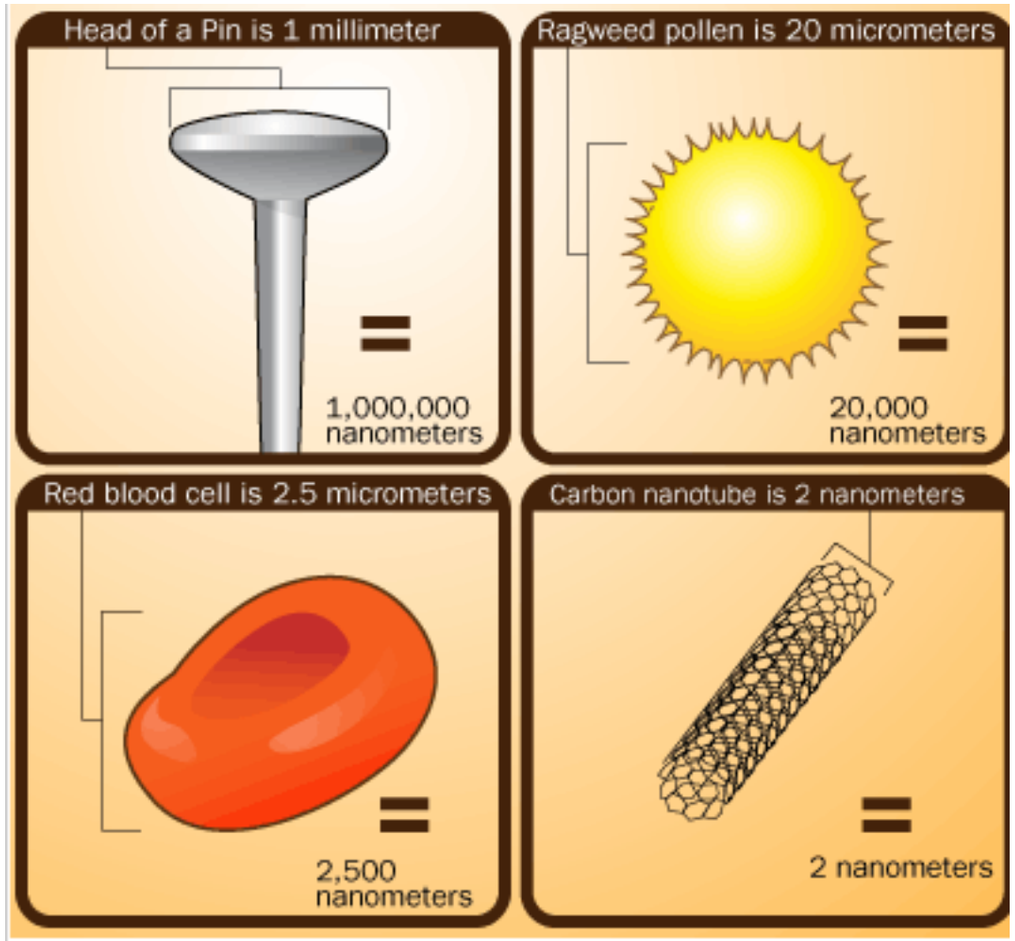
NANOTEHNOLOGIJA



nános (gr.) - palček

Metric prefixes

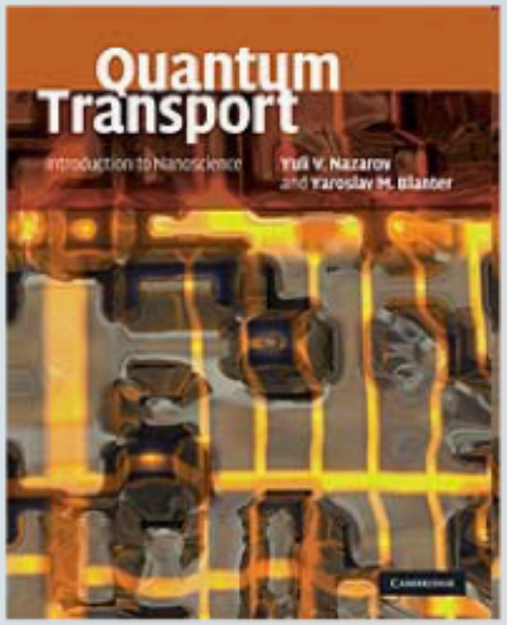
Prefix	Symbol	1000^m	10^n	Decimal	English word		Since[n 1]
					short scale	long scale	
yotta	Y	1000^8	10^{24}	1 000 000 000 000 000 000 000 000	septillion	quadrillion	1991
zetta	Z	1000^7	10^{21}	1 000 000 000 000 000 000 000	sextillion	thousand trillion	1991
exa	E	1000^6	10^{18}	1 000 000 000 000 000 000	quintillion	trillion	1975
peta	P	1000^5	10^{15}	1 000 000 000 000 000	quadrillion	thousand billion	1975
tera	T	1000^4	10^{12}	1 000 000 000 000	trillion	billion	1960
giga	G	1000^3	10^9	1 000 000 000	billion	thousand million	1960
mega	M	1000^2	10^6	1 000 000	million		1960
kilo	k	1000^1	10^3	1 000	thousand		1795
hecto	h	$1000^{2/3}$	10^2	100	hundred		1795
deca	da	$1000^{1/3}$	10^1	10	ten		1795
		1000^0	10^0	1	one		–
deci	d	$1000^{-1/3}$	10^{-1}	0.1	tenth		1795
centi	c	$1000^{-2/3}$	10^{-2}	0.01	hundredth		1795
milli	m	1000^{-1}	10^{-3}	0.001	thousandth		1795
micro	μ	1000^{-2}	10^{-6}	0.000 001	millionth		1960
nano	n	1000^{-3}	10^{-9}	0.000 000 001	billionth	thousand millionth	1960
pico	p	1000^{-4}	10^{-12}	0.000 000 000 001	trillionth	billionth	1960
femto	f	1000^{-5}	10^{-15}	0.000 000 000 000 001	quadrillionth	thousand billionth	1964
atto	a	1000^{-6}	10^{-18}	0.000 000 000 000 000 001	quintillionth	trillionth	1964
zepto	z	1000^{-7}	10^{-21}	0.000 000 000 000 000 000 001	sextillionth	thousand trillionth	1991
yocto	y	1000^{-8}	10^{-24}	0.000 000 000 000 000 000 000 001	septillionth	quadrillionth	1991

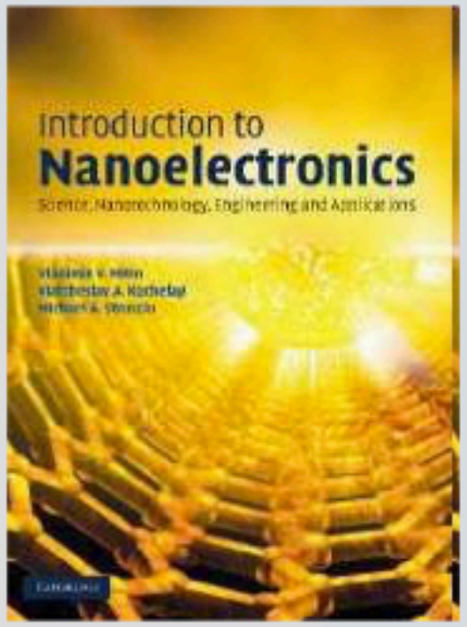
1. ^ The metric system was introduced in 1795 with six prefixes. The other dates relate to recognition by a resolution of the CGPM.

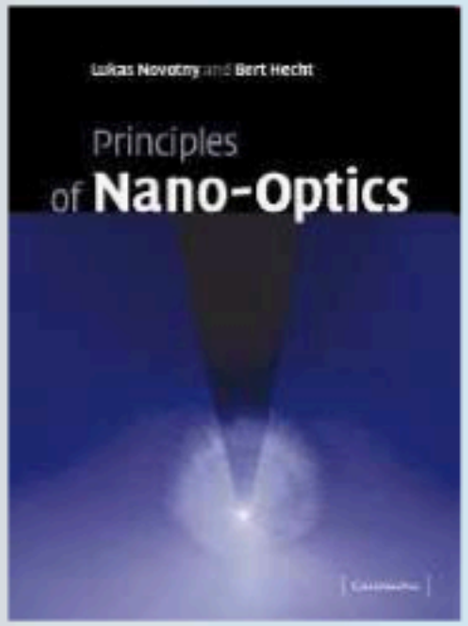
Nanomateriali

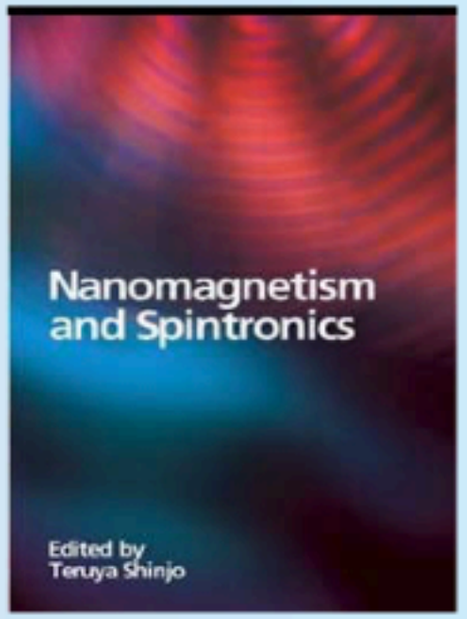
- globalni trg: 11 milijonov ton, 20 milijard EUR
- 300-400 tisoč delovnih mest v Evropi
- Obzorje 2020: “Nanotechnologies, Advanced Materials, Advanced Manufacturing and Processing”, NMP

- sončne kreme in kozmetika (ZnO, TiO_2)
- nanodelci srebra v oblačilih
- različne modifikacije ogljika v gumah
- Li-ion baterije
- kvantne pike kot fluorescenčni biomarkerji
- termoelektrični materiali


Quantum
Transport
Introduction to Nanoscience
Yuli V. Nazarov
and Yaroslav M. Blanter


Introduction to
Nanoelectronics
Science, Nanotechnology, Engineering and Applications


Lukas Novotny and Bert Hecht
Principles
of Nano-Optics

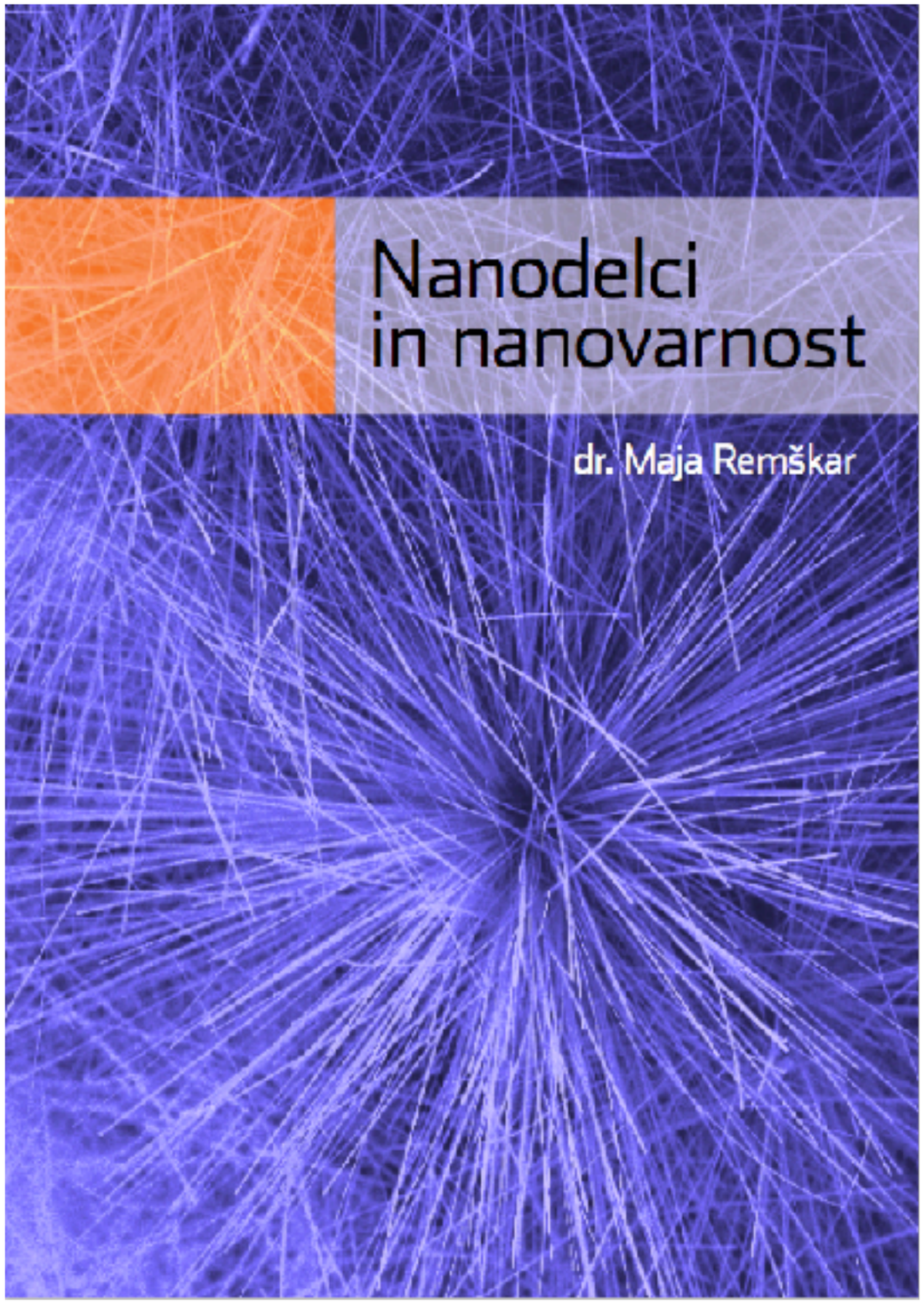

Nanomagnetism
and Spintronics
Edited by
Teruya Shinjo

Edited by
Günter Schmid
WILEY-VCH
Nanoparticles
From Theory to Application

Edited by Sergey P. Gubin
WILEY-VCH
Magnetic
Nanoparticles

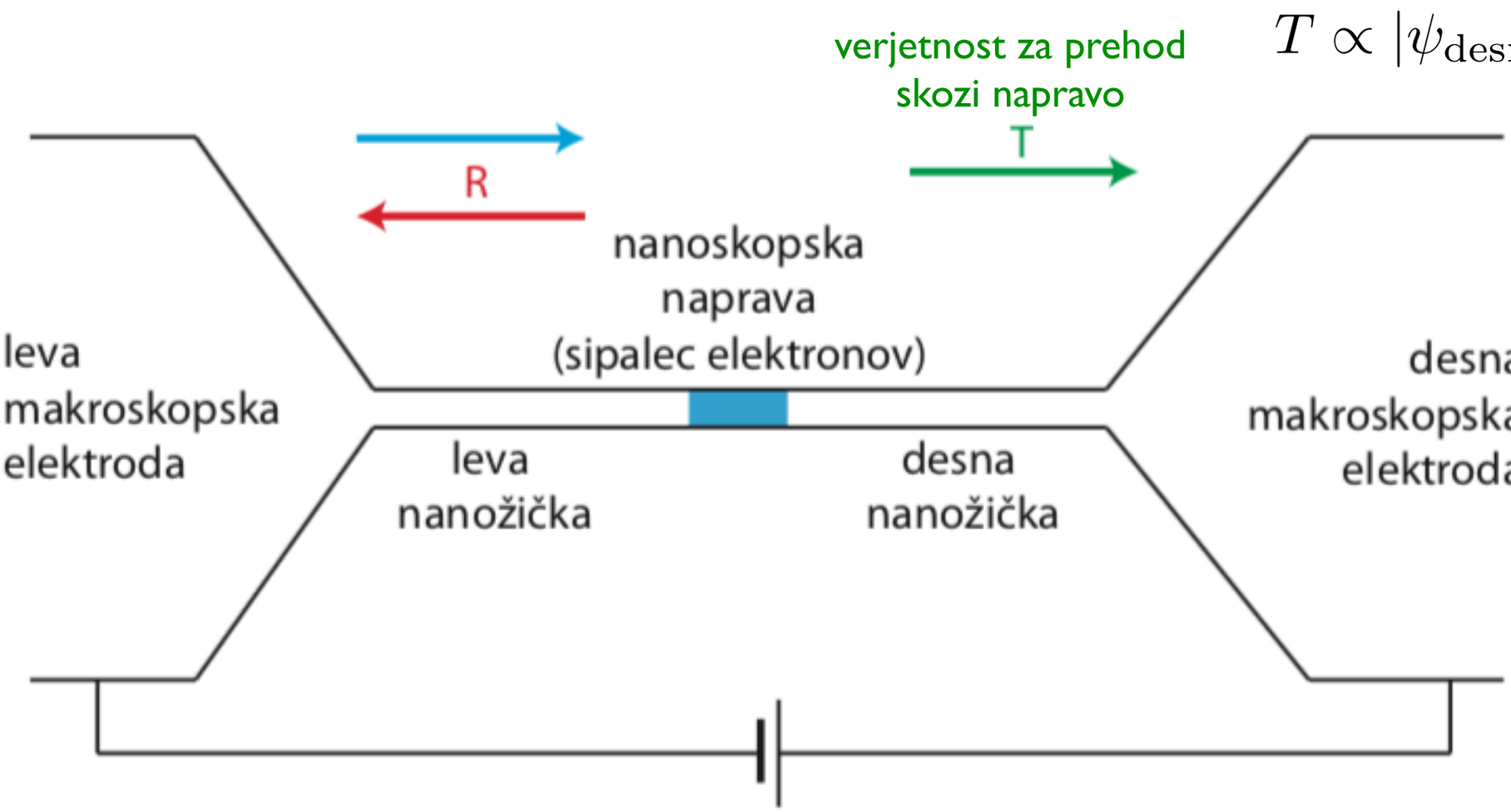
S. Reich, C. Thomsen, J. Maultzsch
WILEY-VCH
Carbon Nanotubes
Basic Concepts and Physical Properties

Nanofluidics
Nanoscience and Nanotechnology
RSC Publishing



http://www.kemijskovaren.si/files/nano_knjiga.pdf

1. Zakaj je prevodnost nanoskopskih naprav kvantizirana?



kvantno koherentno prevajanje:
elektroni ohranijo
kvantno koherenco
med potjo skozi napravo

$$G = \frac{I}{U} = G_0 T$$

$$G_0 = \frac{2e_0^2}{h} = 77{,}5\,\mu\mathrm{S} \qquad \frac{1}{G_0} = 12{,}9\,\mathrm{k}\Omega$$

prevodnost
angl. conductance

lastnost celotne naprave

specifična prevodnost
angl. conductivity

lastnost snovi

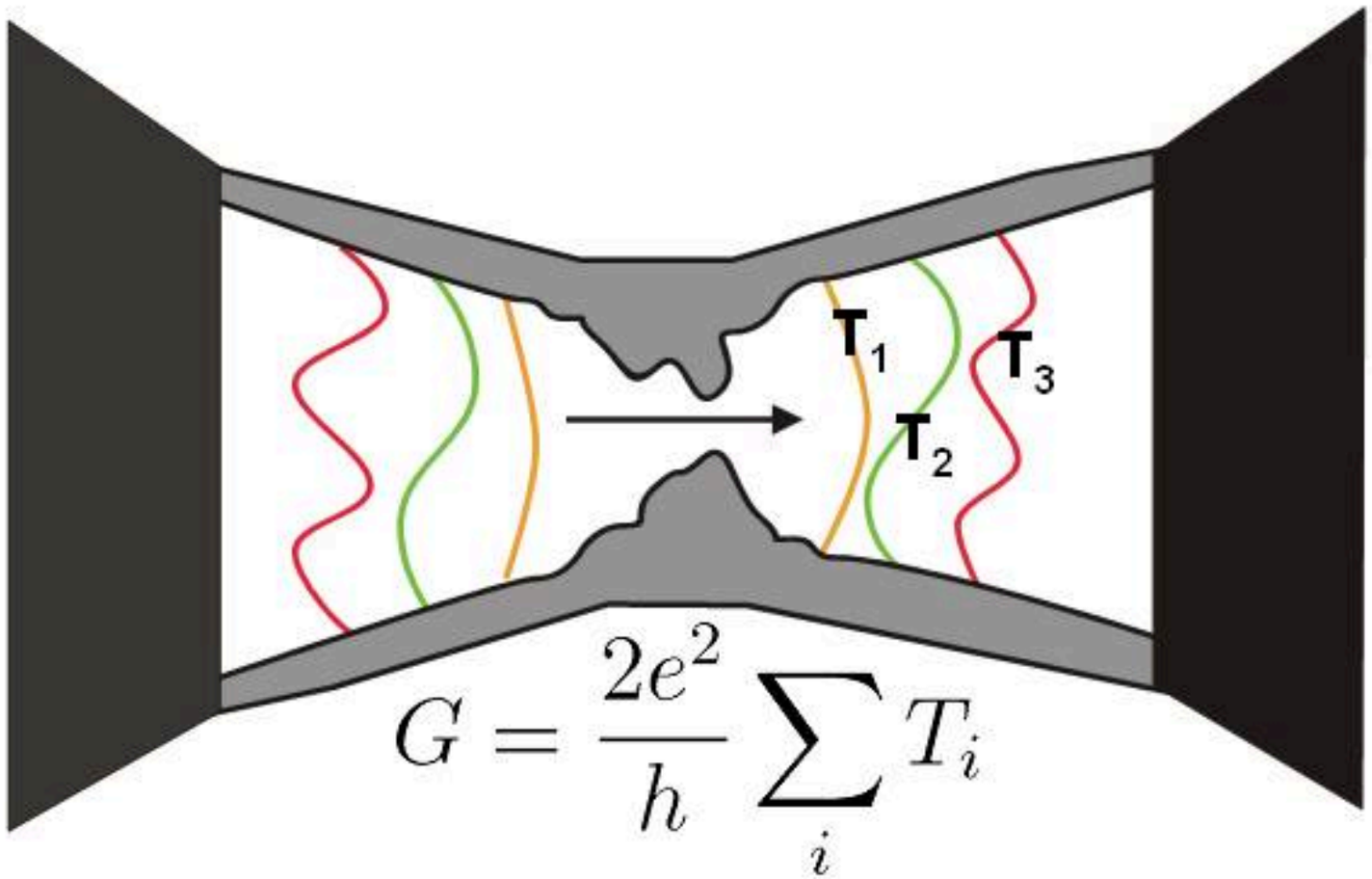
$$G = \sigma S/l$$

velja samo za difuzijsko prevajanje
v makroskopsko velikih vzorcih!

Kje je upornost?!?

