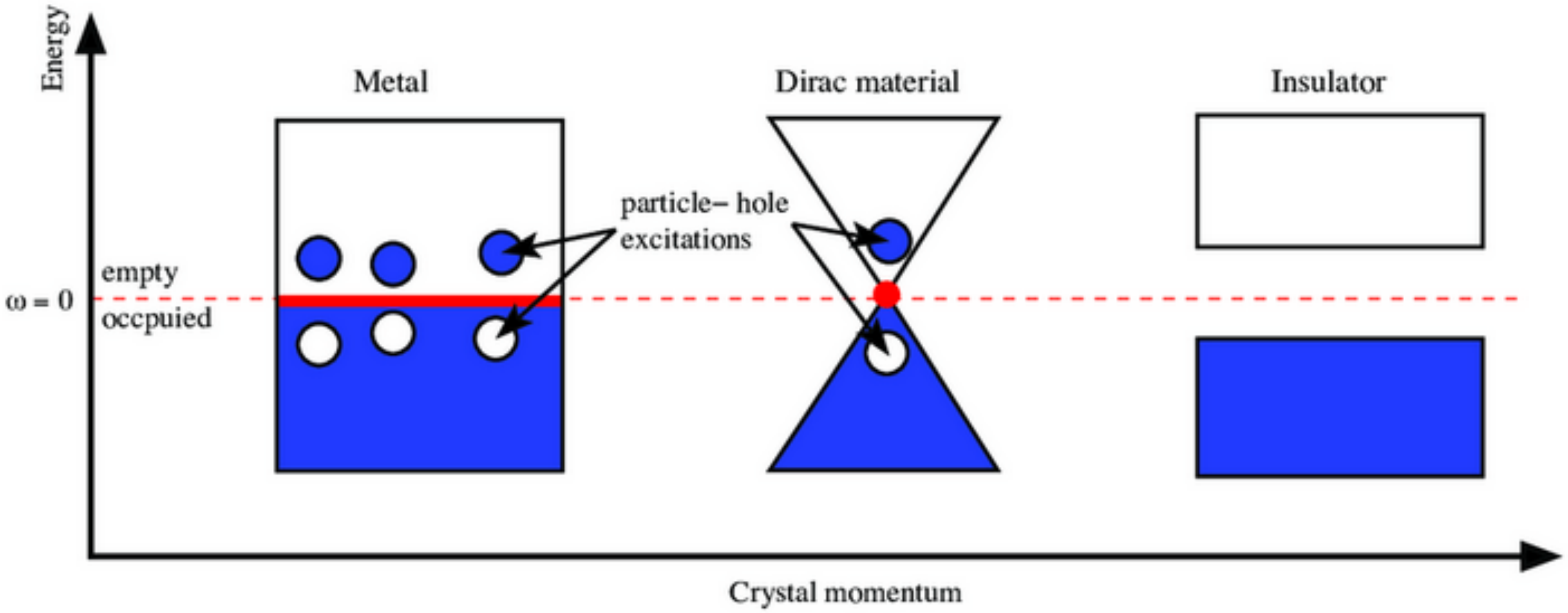
$$k_B \;=\; 1{,}38 \times 10^{-23}\,\mathrm{J/K}\ \text{Boltzmannova konstanta}$$