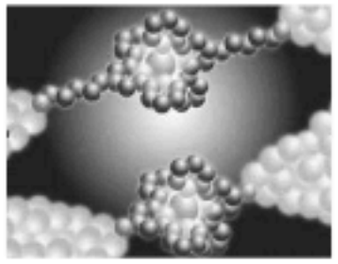
$$\text{upornost} = \frac{h}{2e_0^2}\frac{1}{T} = \frac{h}{2e_0^2}\left(1 + \frac{1-T}{T}\right) = \frac{h}{2e_0^2} + \frac{h}{2e_0^2}\frac{R}{T}$$

kvantizirana kontaktna upornost

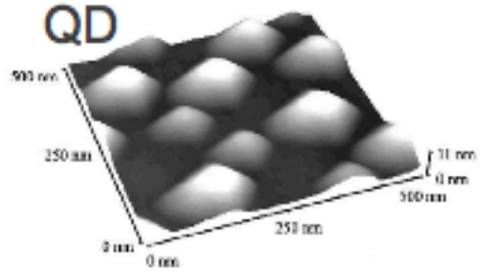

T1
T3
T2
$G = \frac{2e^2}{h} \sum_i T_i$

3. Zakaj kvantnim pikam rečemo tudi umetni atomi?

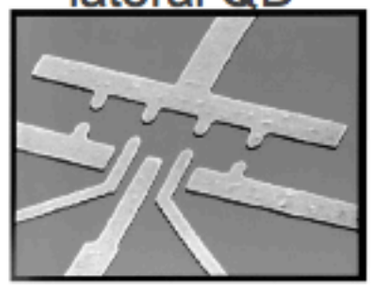
single molecule



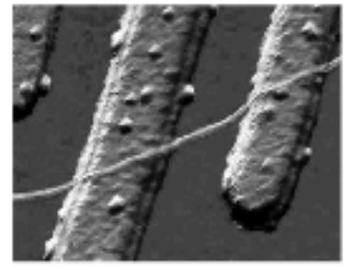
self-assembled QD



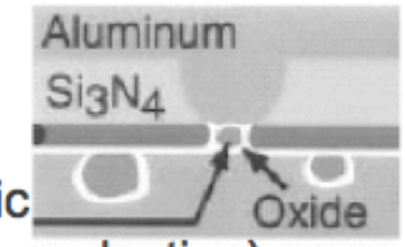
lateral QD



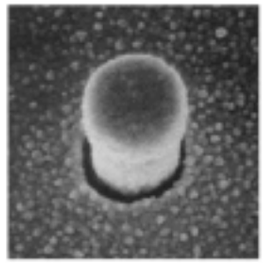
nanotube



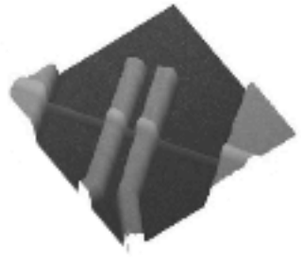
1 nm | 10 nm | 100 nm | 1μm



metallic (superconducting) nanoparticle

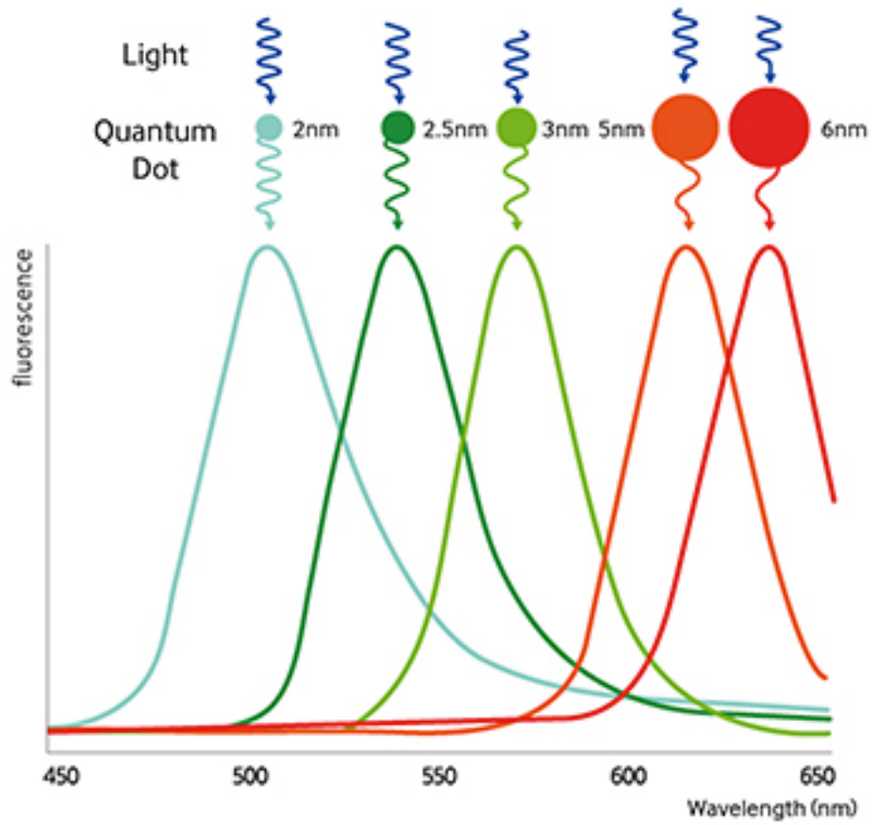


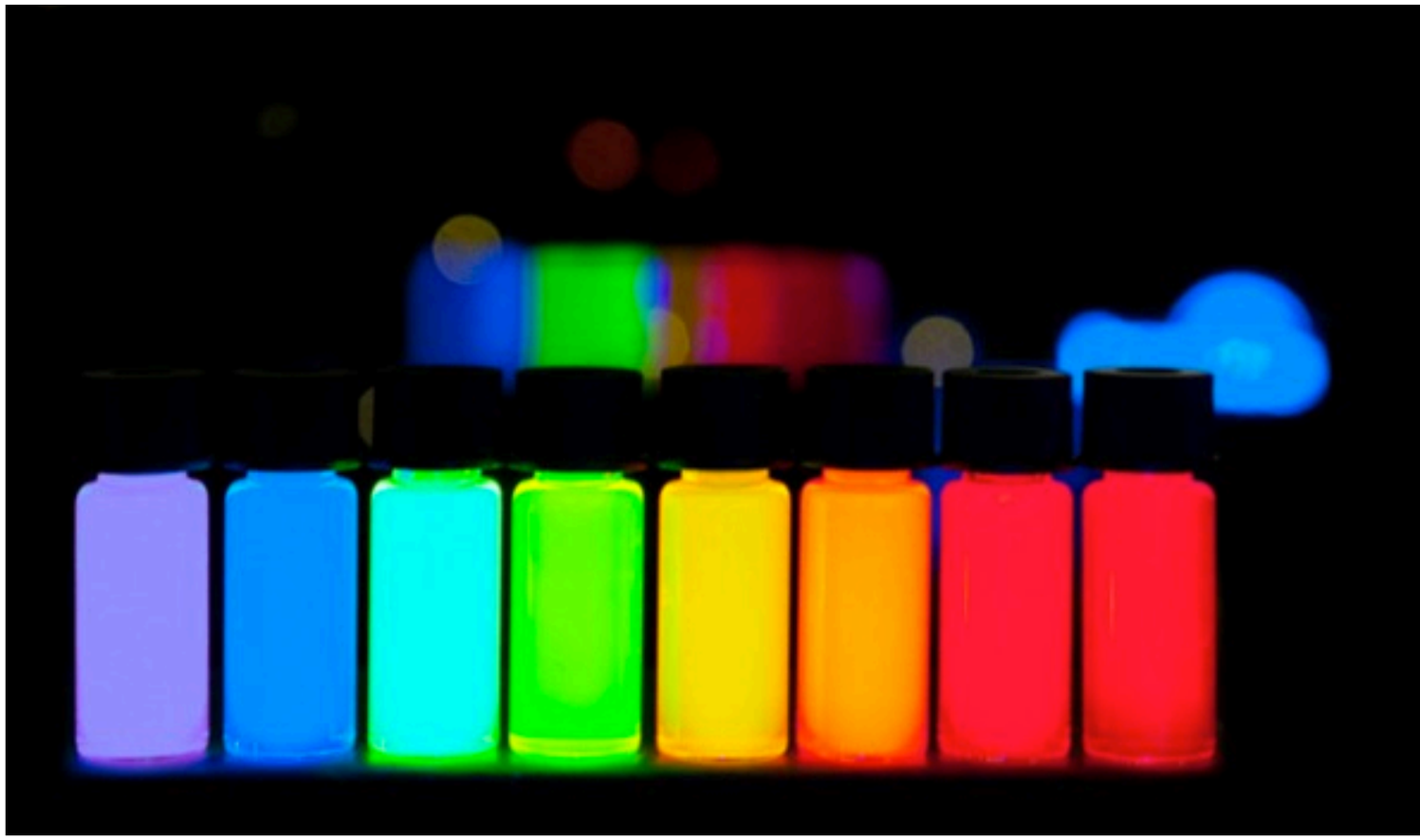
vertical QD

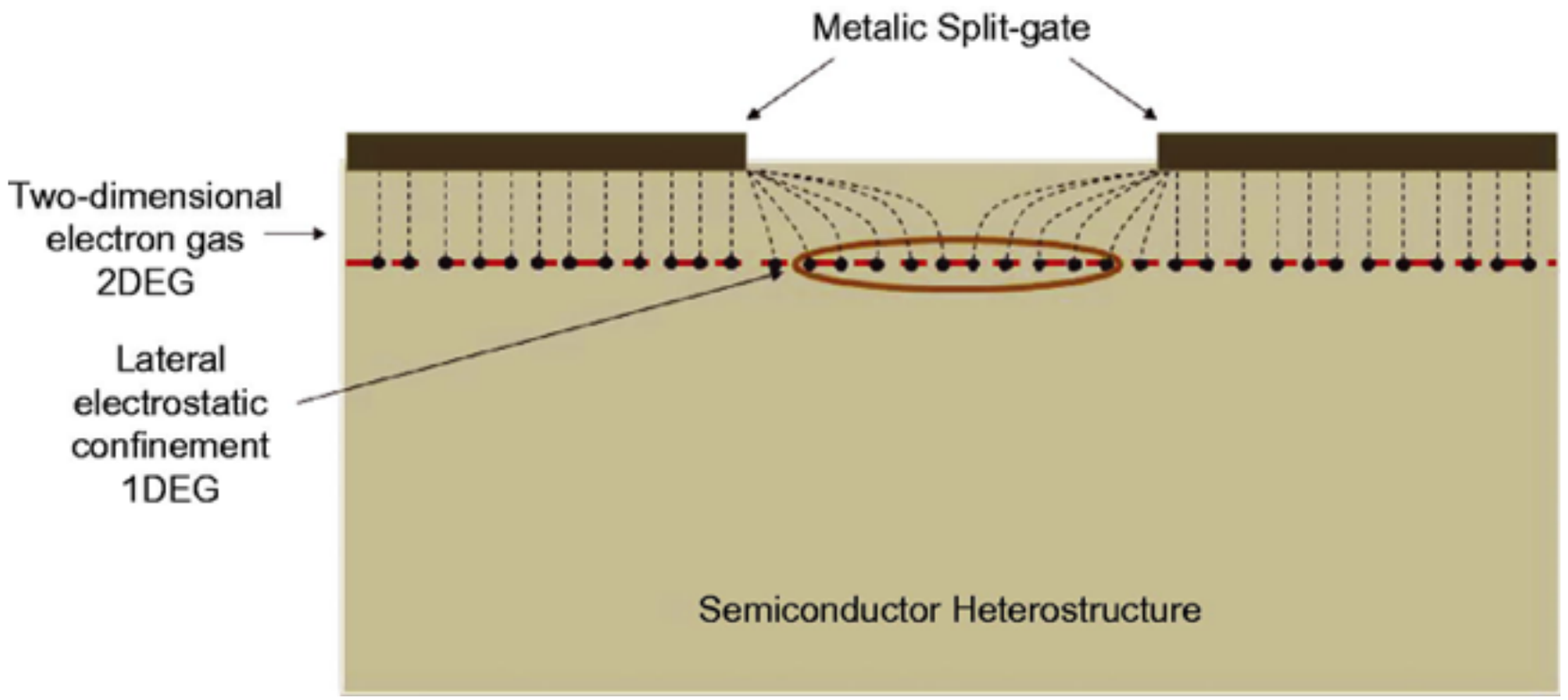


nanowire

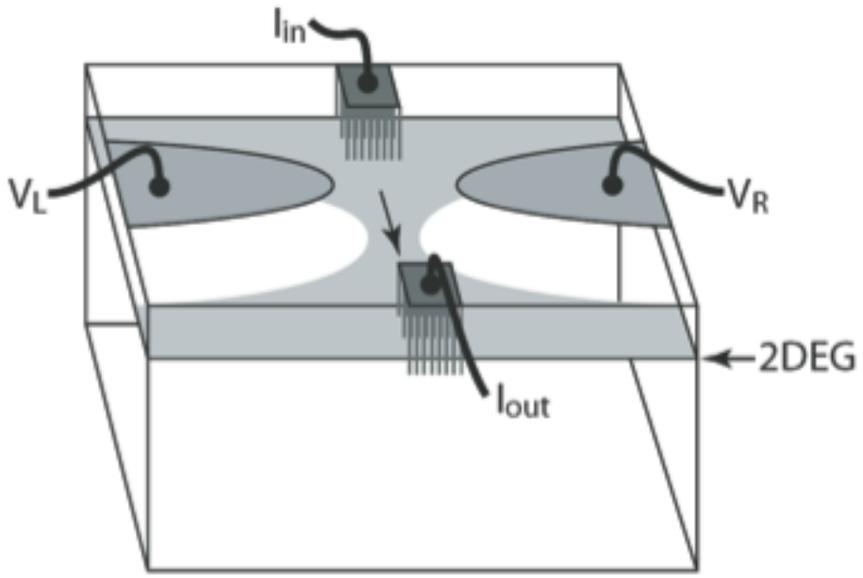
Color of Light Depends On Size of Quantum Dot

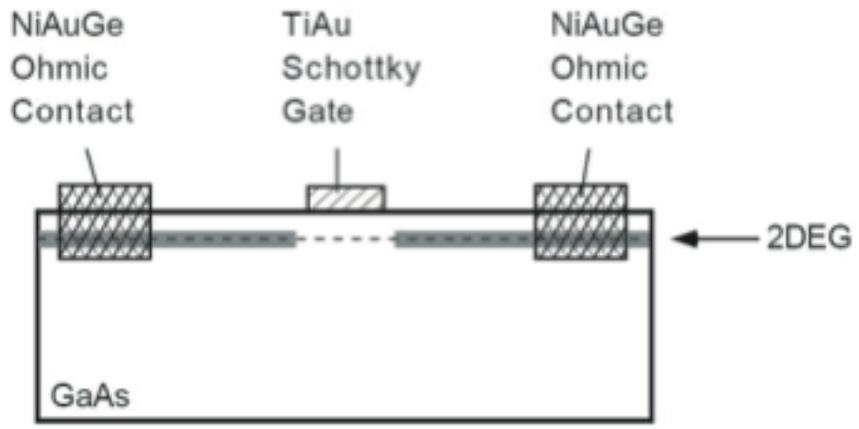




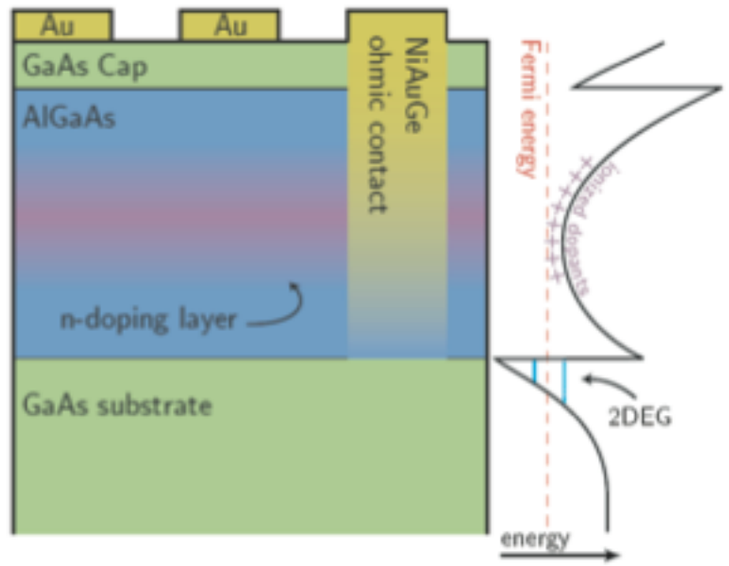

Metalic Split-gate
Two-dimensional
electron gas
2DEG
Lateral
electrostatic
confinement
1DEG
Semiconductor Heterostructure

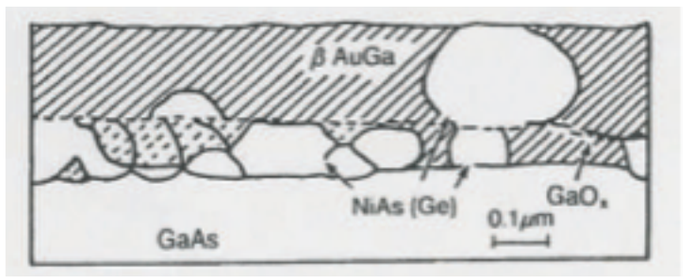
KVANTNI TOČKOVNI STIK

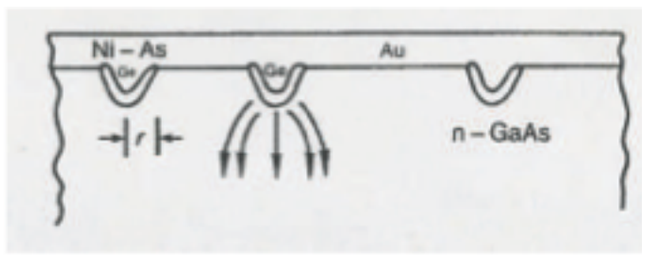


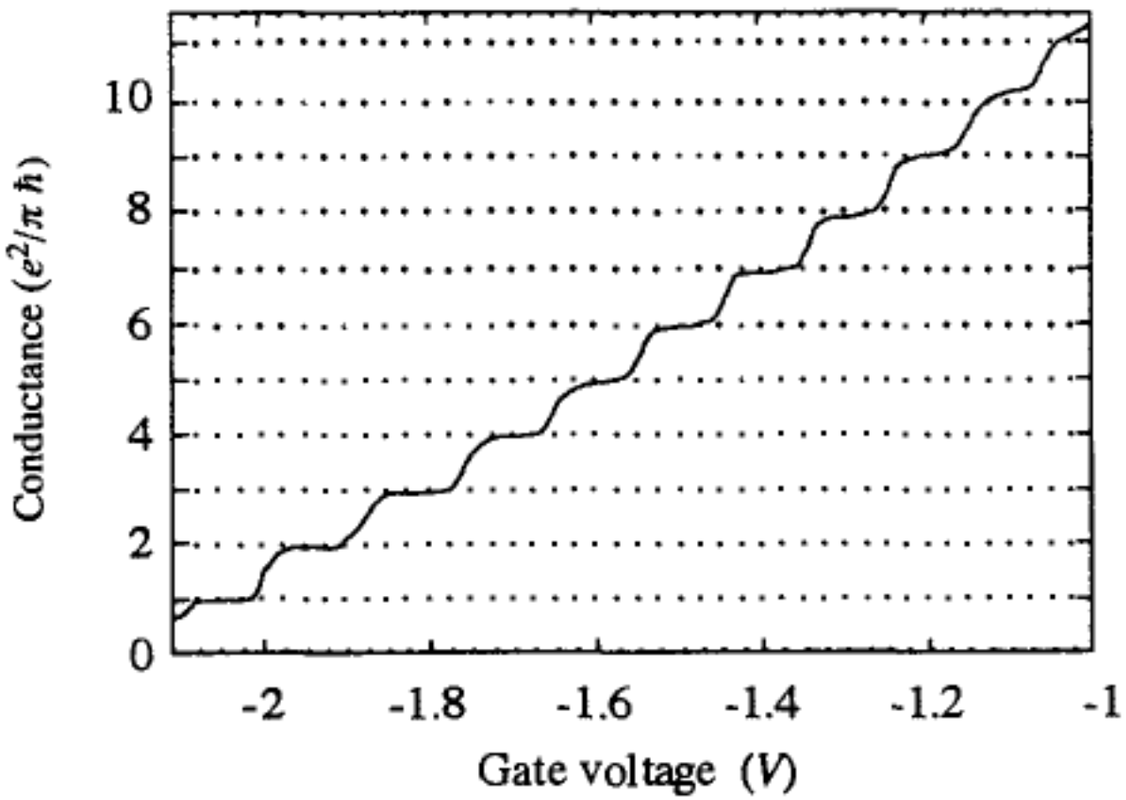


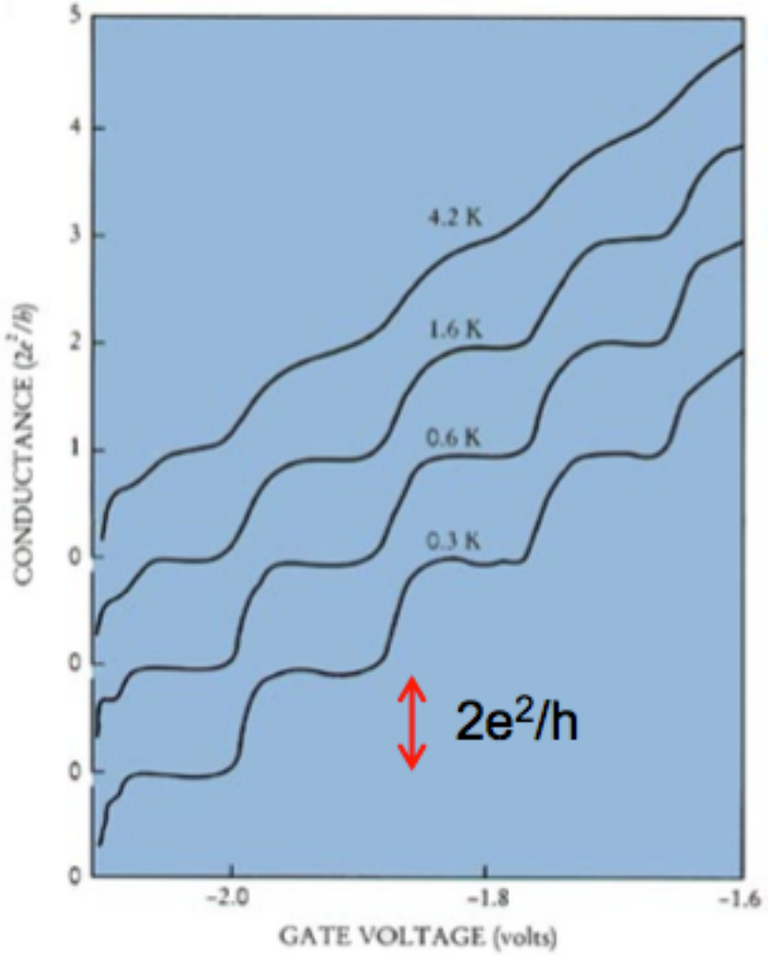
metoda ločenih vrat
(split gate)

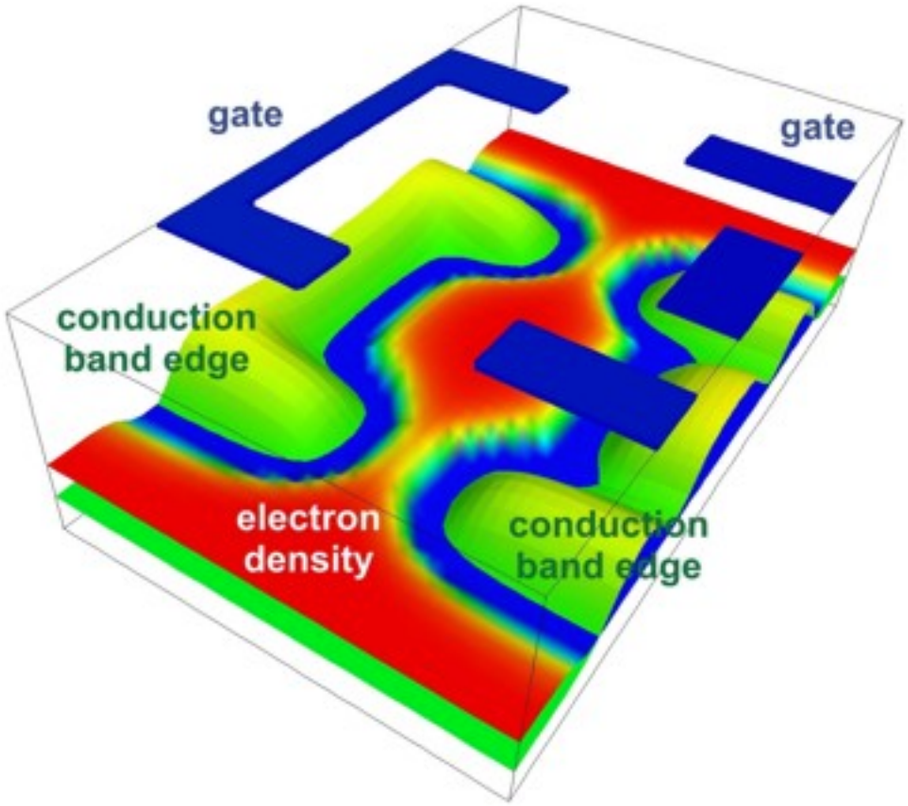


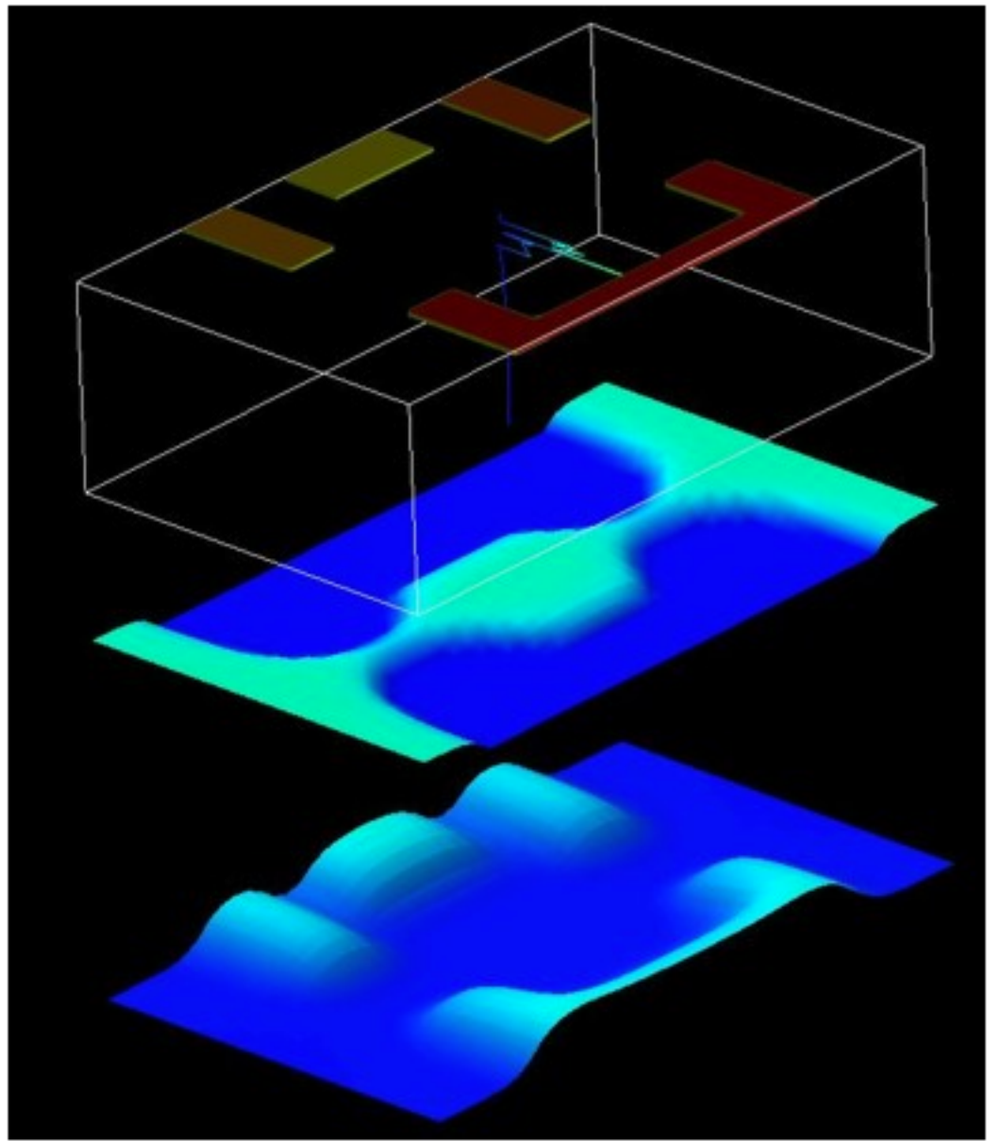


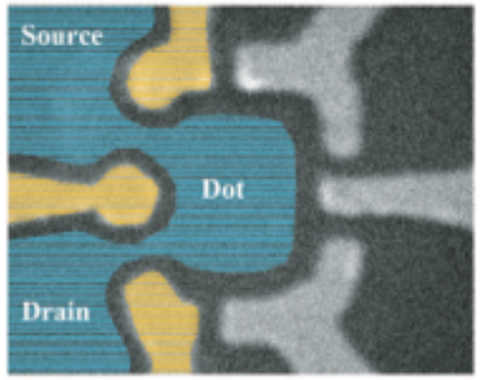



Conductance ($e^2/\pi\hbar$)
0
2
4
6
8
10
-2
-1.8
-1.6
-1.4
-1.2
-1
Gate voltage (V)

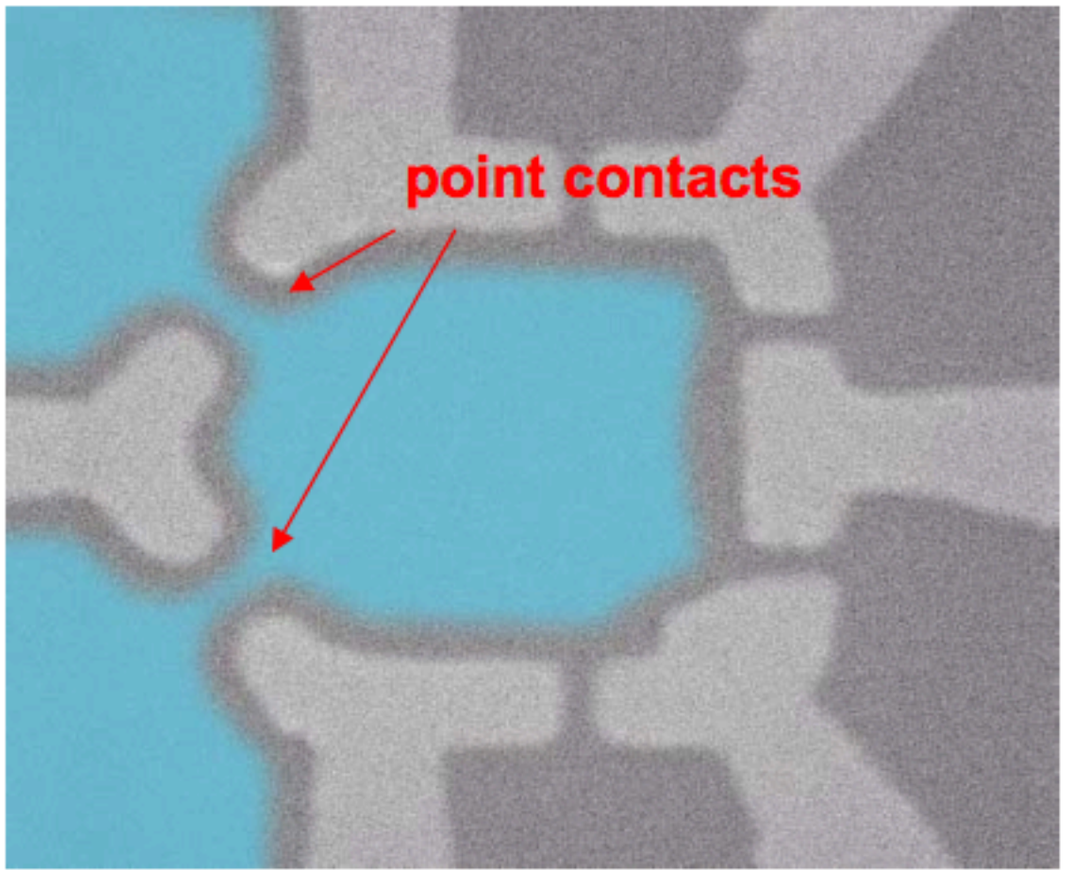

CONDUCTANCE ($2e^2/h$)
0
0
0
1
2
3
4
5
4.2 K
1.6 K
0.6 K
0.3 K
$2e^2/h$
-2.0
-1.8
-1.6
GATE VOLTAGE (volts)


gate
gate
conduction
band edge
electron
density
conduction
band edge

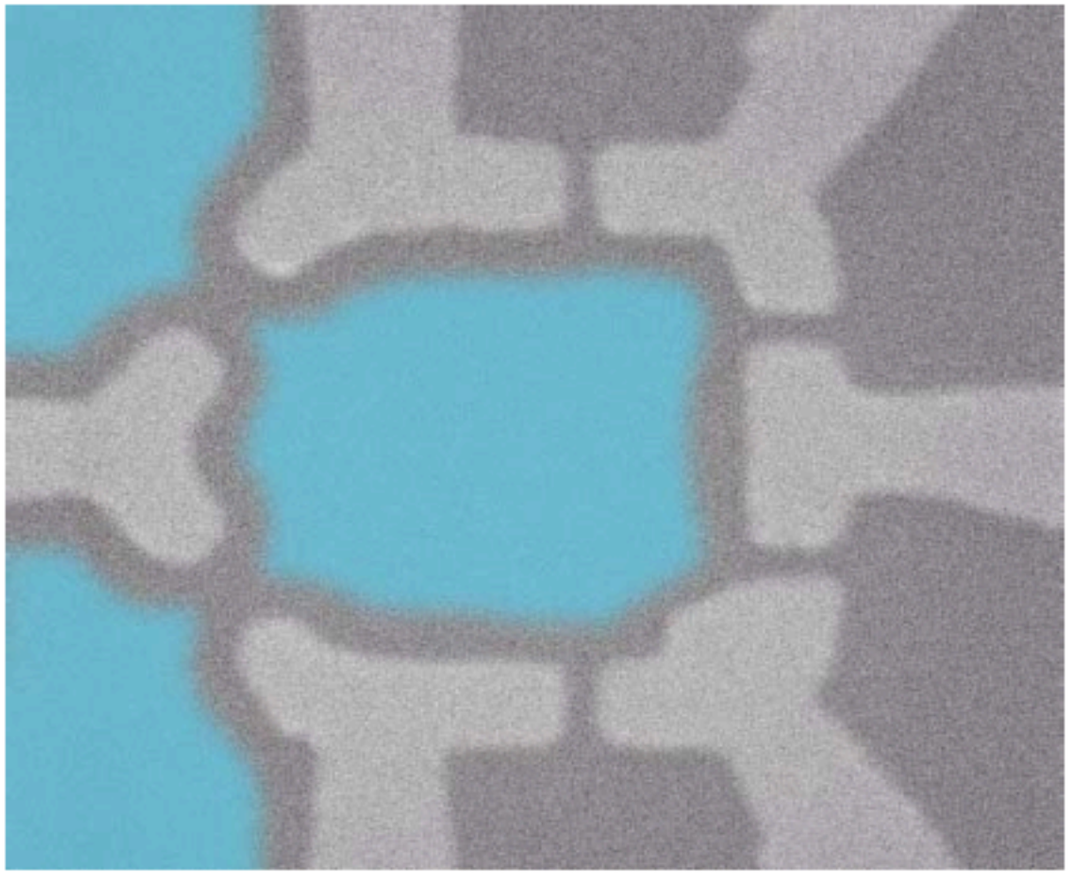




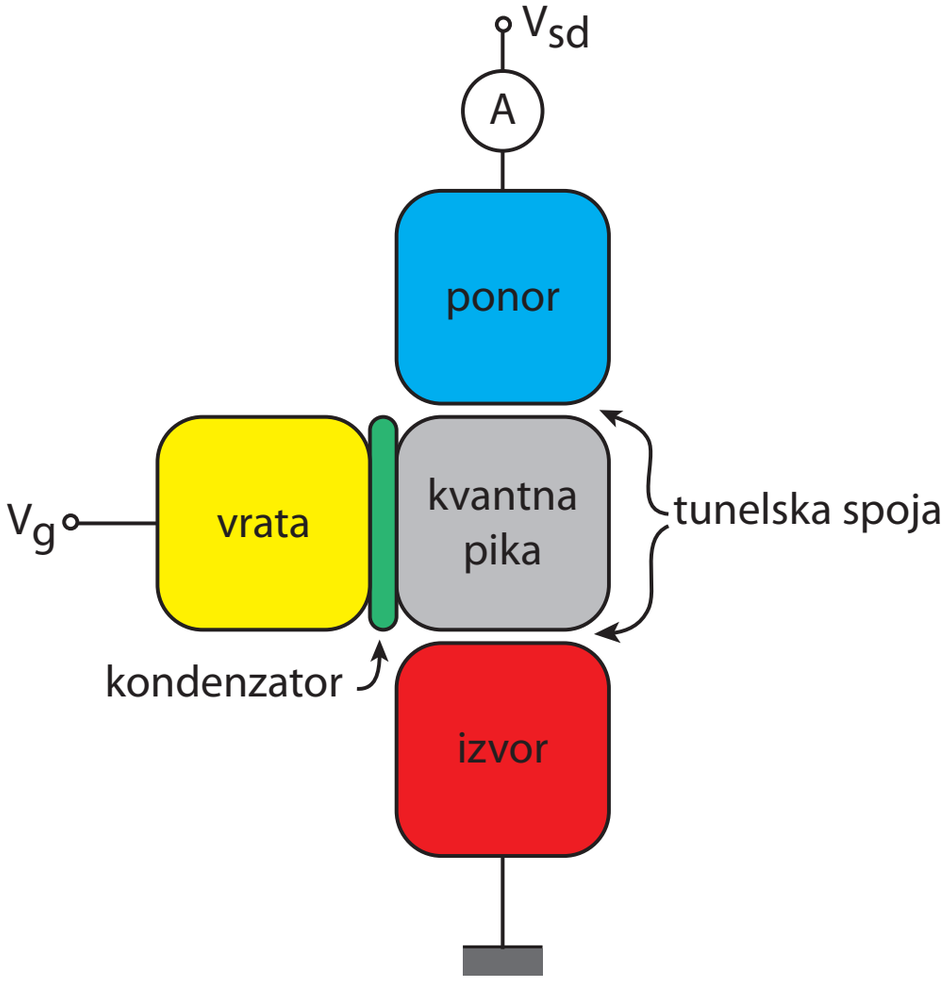
Open Dot

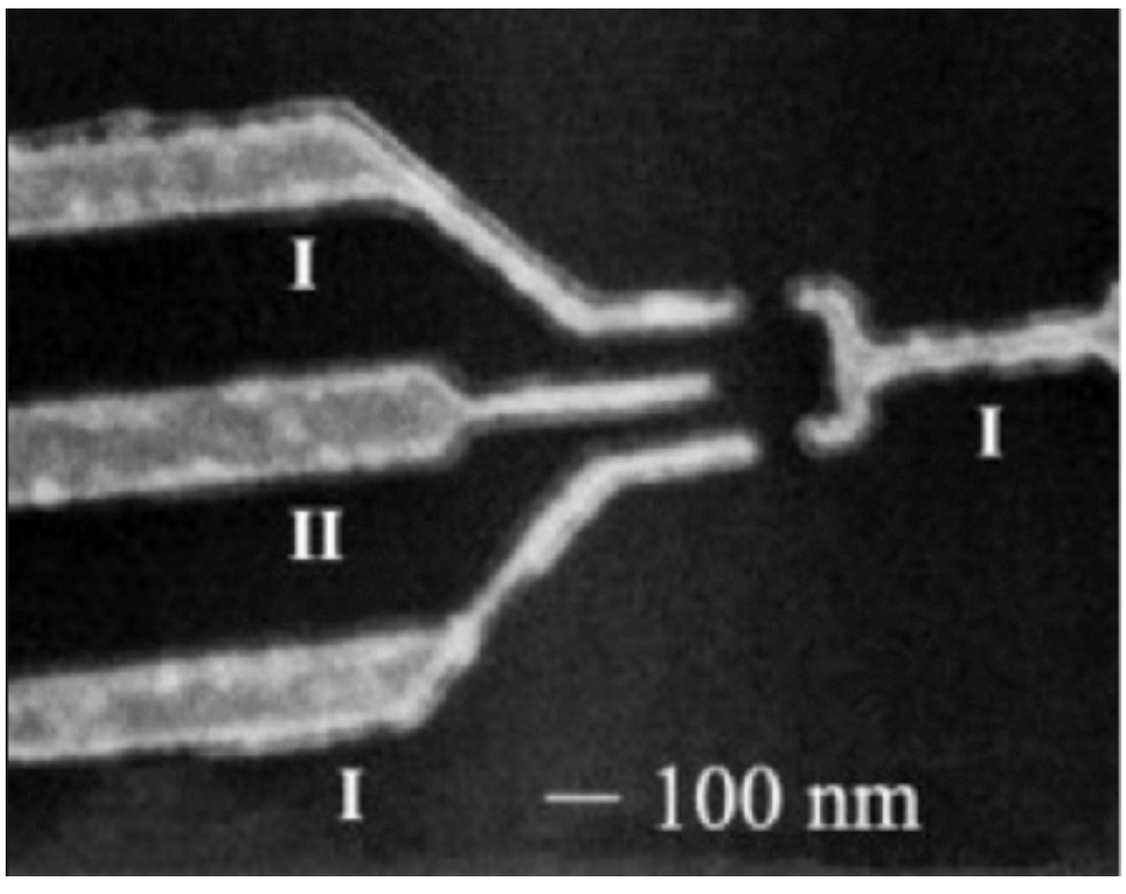


Closed Dot

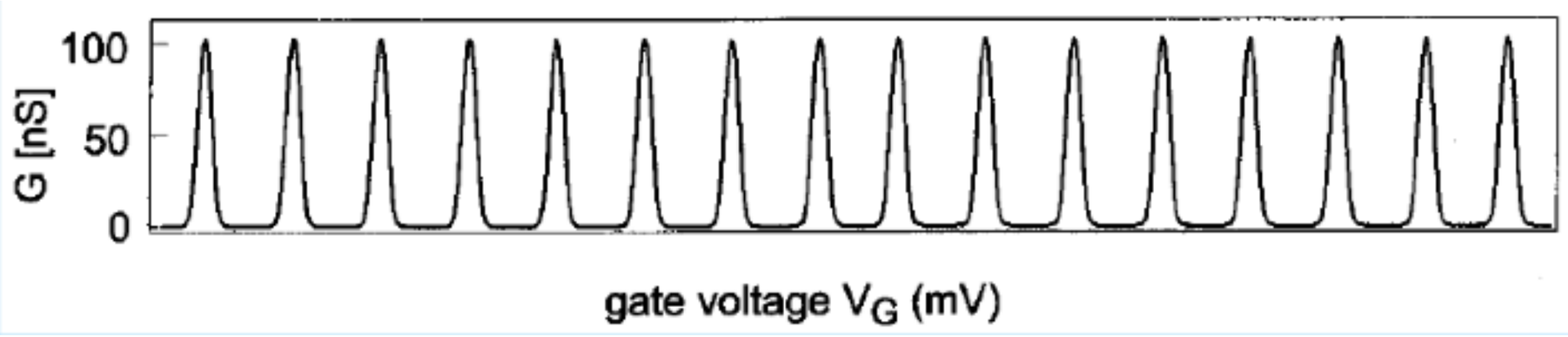


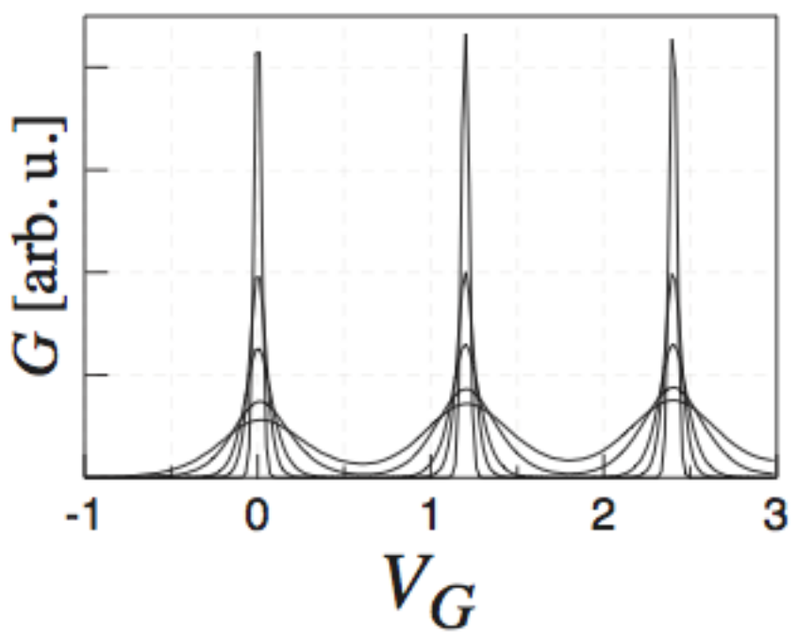
Enoelektronski tranzistor



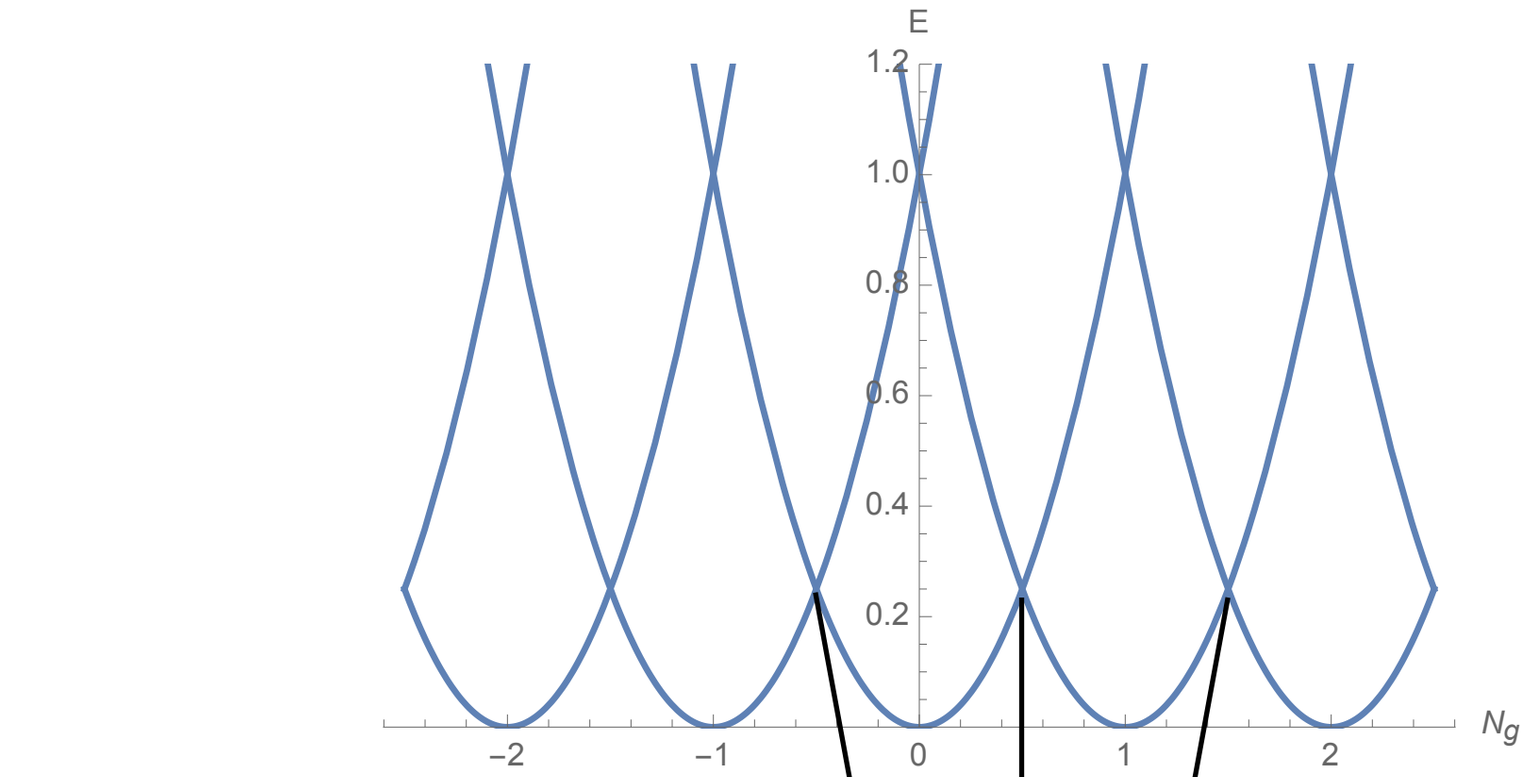


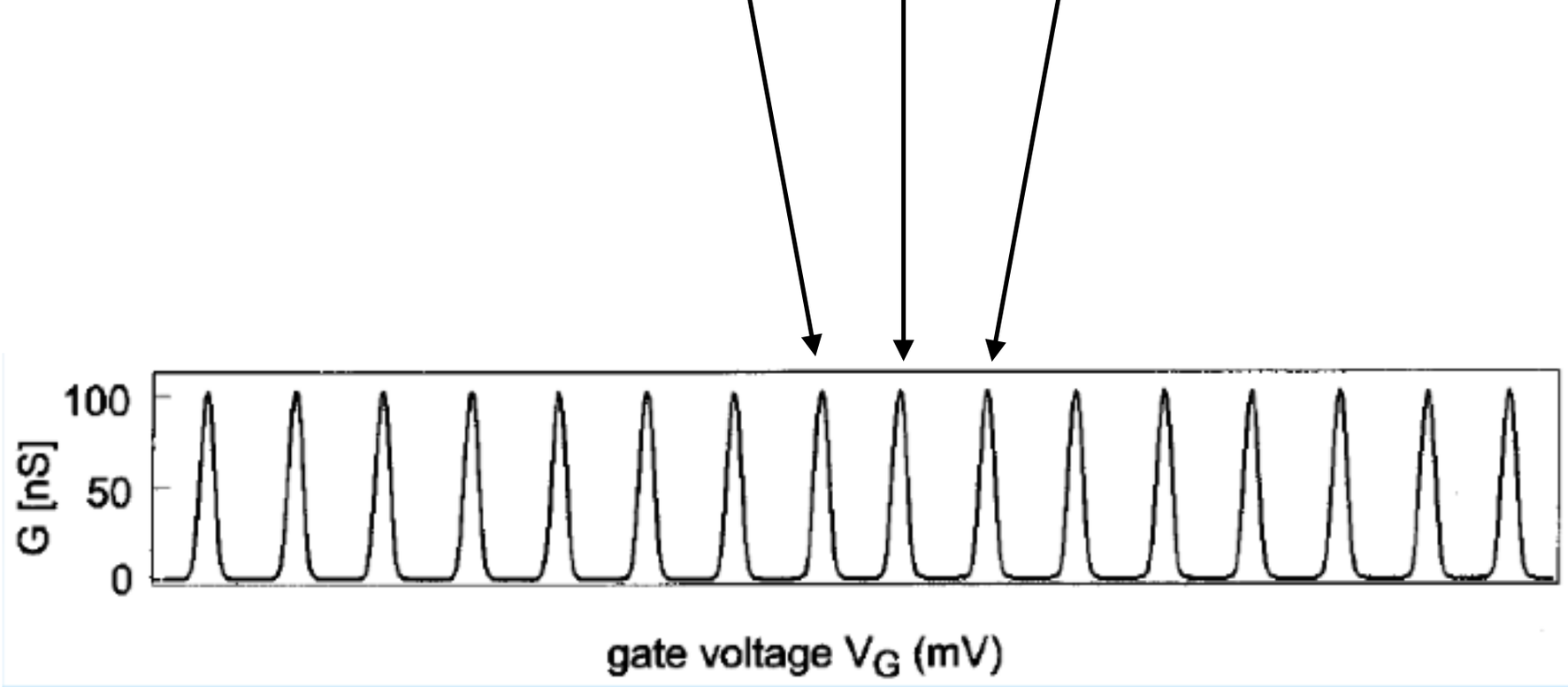
Coulombska blokada





$$E(N, V_g) = E_C N^2 - \alpha e_0 V_g N = E_C (N - N_g)^2 + \text{konst.}$$





aivon

STORE

Aivon Store

- Isolation amplifier
- Metrology
- Amplifiers
- Logic
- Sample holders
- Thermalization
- Aivon Dipstick and Cap
- Battery
- Breakout Box
- Coulomb Blockade Thermometer
- Do-It-Yourself kits