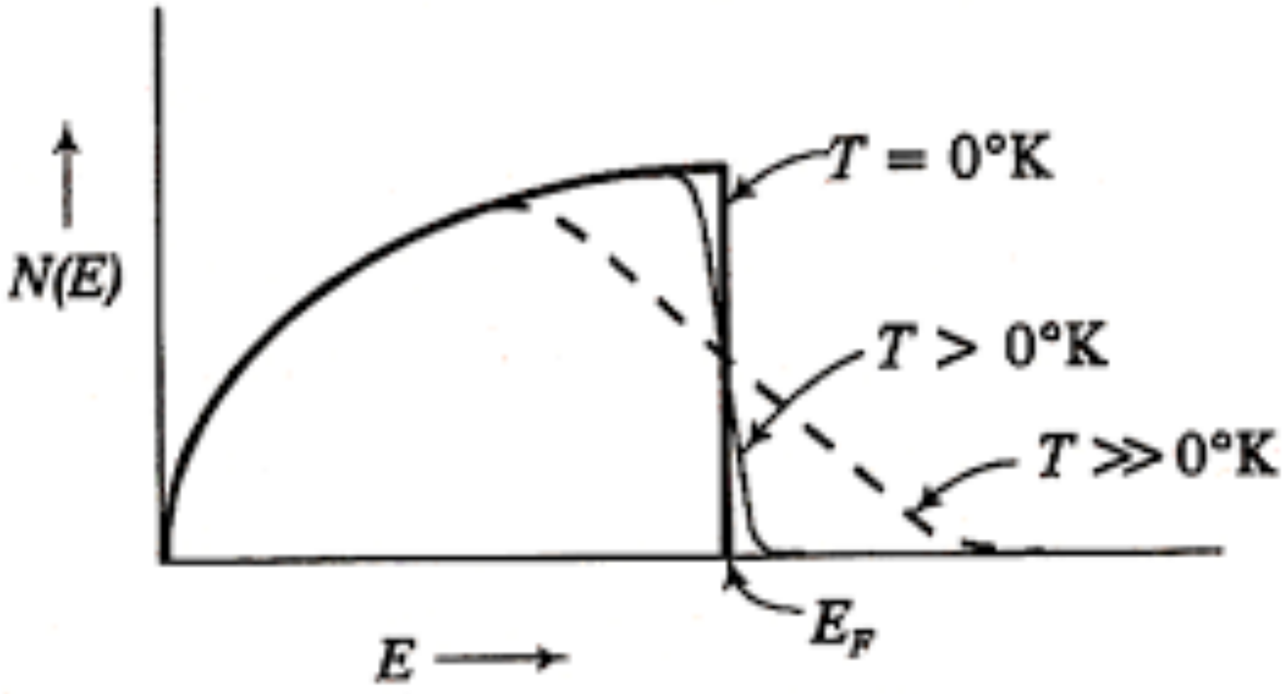
μ **kemijski potencial = Fermijev nivo** $\quad \mu = \mu(T)$

Definicija: termodinamsko delo, ki ga moramo opraviti, da v sistem dodamo en elektron. Po domače: "do katere energije so elektronski nivoji zapolnjeni".



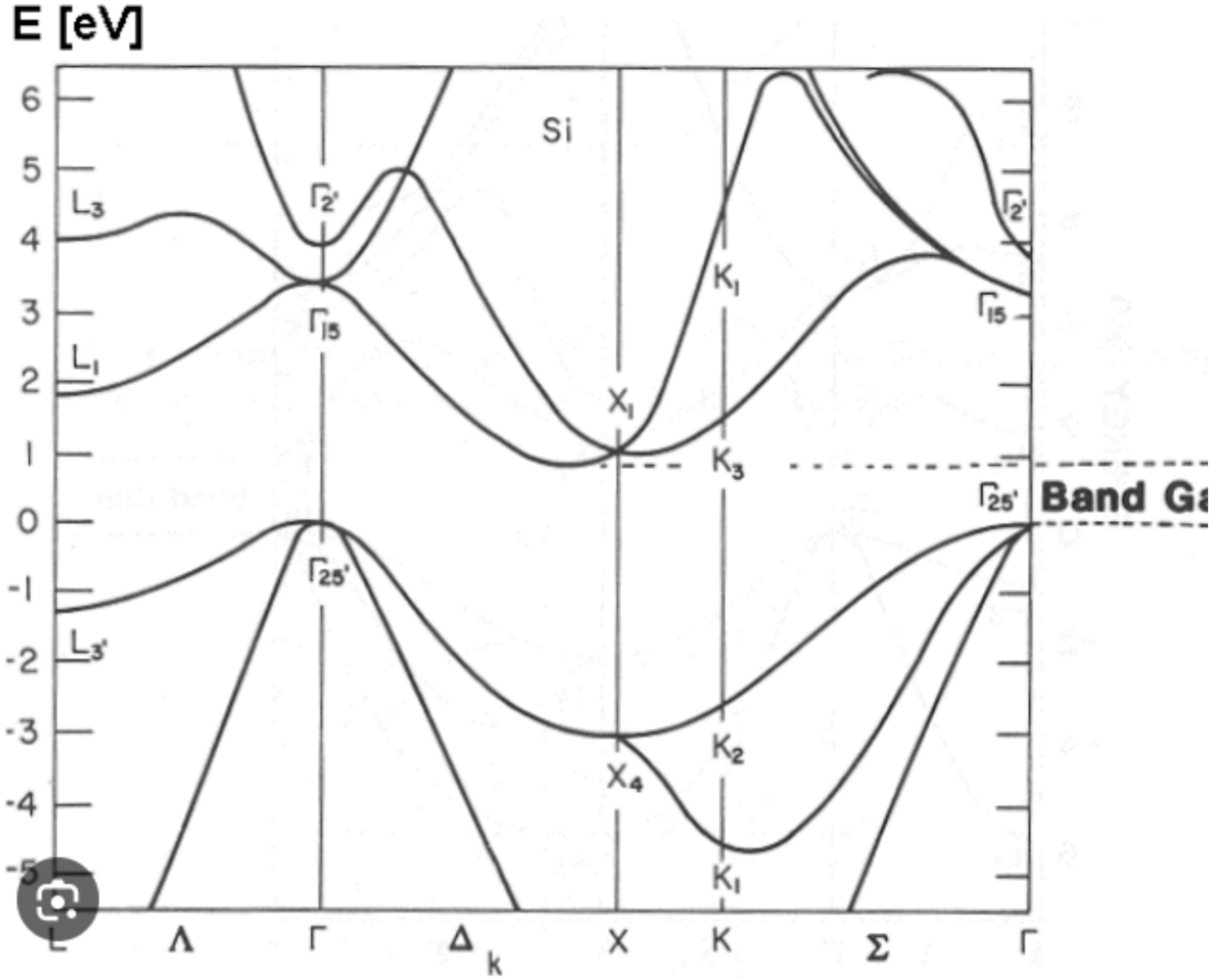
$$k_B T_{\text{sobna}} \approx \frac{1}{100}$$