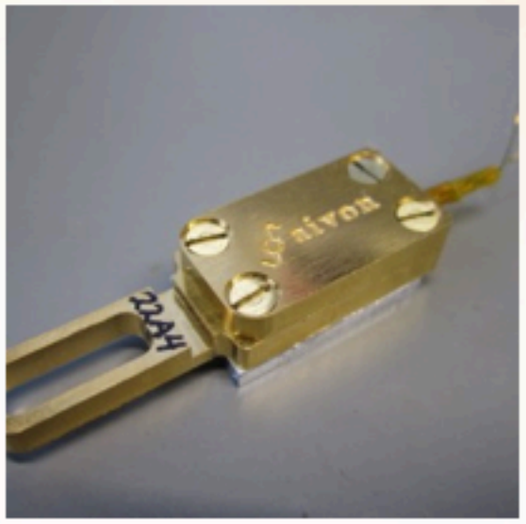
STORE

Terms and conditions

Store / Coulomb Blockade Thermometer

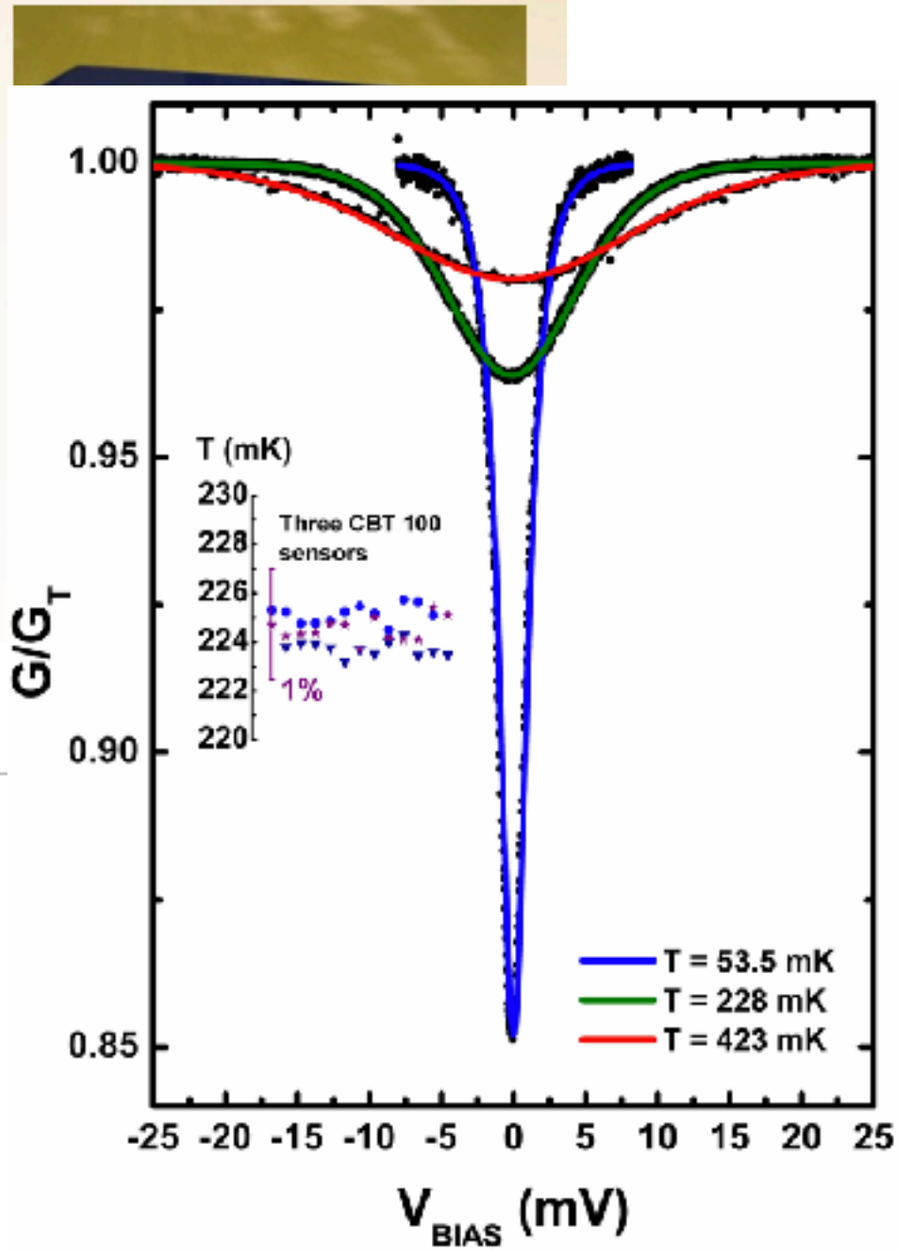
Custom sensor Ask a quote

Custom CBT sensor with user-defined dimensions. Example: cylindrical

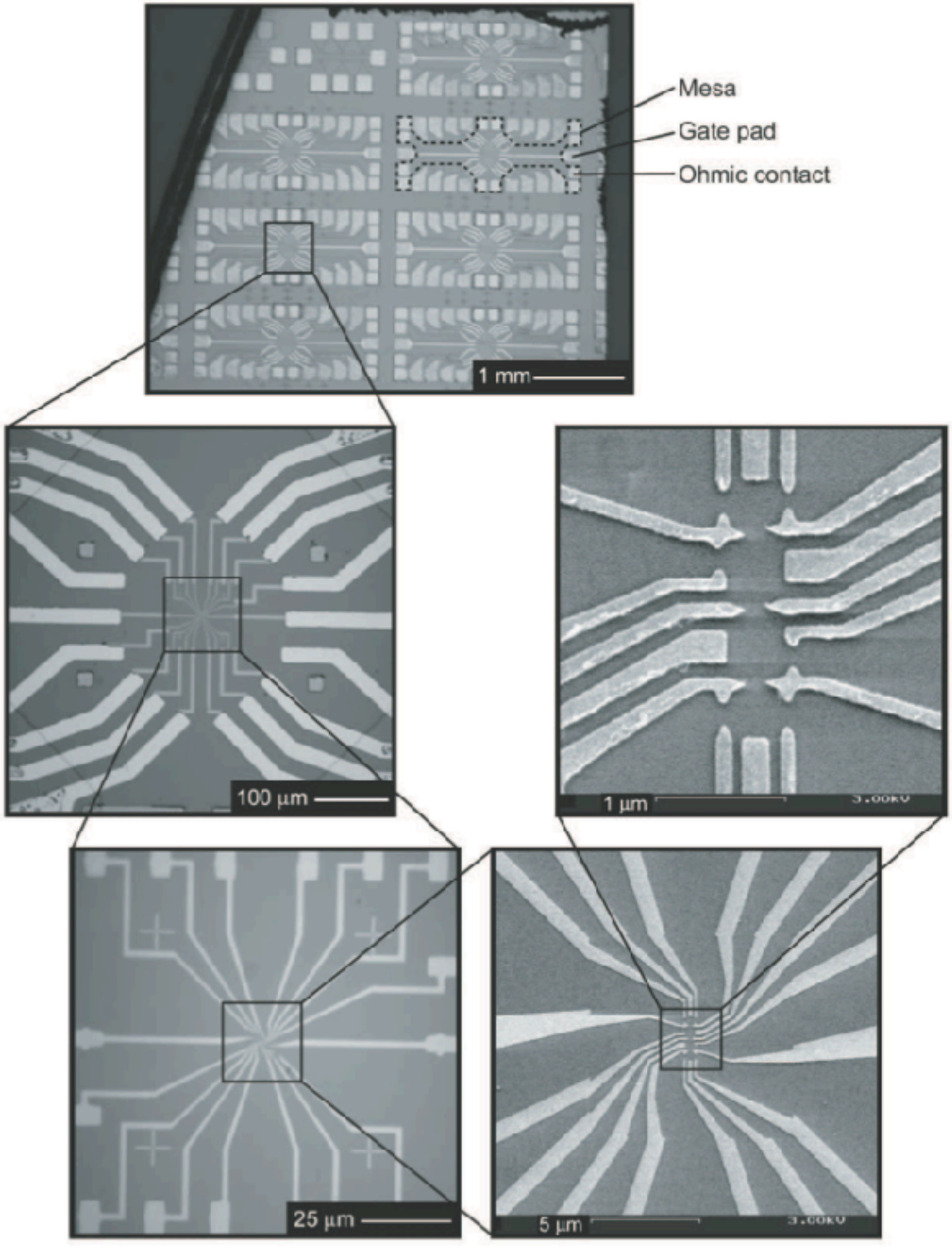


New CBT10 Ask a quote

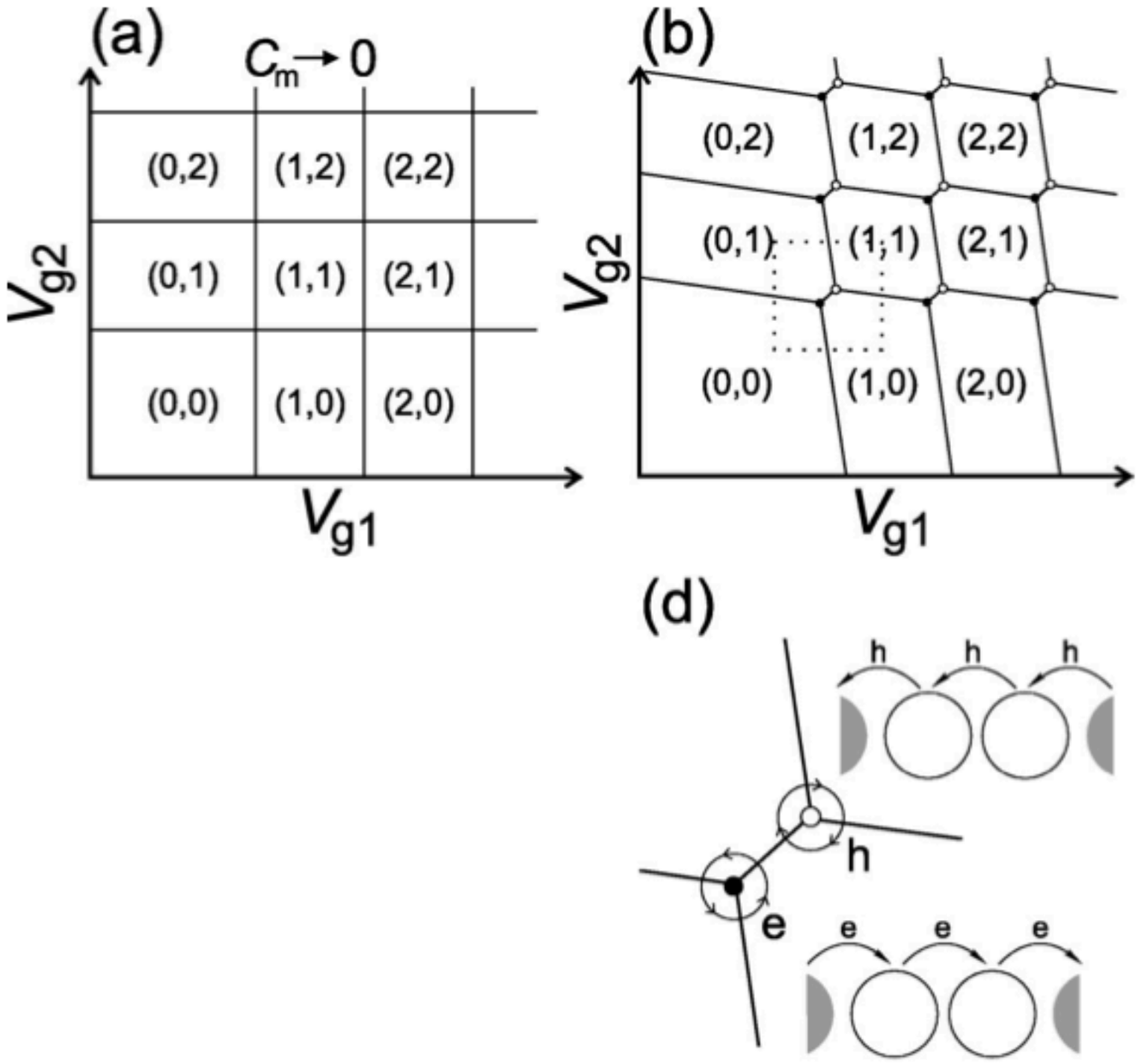
New CBT sensor reaching 10 mK. Four-wire measurement of differential



http://www.aivon.fi/store/coulomb-blockade-thermometer/

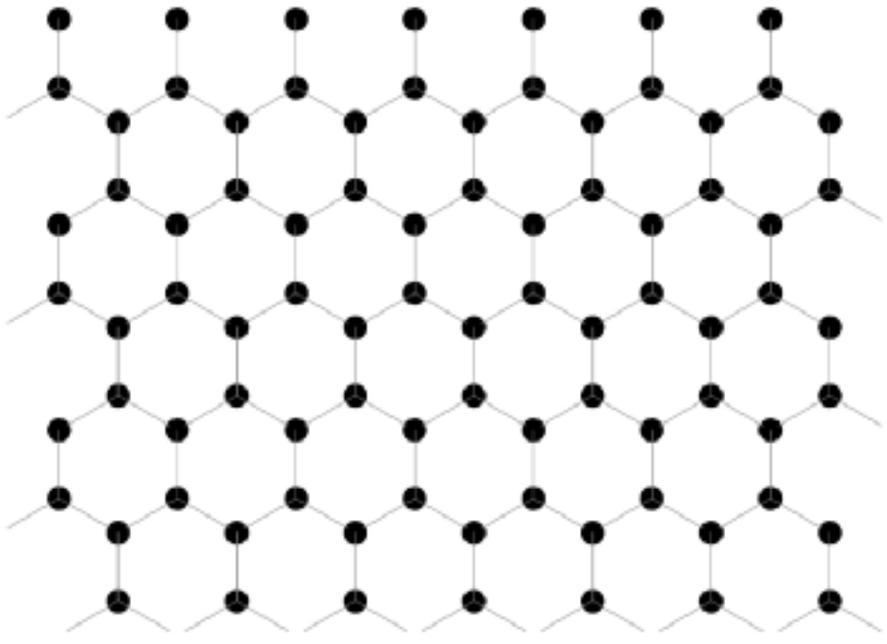

Mesa
Gate pad
Ohmic contact
1 mm
100 µm
1 µm
25 µm
5 µm

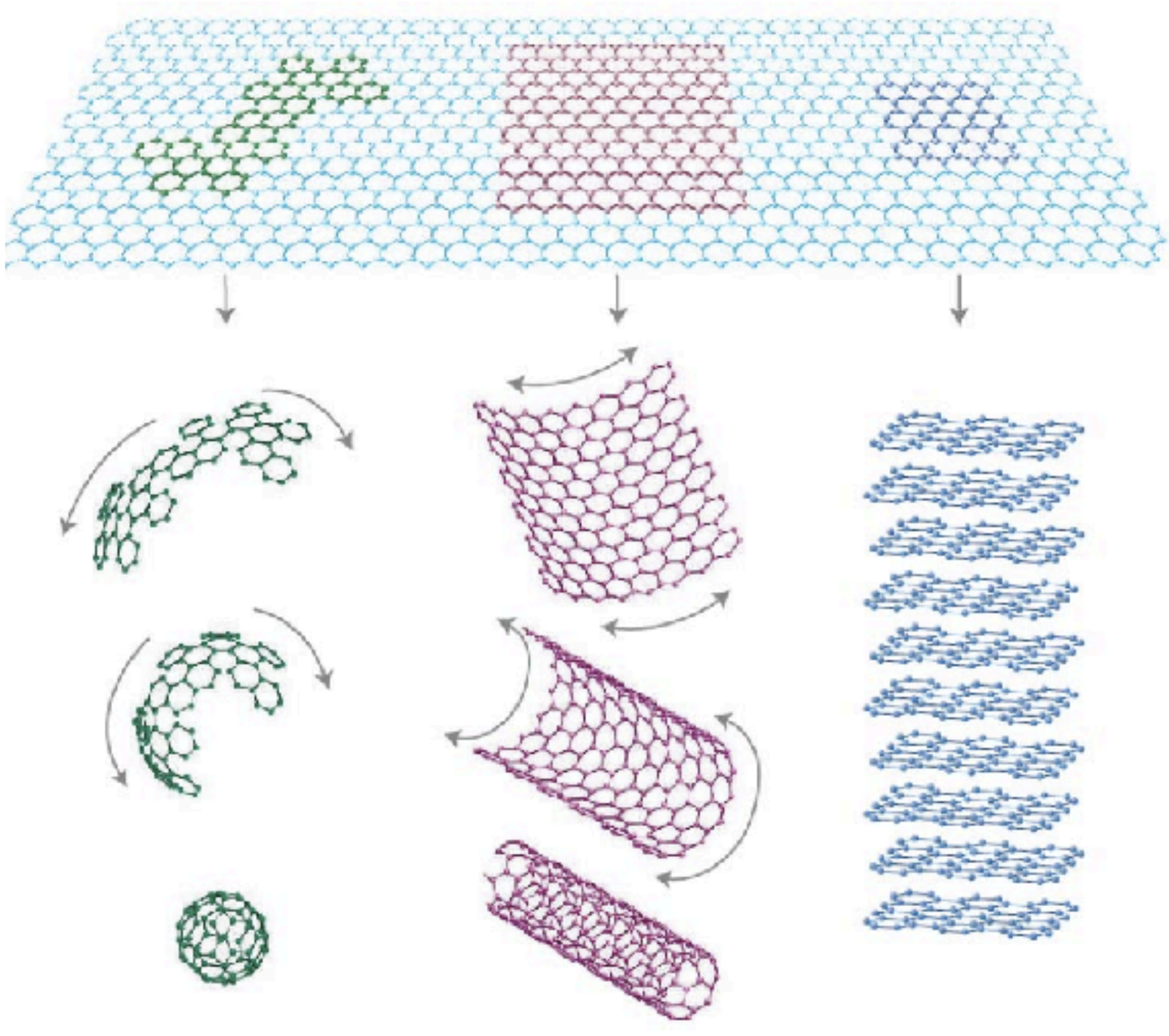
ČRPALKA ZA POSAMEZNE NABOJE



kvantizirano črpanje naboja: $I = (-e_0)f$

4. Kaj je grafen? Drugi alotropi? Posebne lastnosti?

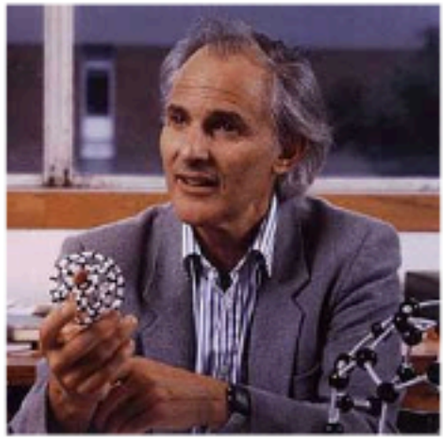


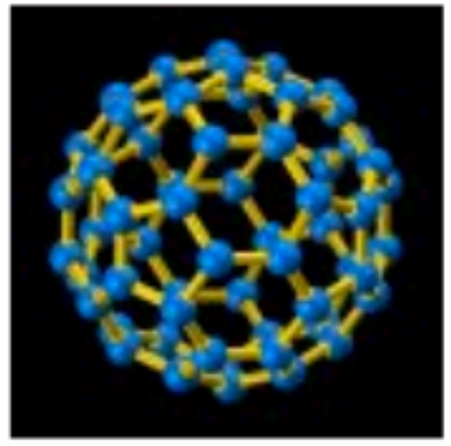


New forms of carbon

- Fullerenes 1985

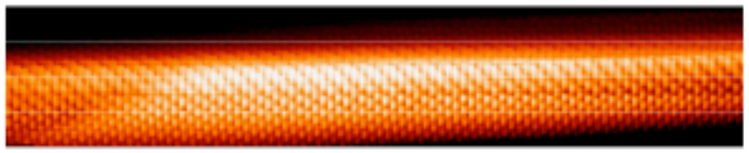
  H. W. Kroto, J. R. Heath, S. C. O'Brien, R. F. Curl and R. E. Smalley, Nature **318** (1985) 162

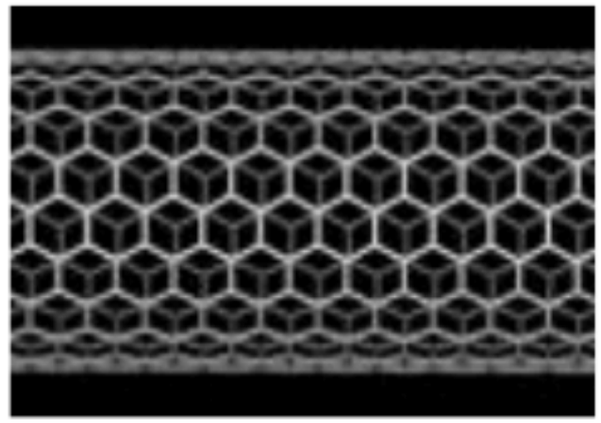




- Nanotubes 1991

  S. Iijima, Nature **354** (1991) 56





Grafen

The Nobel Prize in Physics 2010

Photo: U. Montan

Andre Geim

Prize share: 1/2

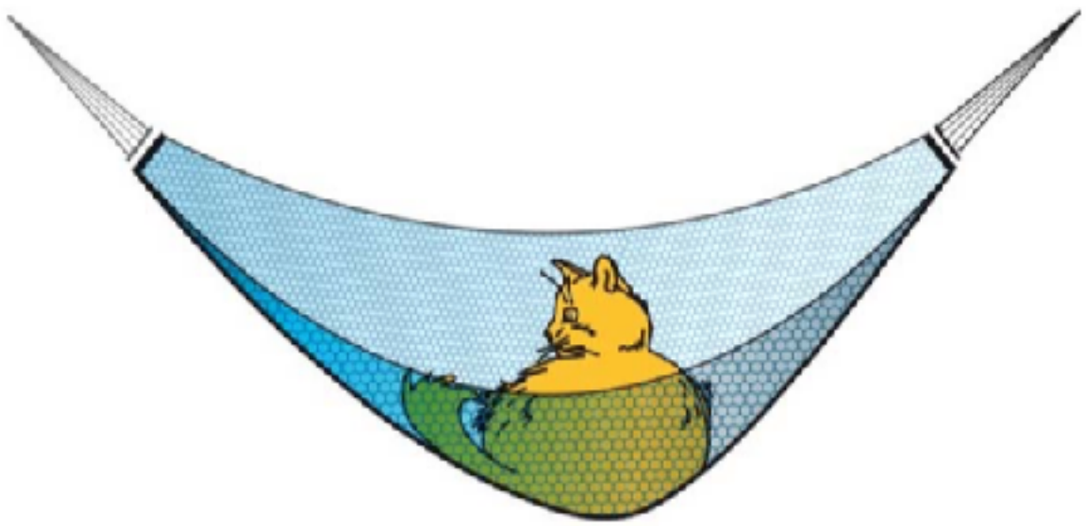
Photo: U. Montan

Konstantin Novoselov

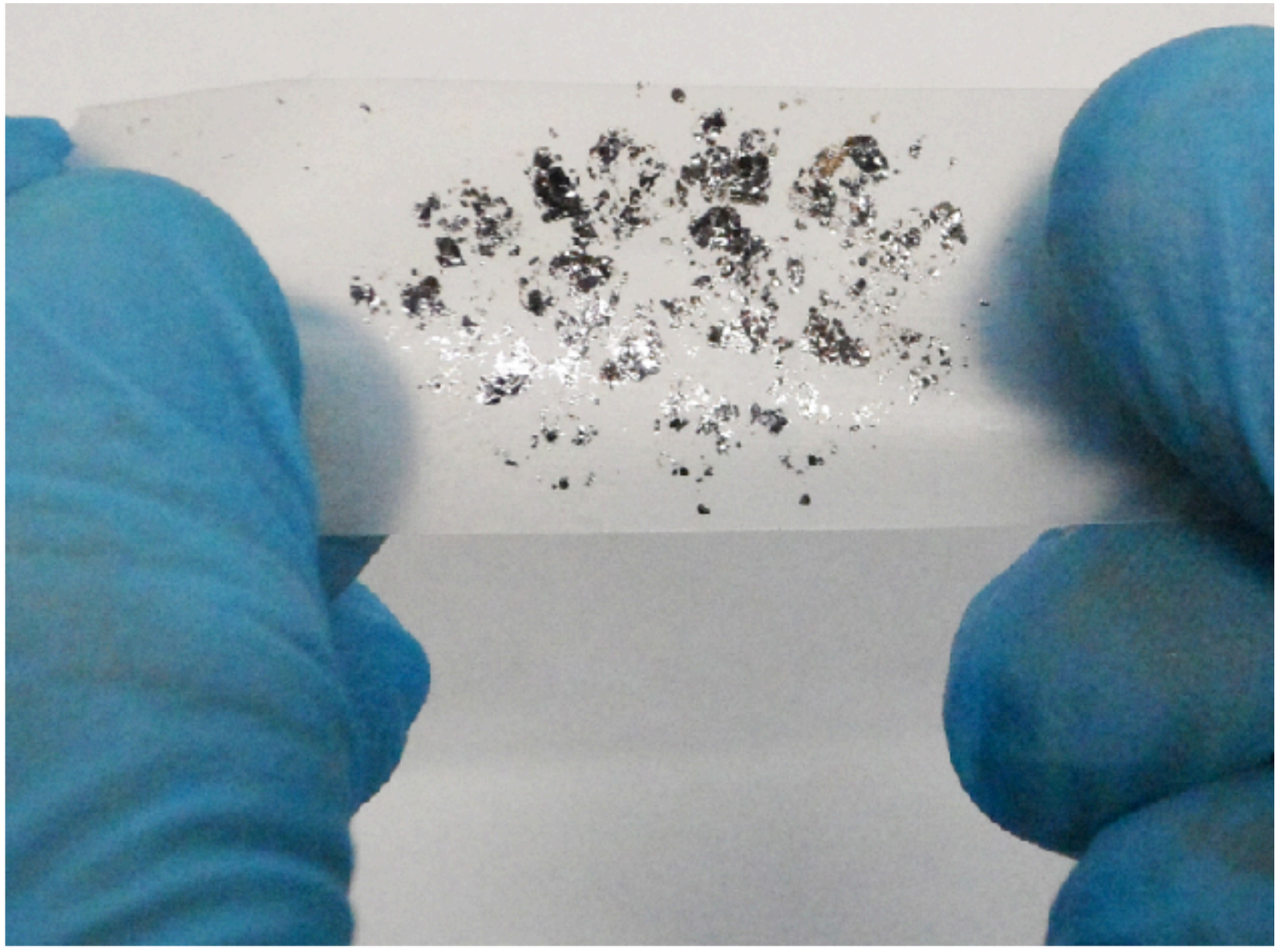
Prize share: 1/2

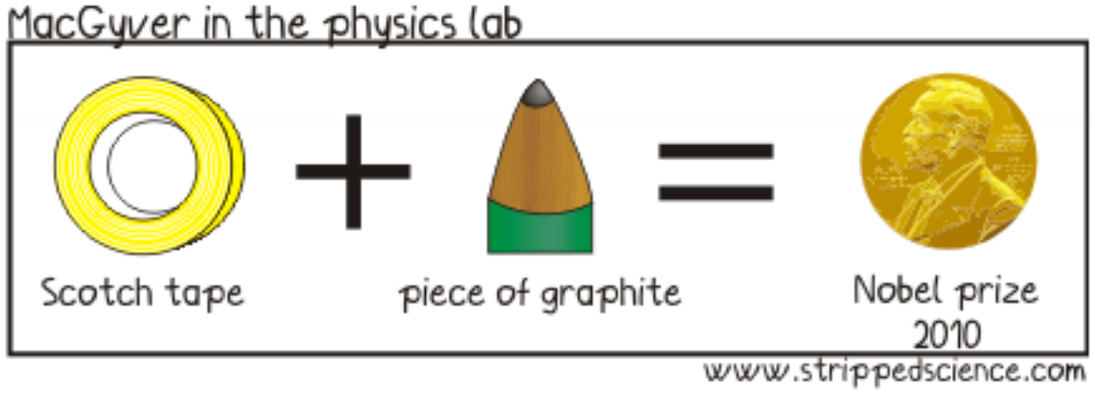
The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov *"for groundbreaking experiments regarding the two-dimensional material graphene"*

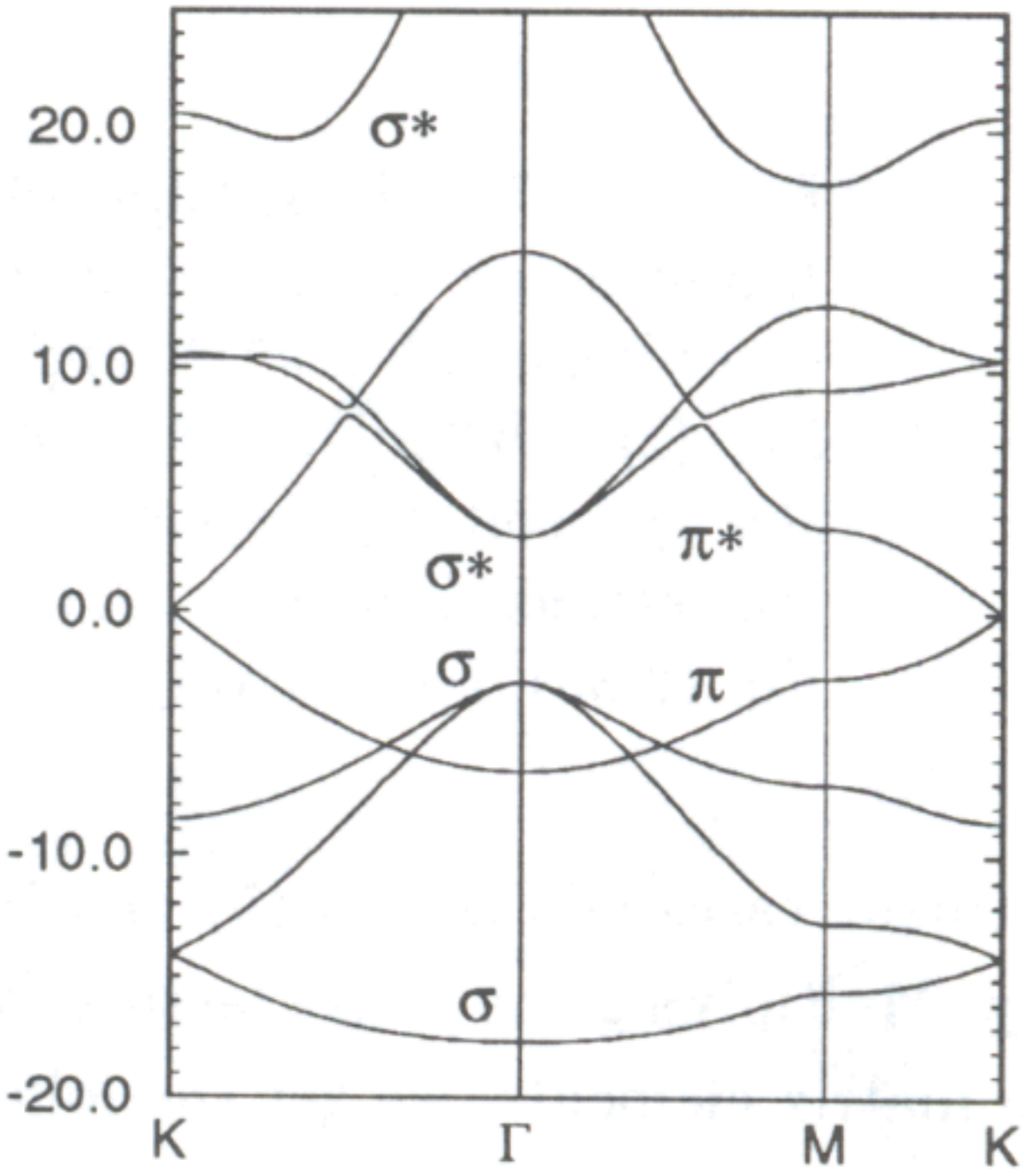
- 2D material
- močnejši od jekla
- upogljiv
- prozoren za svetlobo
- električno prevoden
- toplotno prevoden
- lahek: $1m^2 = 0.77mg$

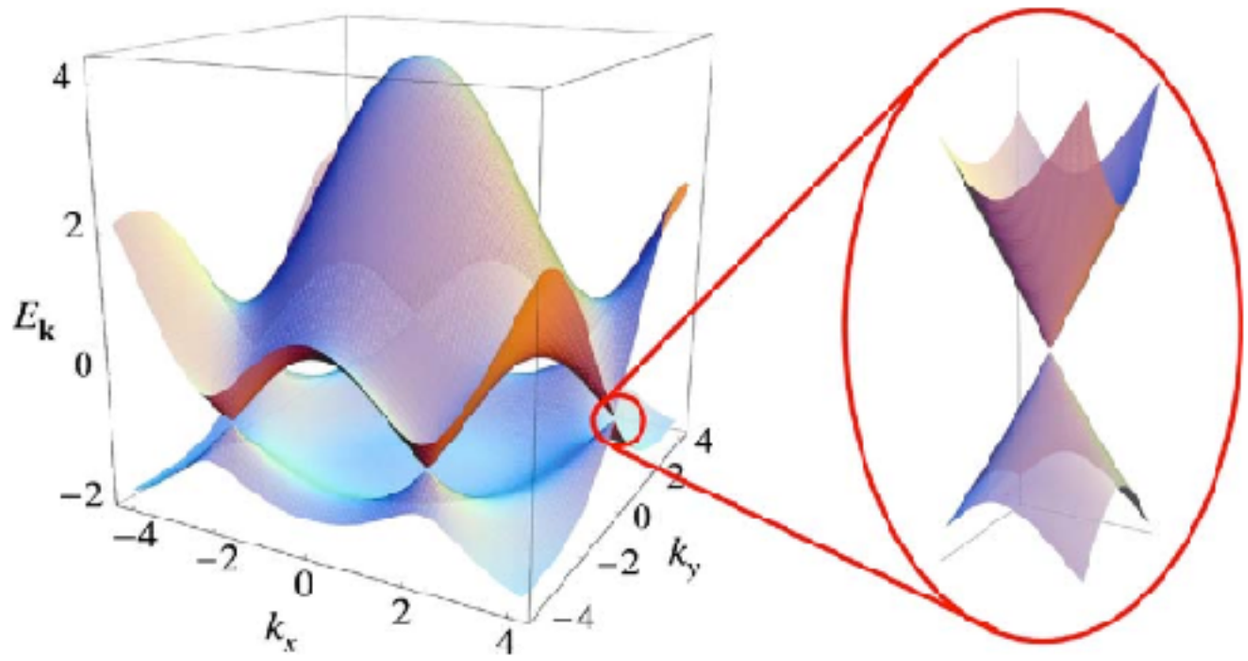


Sinteza: tehnika selotejpa

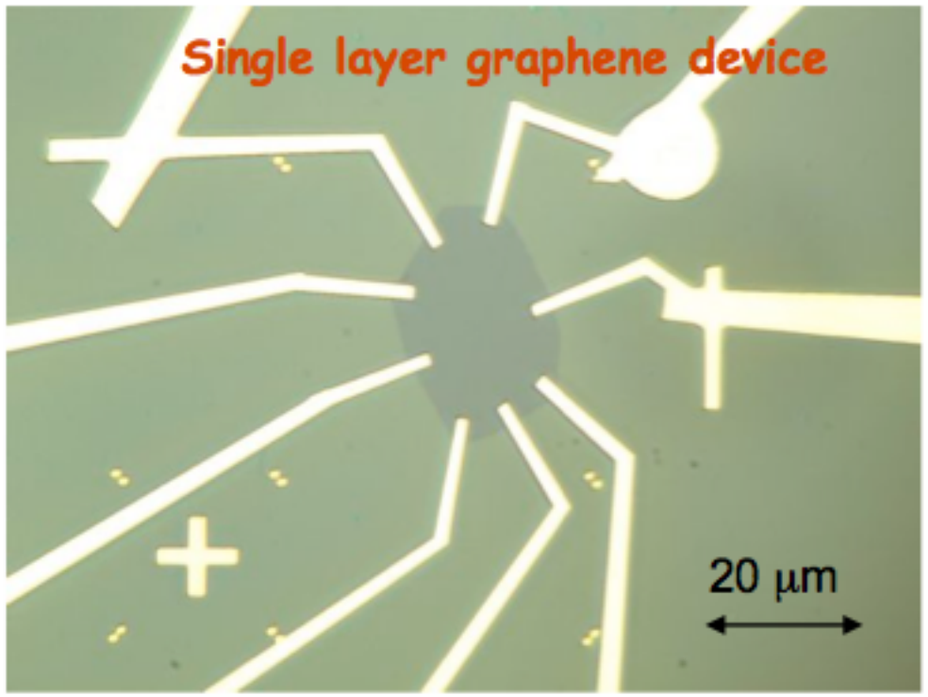


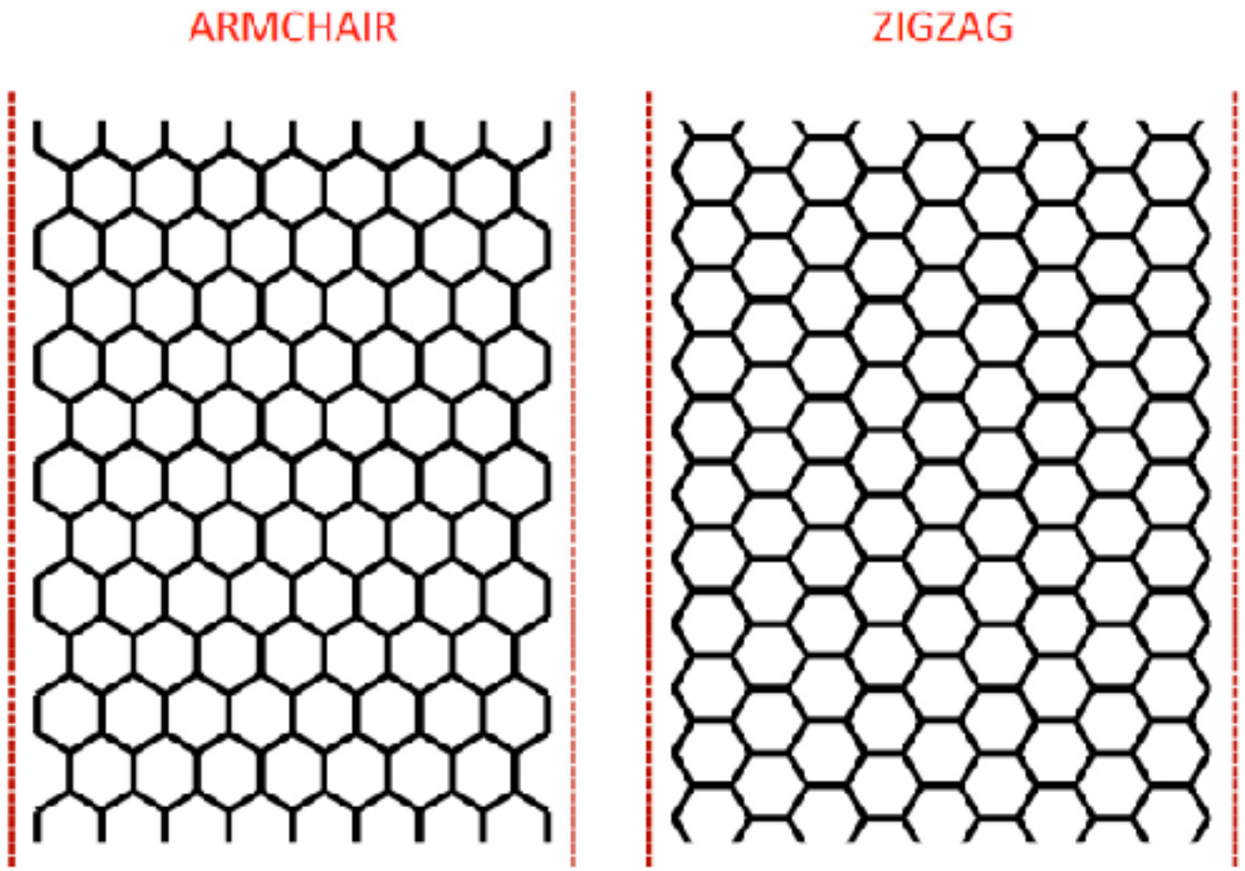


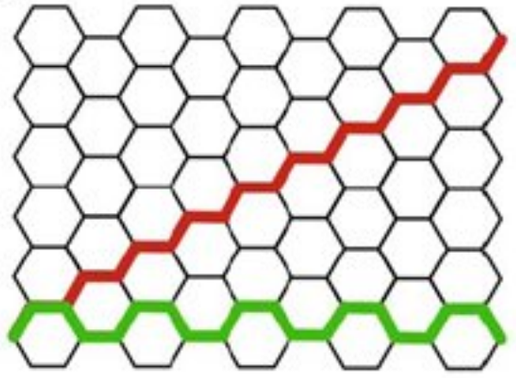


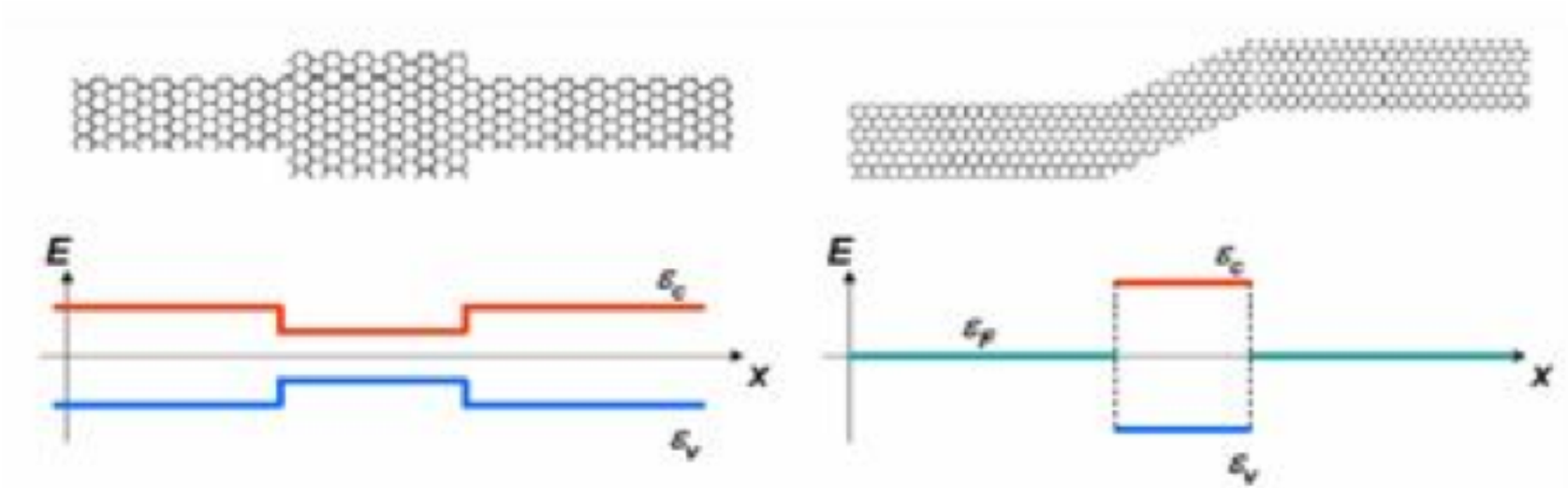


Elektroni v grafenu se obnašajo kot brezmasni delci.