FERMI-DIRAC DISTRIBUTION AT DIFFERENT TEMPERATURES

4. Gibanje elektrona v zunanjem polju



$$m^*(k) = \left(\frac{1}{\hbar^2}\frac{\mathrm{d}^2 E(k)}{\mathrm{d}k^2}\right)^{-1}$$

prosti elektroni:

$$E(k) = \hbar^2 k^2 / 2m_e$$

$$m^*(k) = \left(\frac{1}{\hbar^2}\frac{\hbar^2}{m_e}\right)^{-1} = m_e$$

model verige atomov:

$$E(k) = \epsilon - 2t\cos(ka)$$

$$m^*(k) = \left(\frac{1}{\hbar^2}2ta^2\cos(ka)\right)^{-1} = \frac{\hbar^2}{2ta^2}\frac{1}{\cos(ka)}$$

$$m^*(k) \approx \frac{\hbar^2}{2ta^2}$$

5. Kaj je Ohmov zakon?
Kaj je razlika med prevodnostjo in specifično prevodnostjo?

$$\boxed{U = R\,I}$$

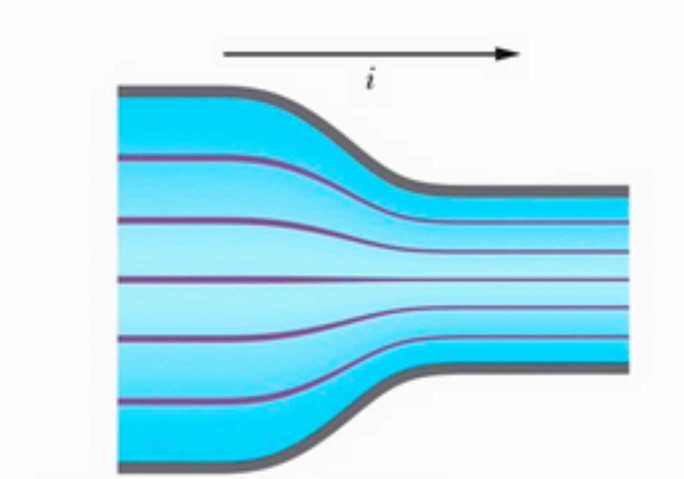
$$U = \frac{A}{q} \qquad I = \frac{q}{t}$$