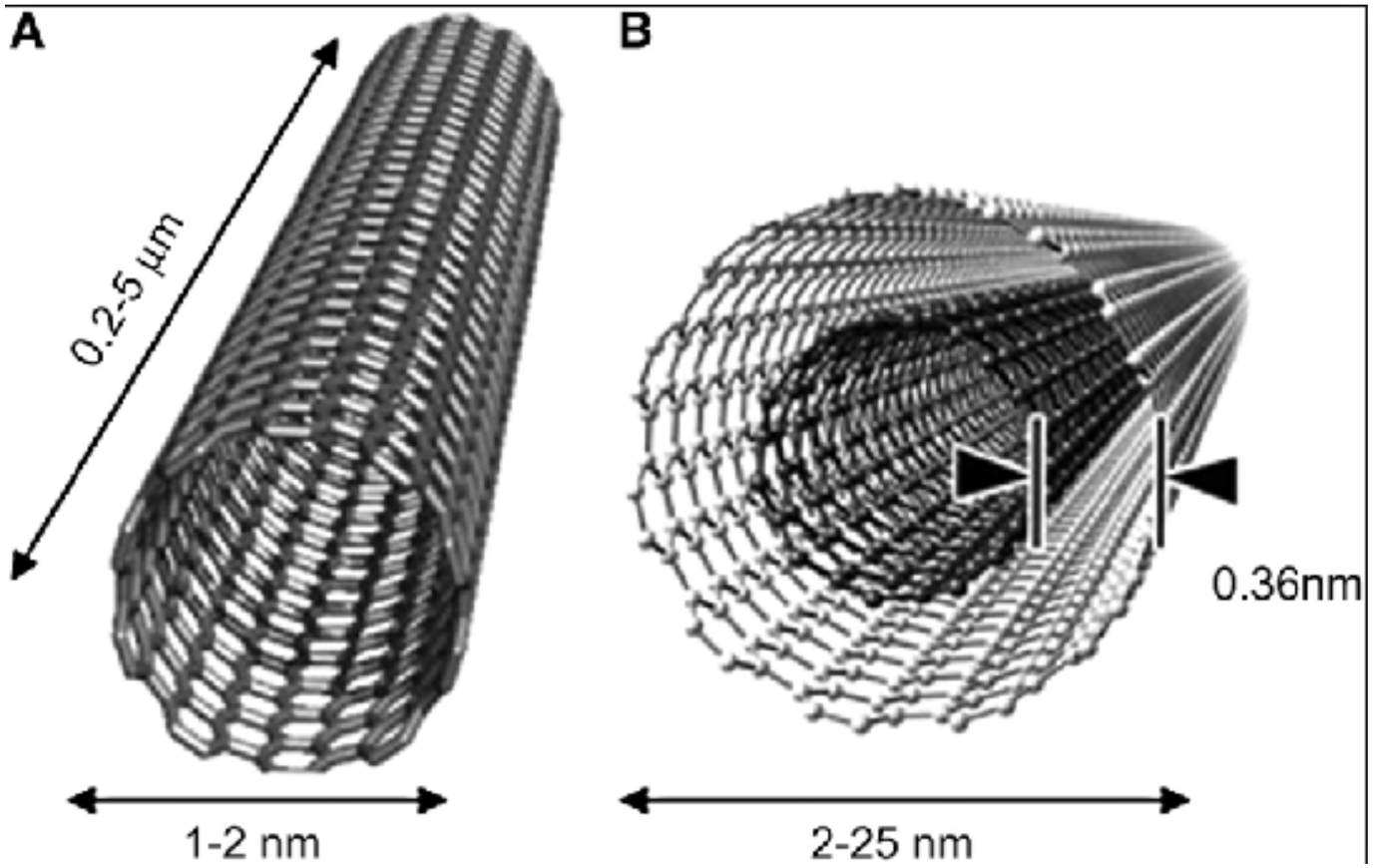

Single layer graphene device
20 μm

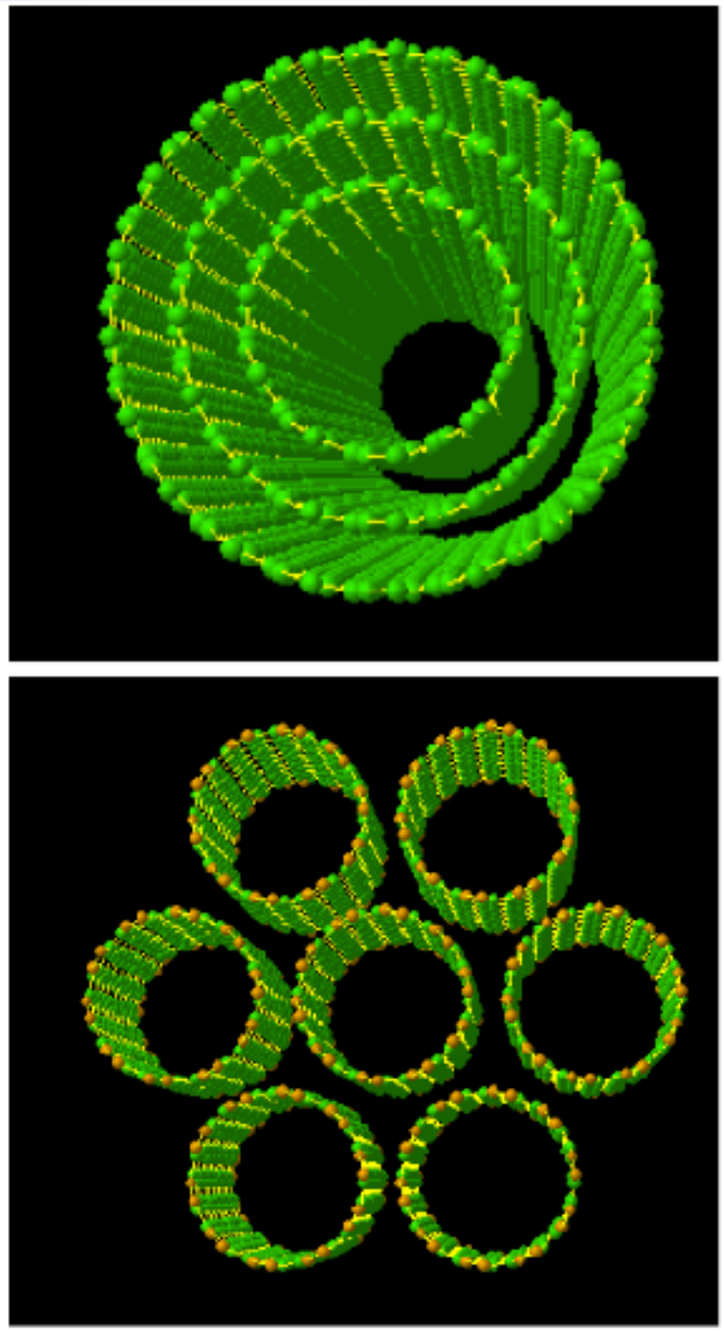

ARMCHAIR
ZIGZAG

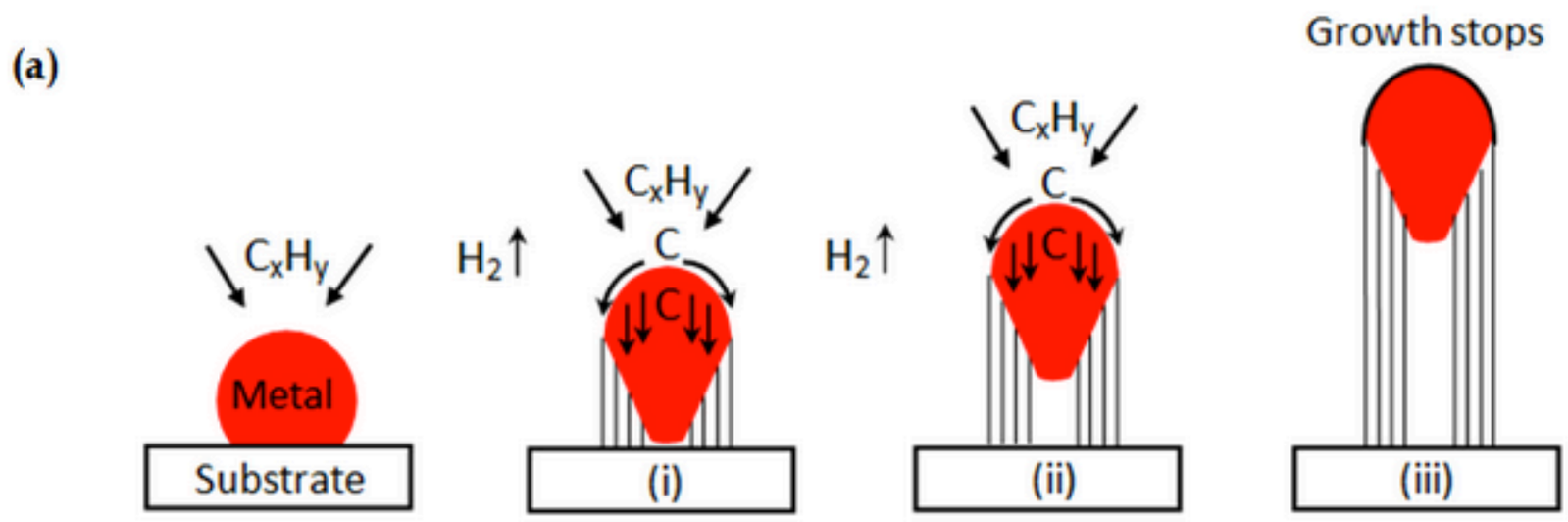


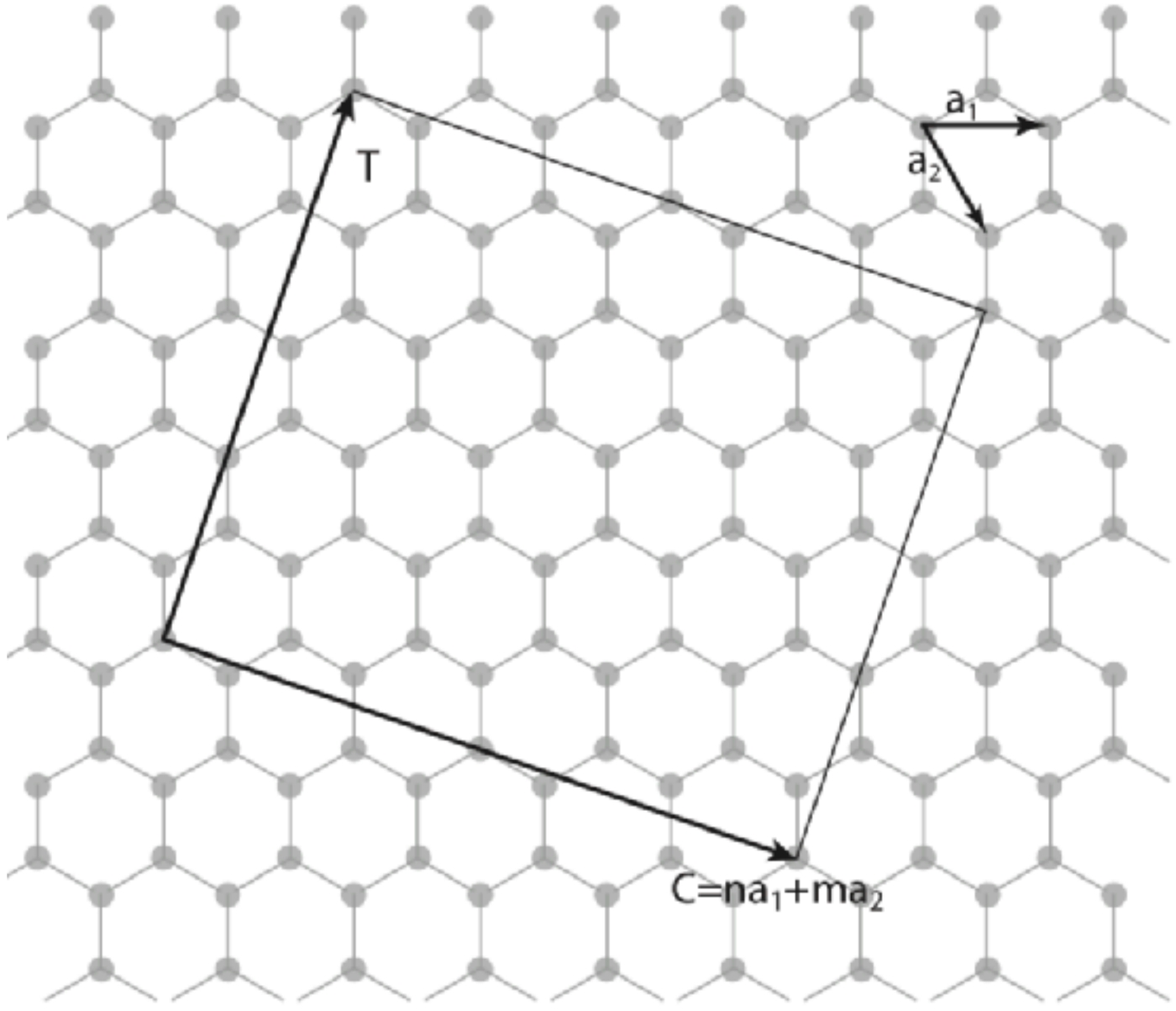

E
ε_c
x
ε_v
E
ε_c
ε_F
x
ε_v

5. Kaj so nanocevke?

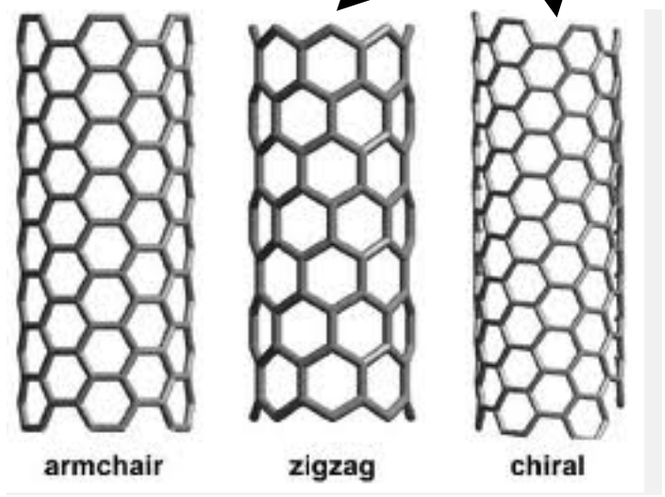

A
0.2-5 µm
1-2 nm
B
0.36nm
2-25 nm




(a)
Growth stops
C_xH_y
Metal
Substrate
H_2
C
(i)
(ii)
(iii)
(b)
Metal
Substrate

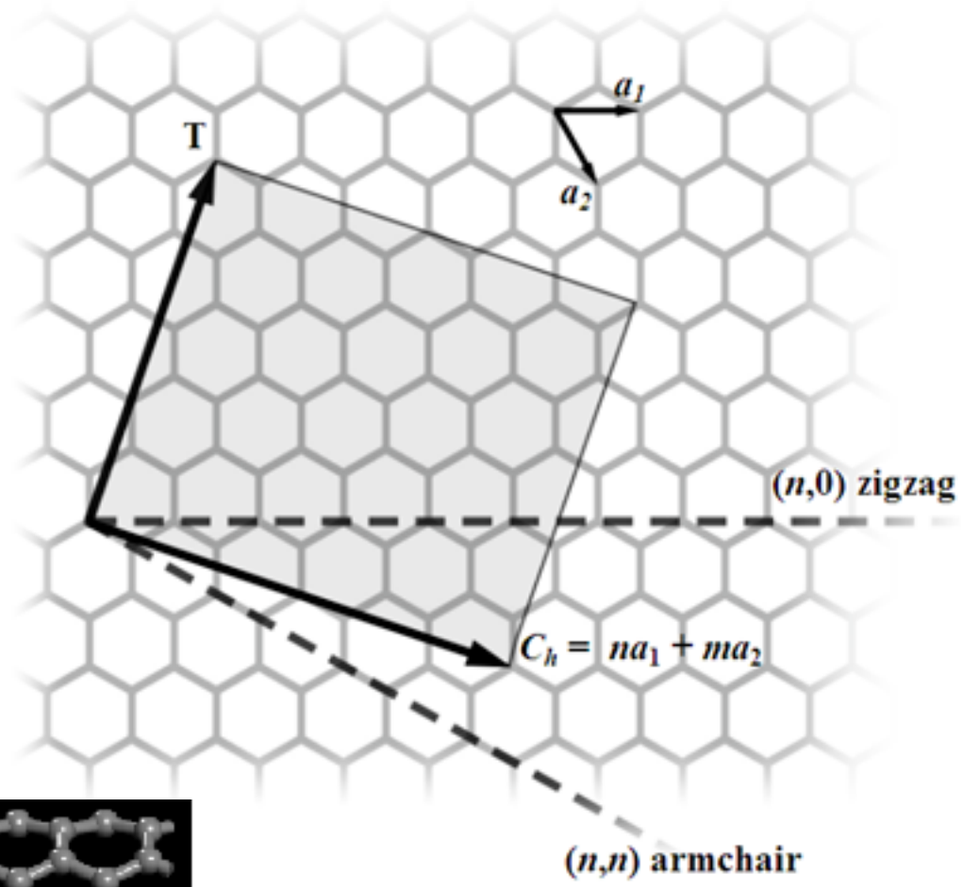

T
a1
a2
C=na1+ma2

polprevodni

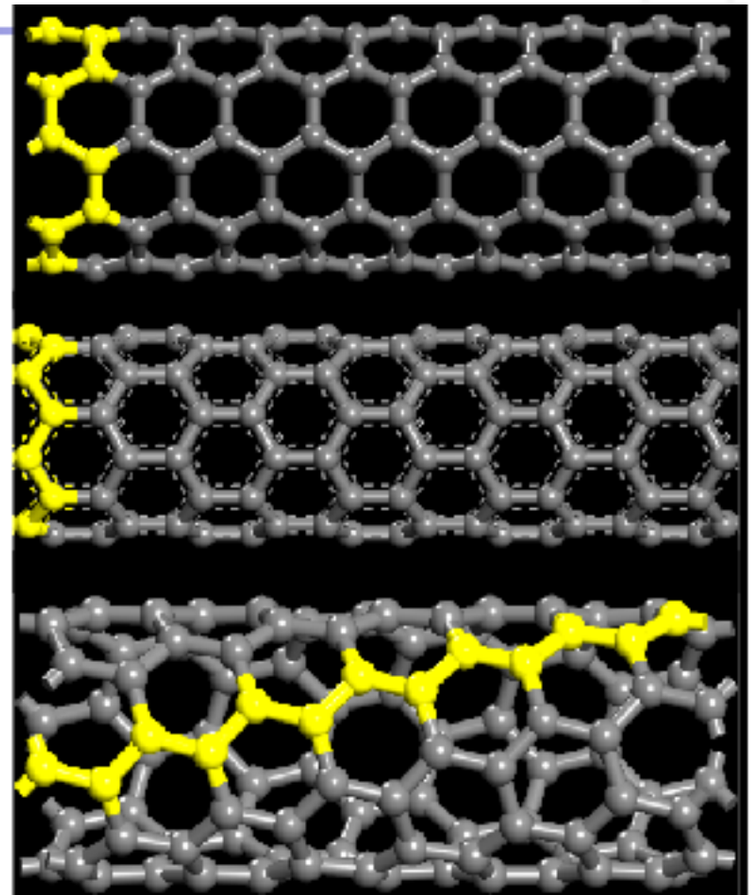


kovinska (m=n)

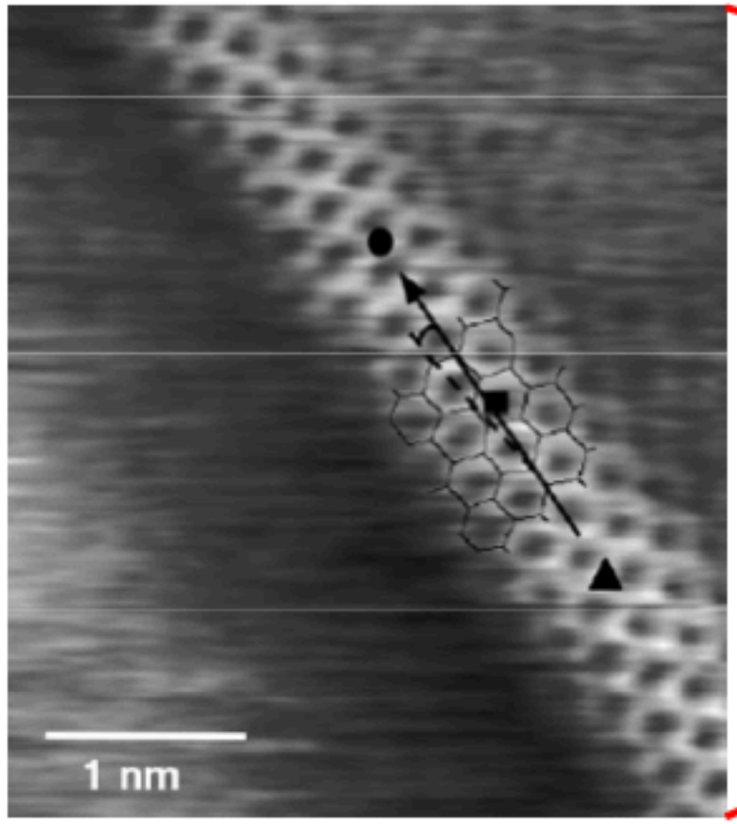
$$d = \frac{a}{\pi}\sqrt{n^2 + nm + m^2}$$

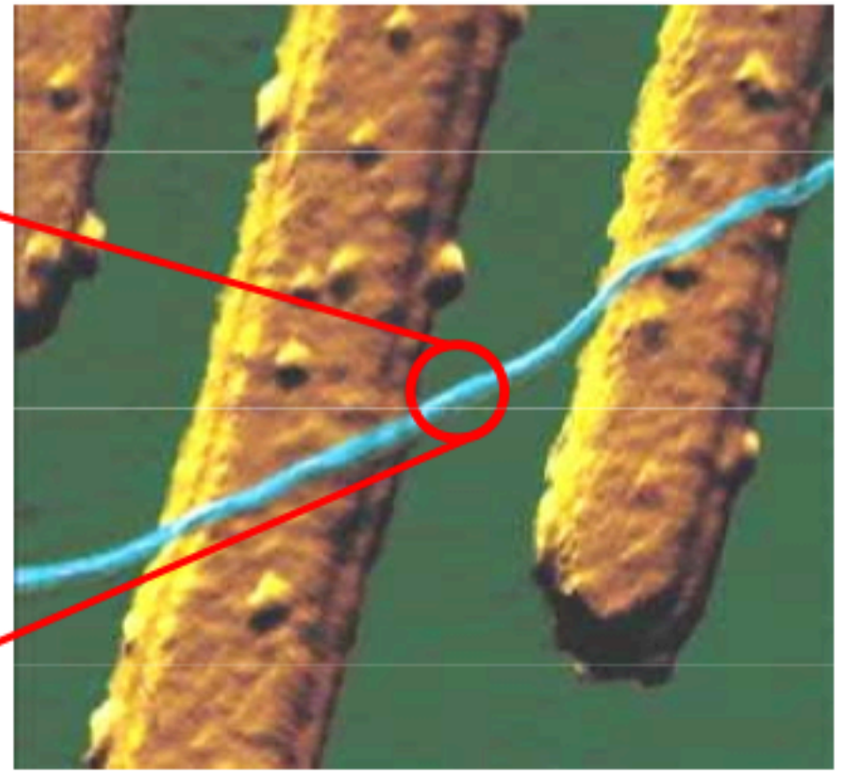


- (*n*,*n*) gives an "armchair" tube, e.g. (5,5)
- (*n*,*0*) gives an "zig-zag" tube, e.g. (6,0)
- Other tubes are "chiral", e.g. (6,2)



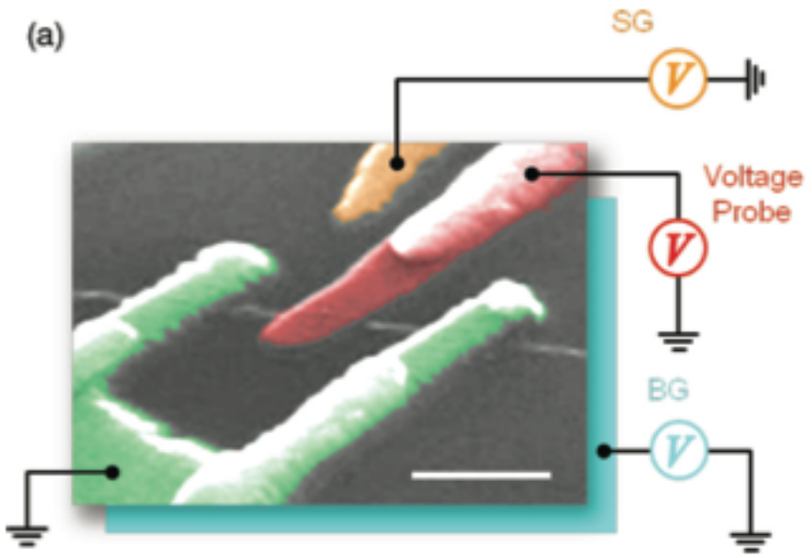
Elektronika z nanocevkami

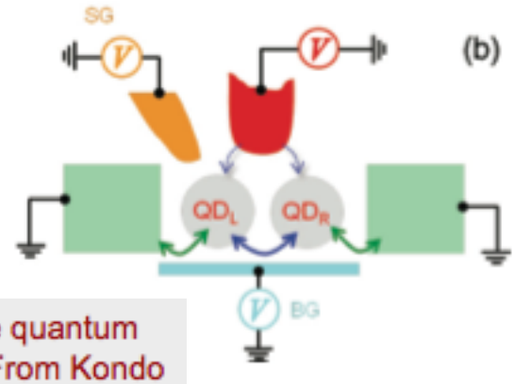




Yao *et al* (TUDelft)1999

Nanocevka priključena na superprevodne nanožice

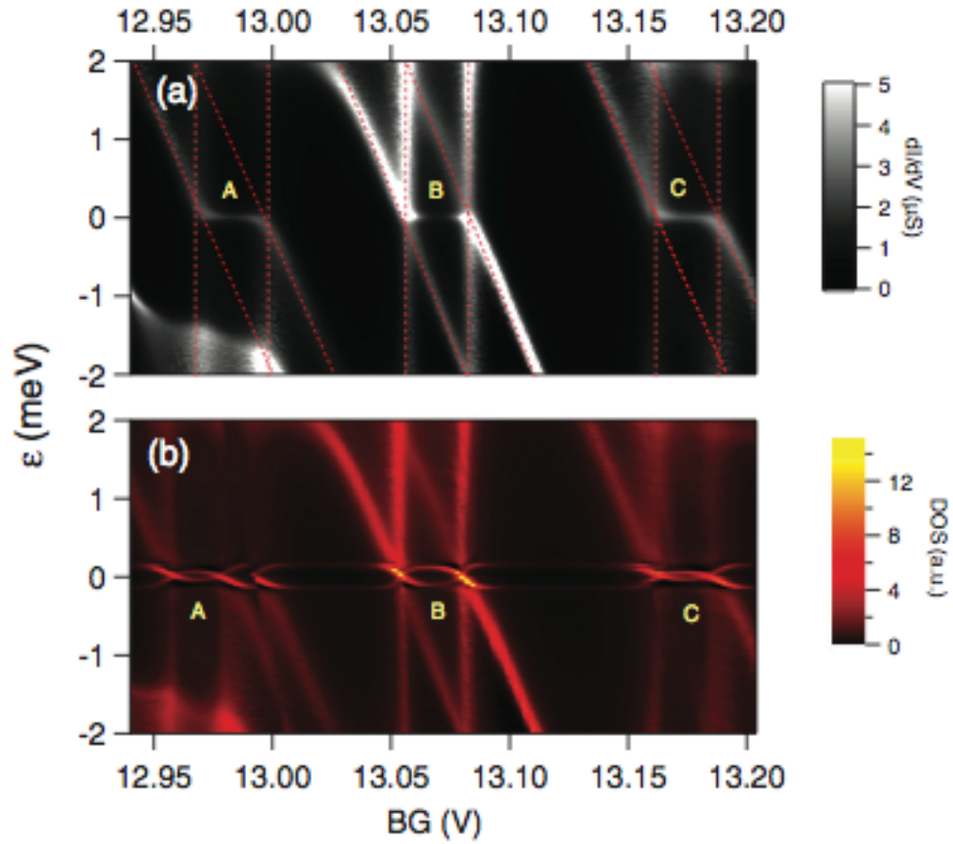


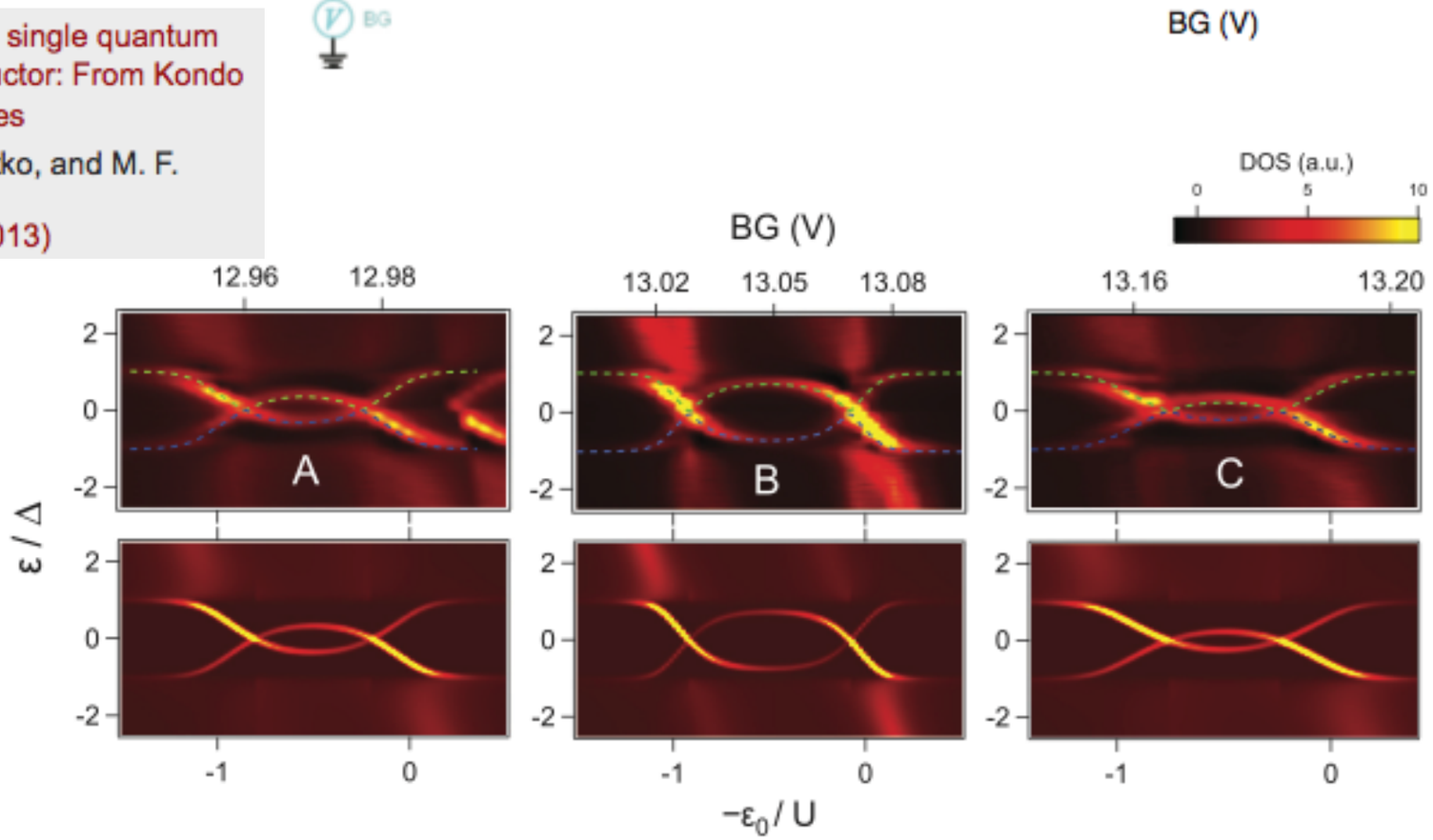


Tunneling spectroscopy of a single quantum dot coupled to a superconductor: From Kondo ridge to Andreev bound states

J.-D. Pillet, P. Joyez, Rok Žitko, and M. F. Goffman

Phys. Rev. B 88, 045101 (2013)

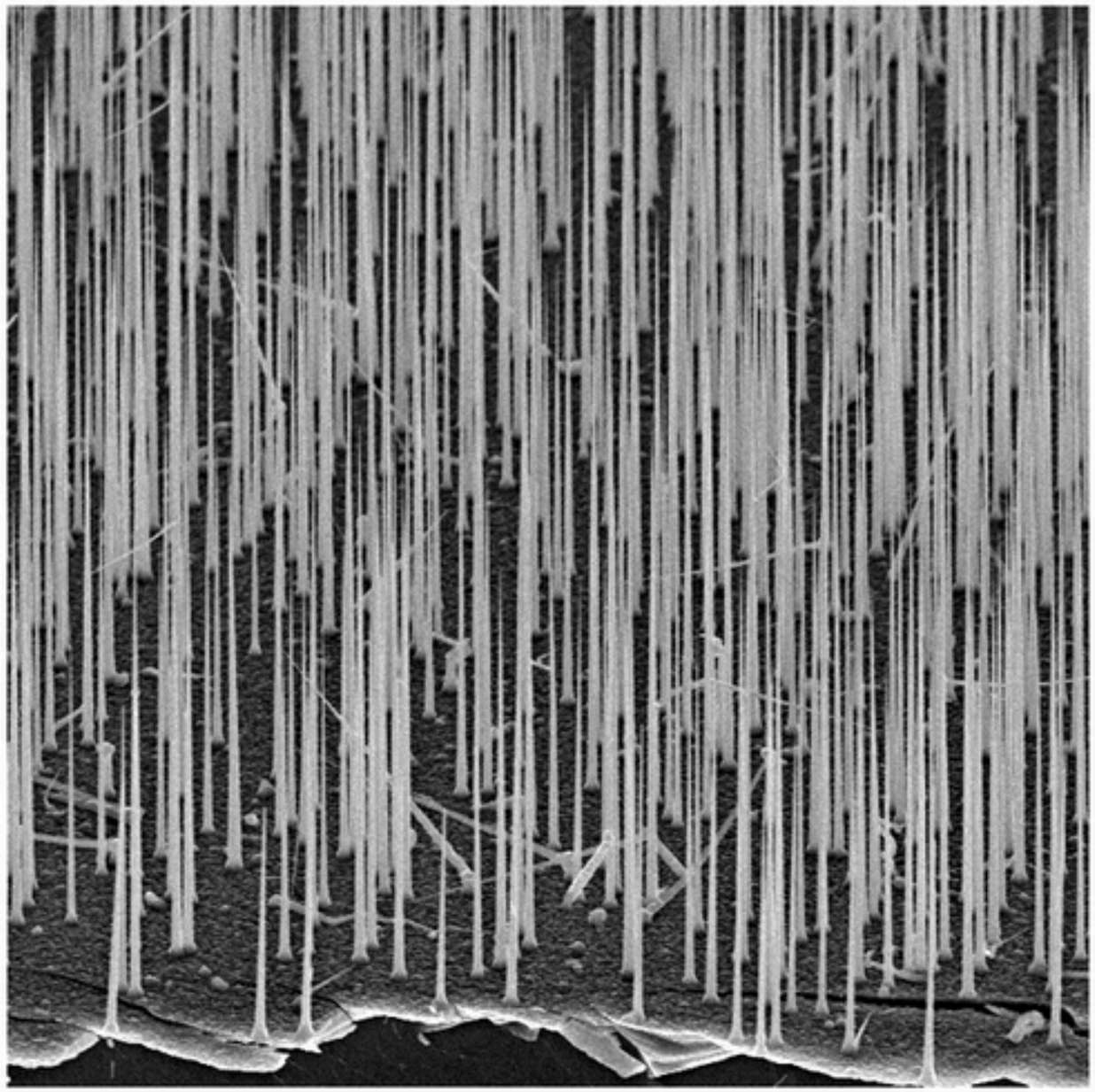


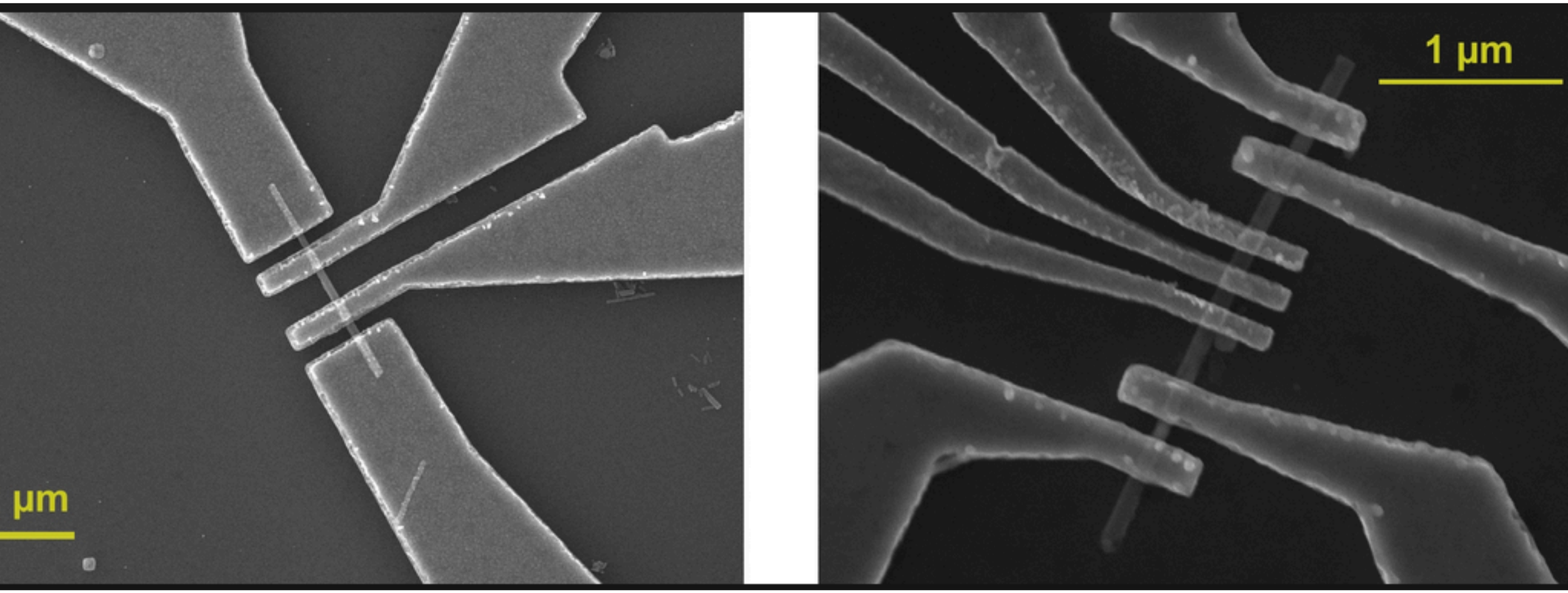


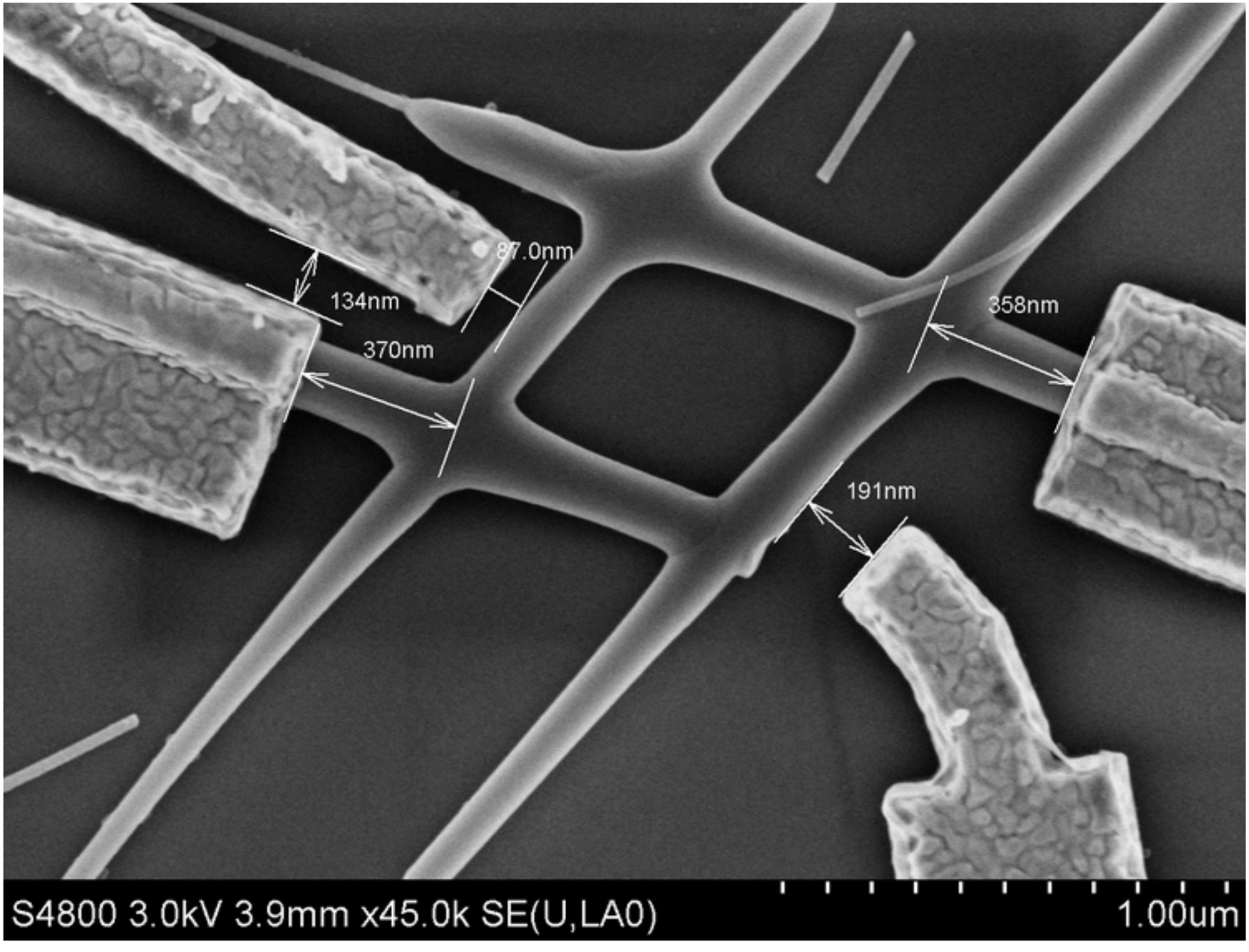
meritev

račun

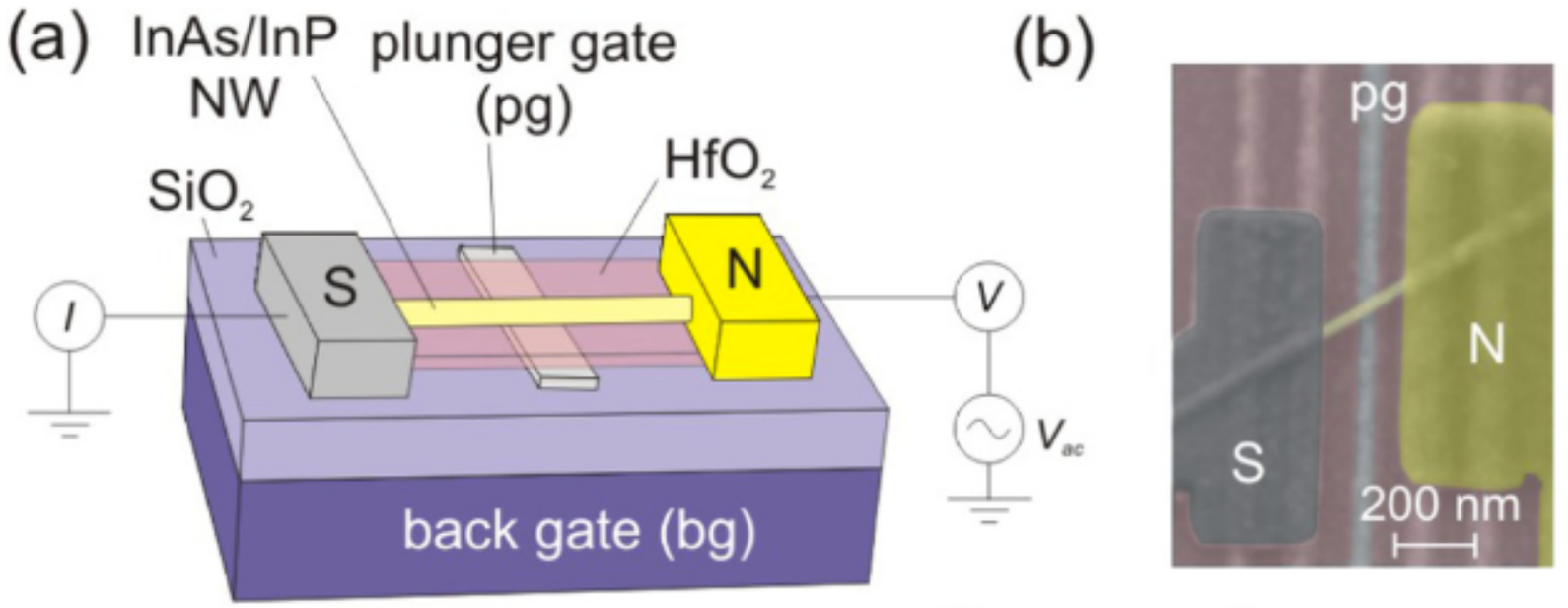
Polprevodniške nanožice

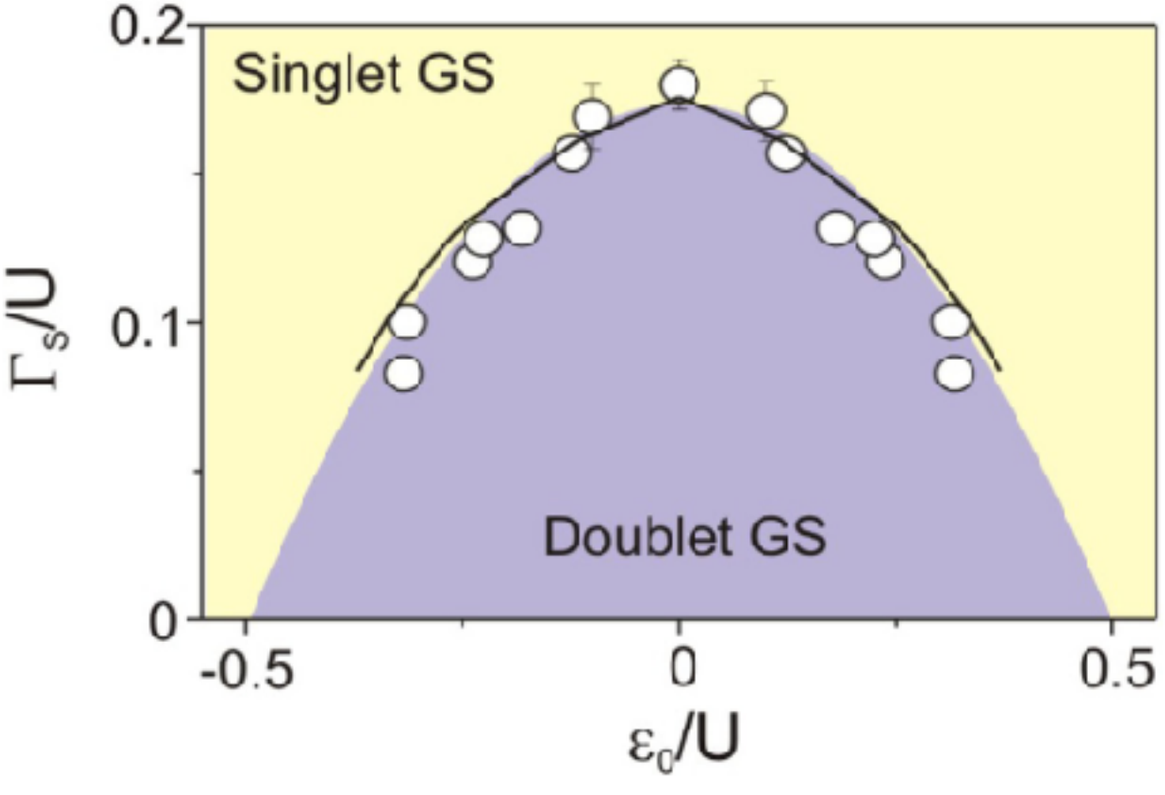


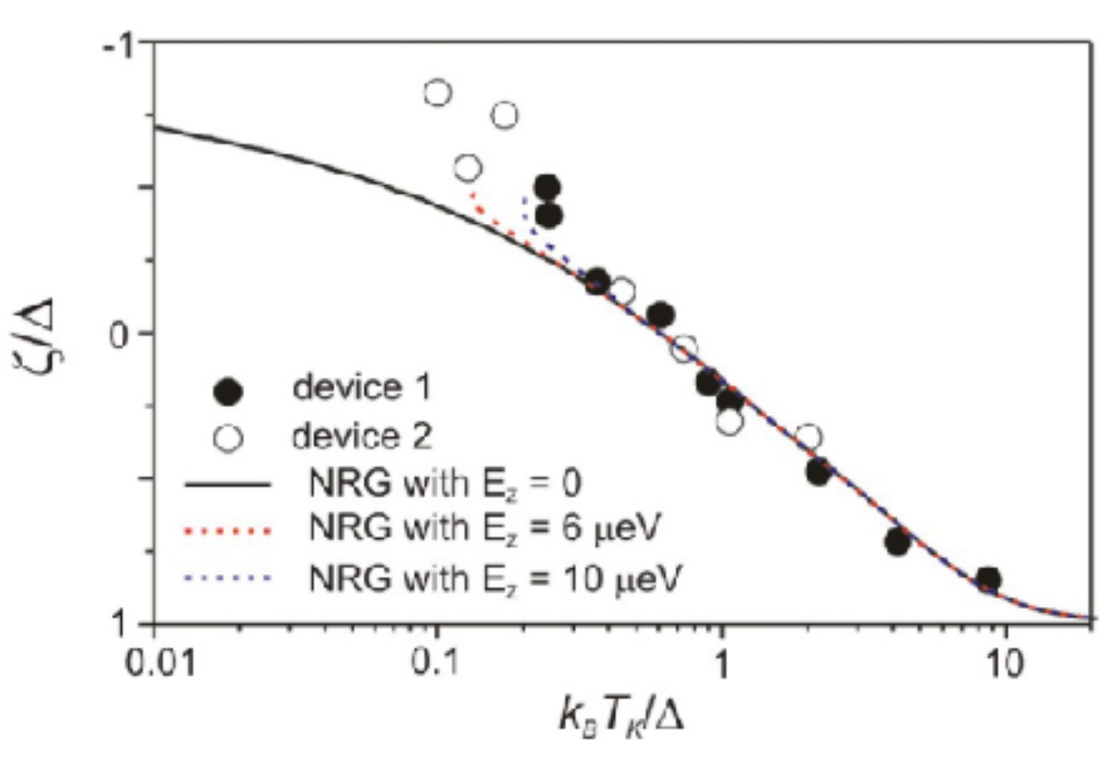

μm
1 μm


87.0nm
134nm
370nm
358nm
191nm
S4800 3.0kV 3.9mm x45.0k SE(U,LA0)
1.00um

Nanožičke iz InAs

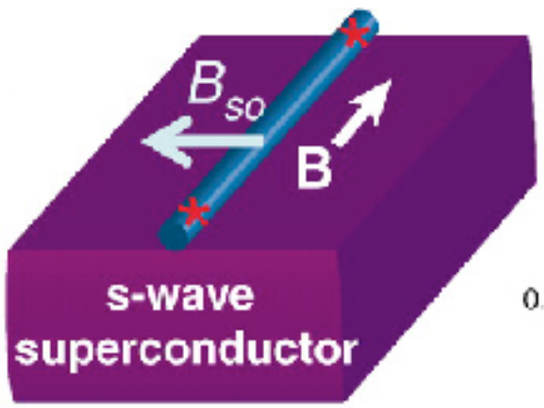


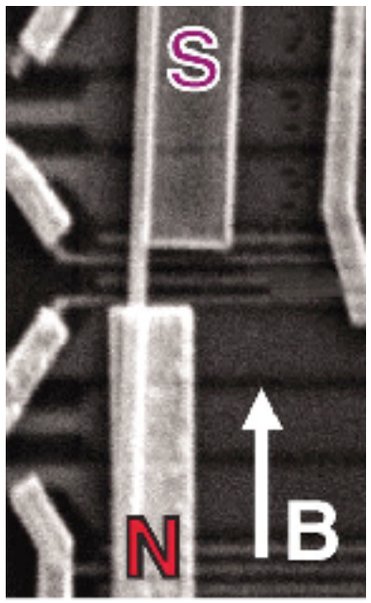


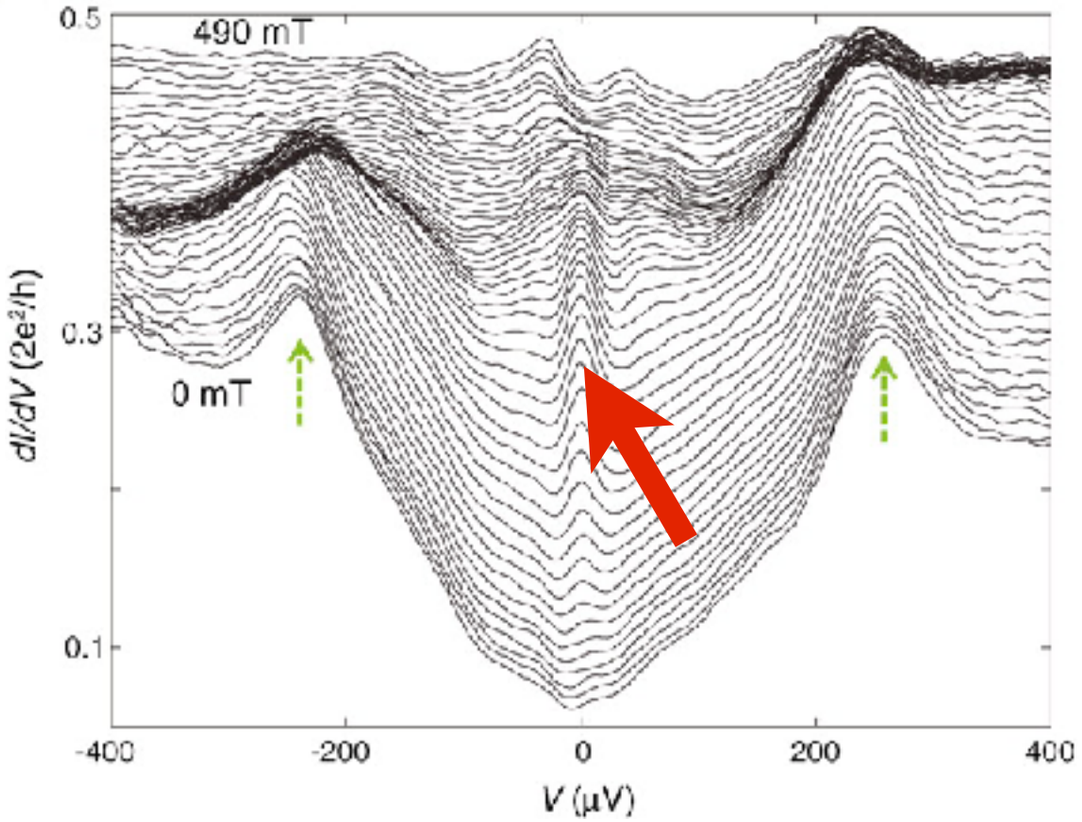


Scaling of subgap excitations in a superconductor-semiconductor nanowire quantum dot
Eduardo J. H. Lee, Xiaocheng Jiang, Rok Žitko, Ramón Aguado, Charles M. Lieber, and Silvano De Franceschi
Phys. Rev. B **95**, 180502(R) (2017) (PDF)