$$\boxed{R = \zeta \frac{l}{S}} \qquad \boxed{\sigma = \frac{1}{\zeta}}$$

$$\boxed{j = \sigma E}$$

$$j = \frac{I}{S} \qquad E = \frac{U}{l}$$

6. Od česa je odvisna specifična prevodnost kovin v Drudejevi teoriji?



$$j = \frac{I}{S}$$

$$Q = It = (Sln)q$$

$$l = vt$$

$$j = \frac{I}{S} = \frac{Q}{St} = \frac{Svtnq}{St} = nqv$$

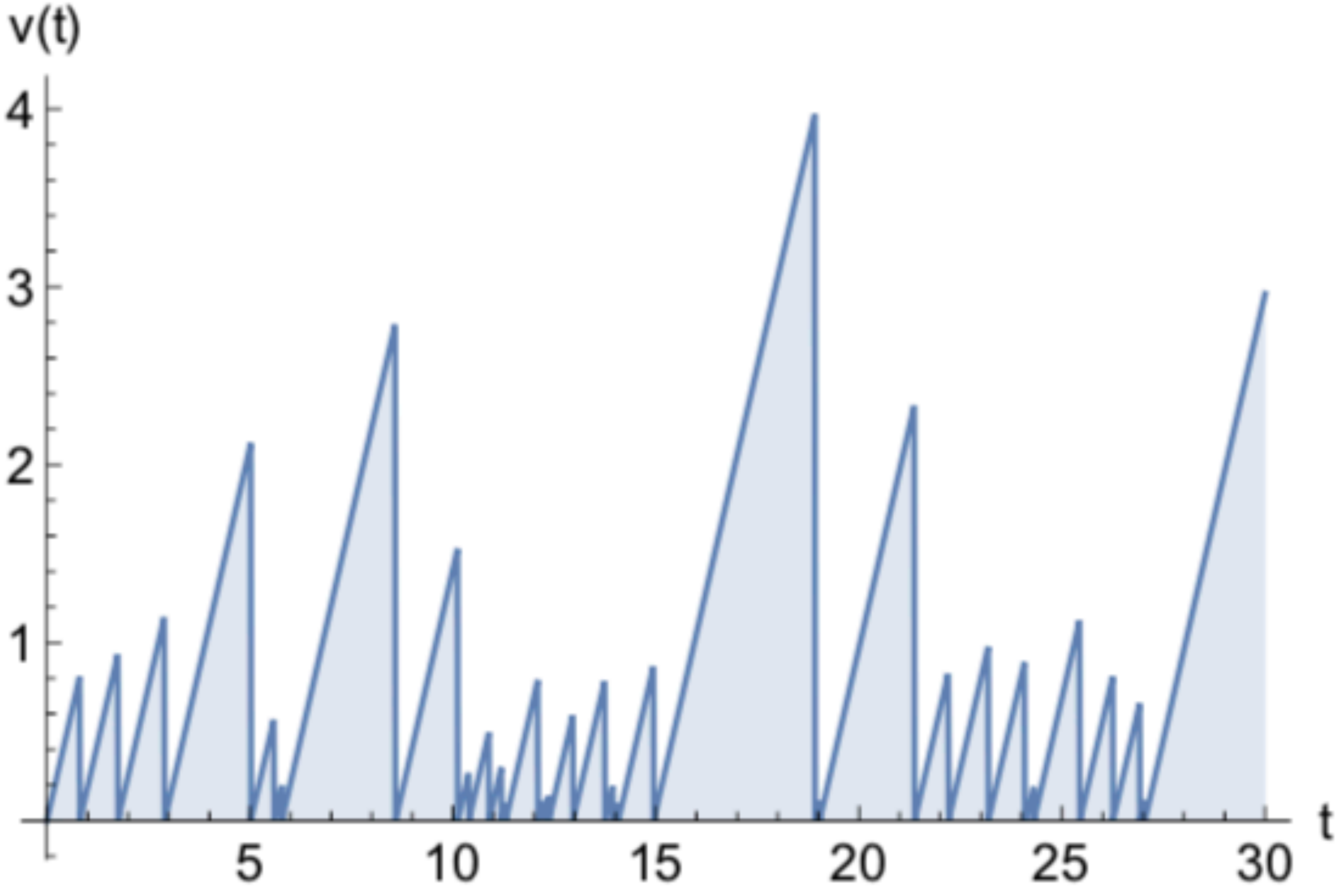
$$m^* \frac{dv}{dt} = qE$$

$$v_{\text{potovanja}} = \frac{qE\tau}{m^*}$$

relaksacijski čas τ

$$j = \frac{nq^2\tau}{m^*} E = \sigma E$$

$$\sigma = \frac{nq^2\tau}{m^*}$$

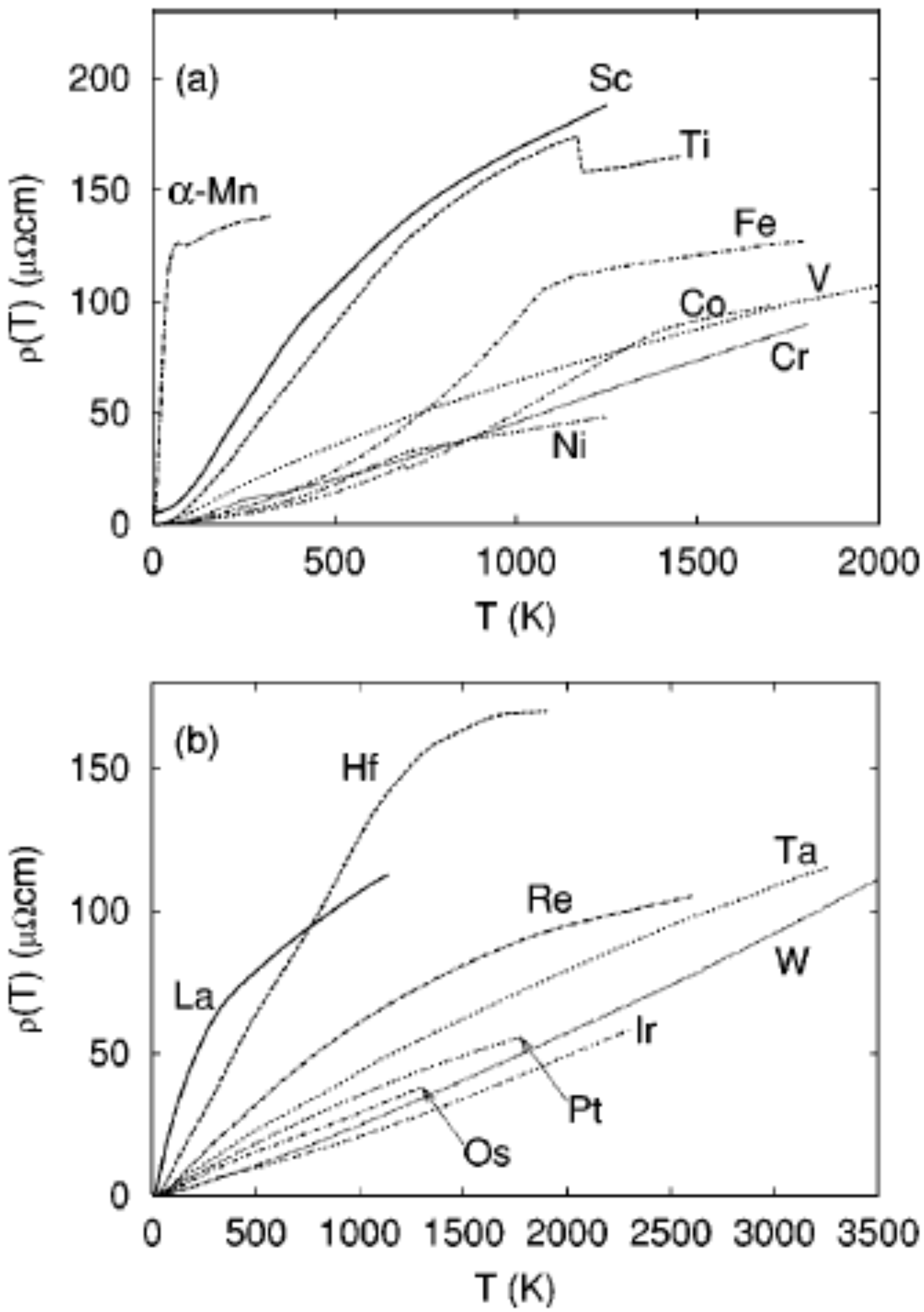


$$l = v_F \tau$$

$l = 39\,\mathrm{nm}$ baker pri sobni temperaturi

$c = 3 \cdot 10^8\,\mathrm{m/s}$ $v_F = 10^6\,\mathrm{m/s}$ $v_{\mathrm{potovalna}} = 0.1\,\mathrm{mm/s}$

Upornost običajnih kovin



sipanje zaradi nihanja ionov