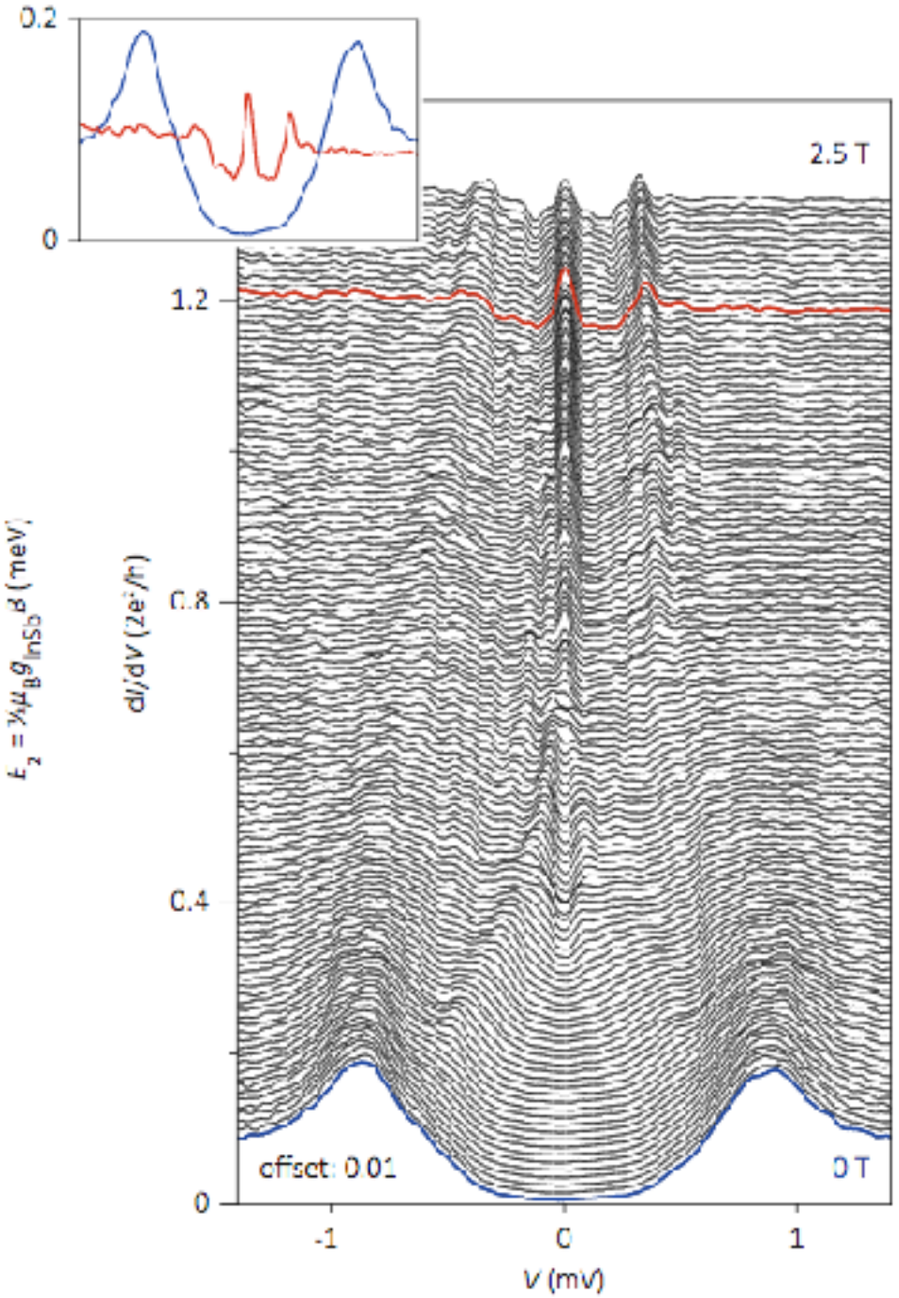
Majoranovi fermioni v nanožičkah: anomalija pri V=0





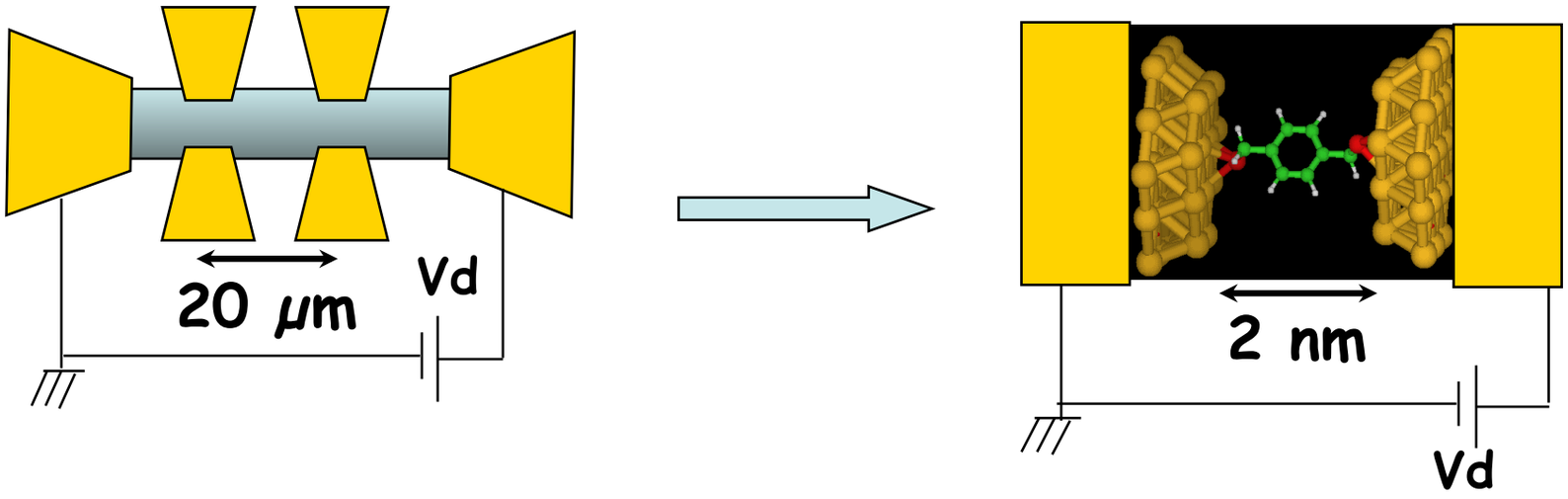


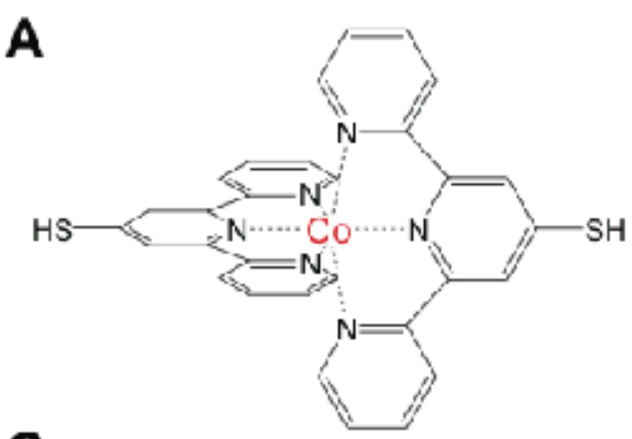
V Mourik, K Zuo, SR Plissard, EPAM Bakkers,
LP Kouwenhoven, Science **336**, 1003 (2012)

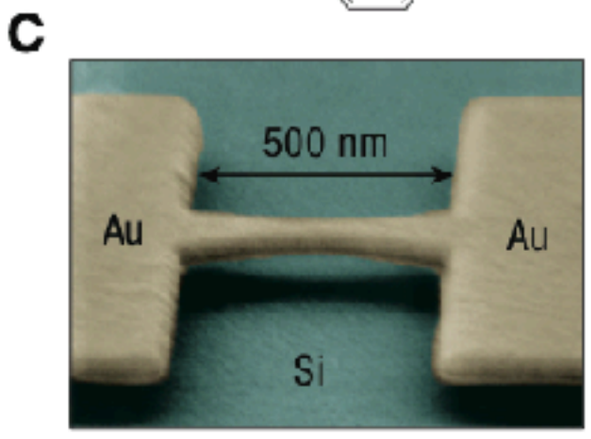


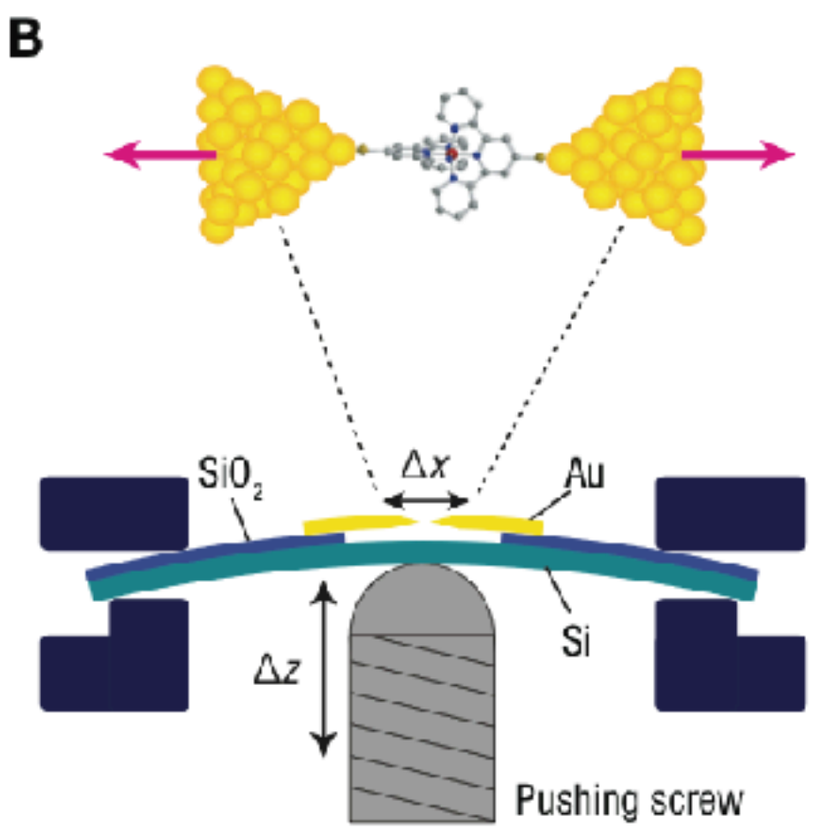
arxiv:1603.04069

MOLEKULARNA ELEKTRONIKA









MOLECULAR RECTIFIERS

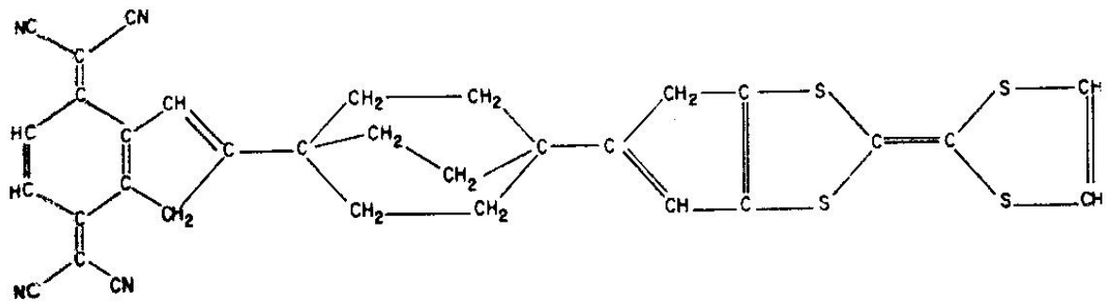
Arieh AVIRAM
IBM Thomas J. Watson Research Center, Yorktown Heights, New York 10598, USA

and

Mark A. RATNER*
Department of Chemistry, New York University, New York, New York 10003, USA

Received 10 June 1974

The construction of a very simple electronic device, a rectifier, based on the use of a single organic molecule is discussed. The molecular rectifier consists of a donor pi system and an acceptor pi system, separated by a sigma-bonded (methylene) tunnelling bridge. The response of such a molecule to an applied field is calculated, and rectifier properties indeed appear.

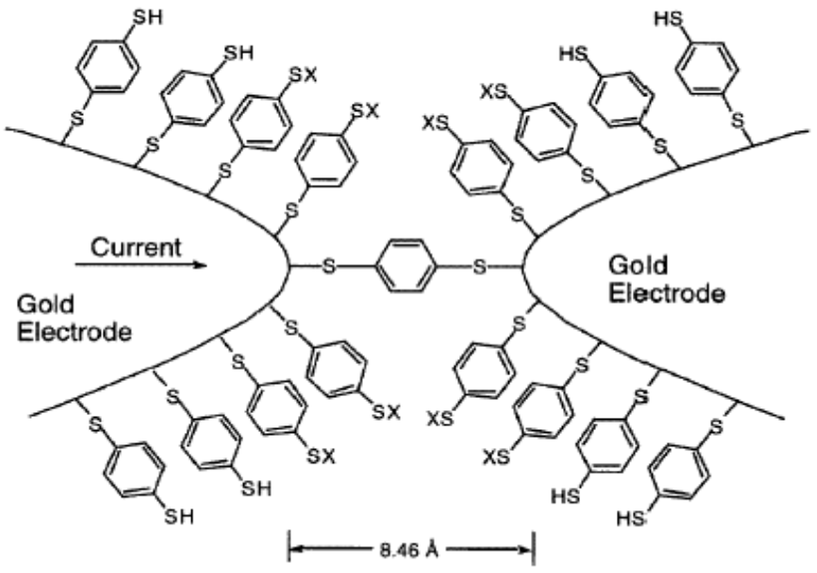


akceptor donor

Conductance of a Molecular Junction

M. A. Reed,* C. Zhou, C. J. Muller, T. P. Burgin,
J. M. Tour*

SCIENCE • VOL. 278 • 10 OCTOBER 1997

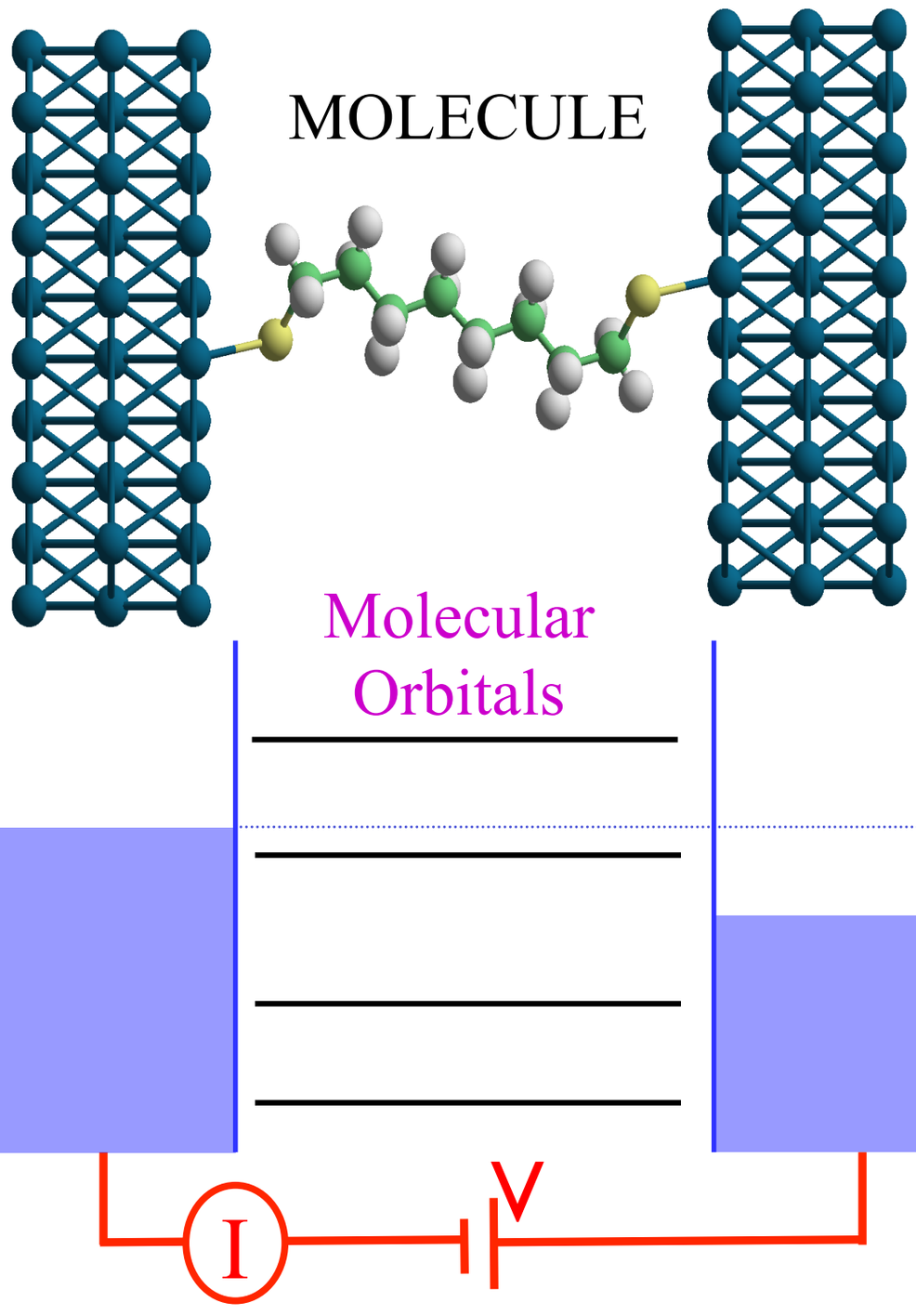


-SH : molekularni krokodilček

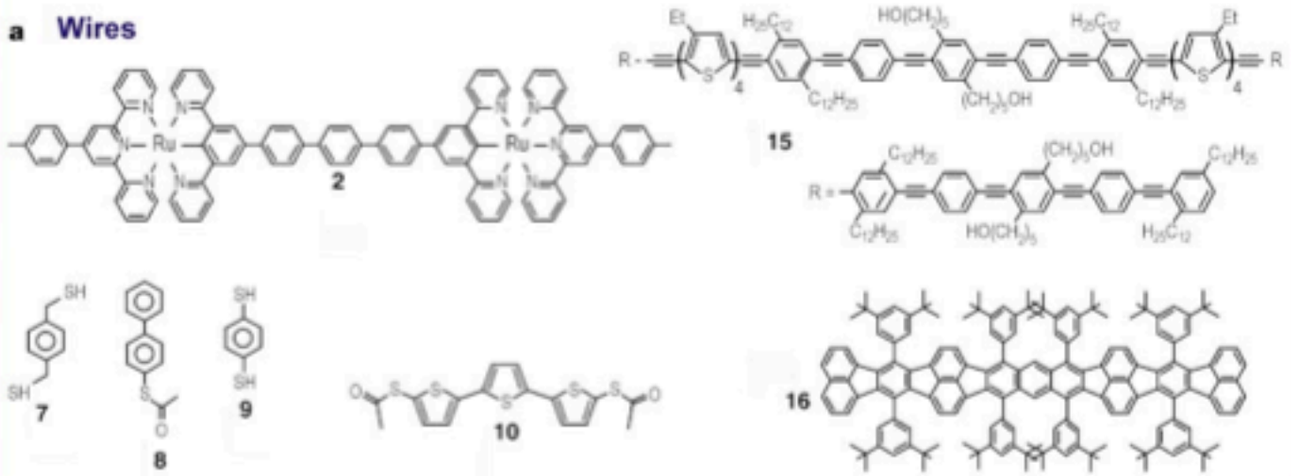
L
ELECTRODE

MOLECULE

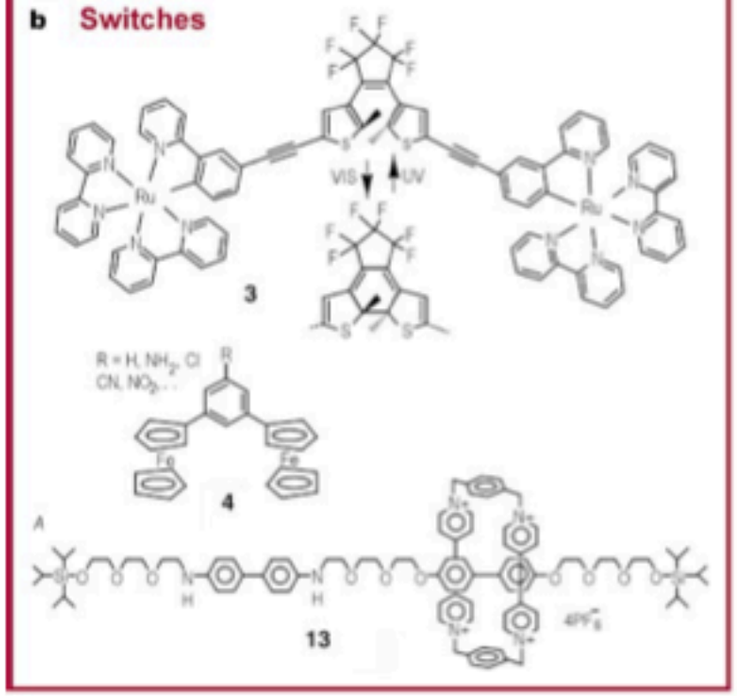
R
ELECTRODE



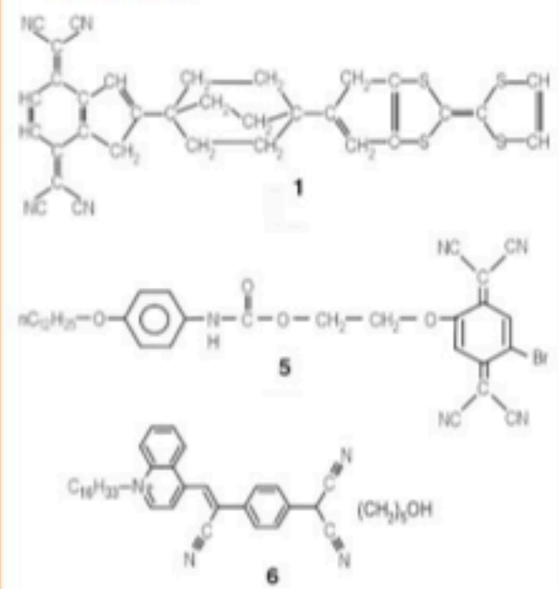
a Wires



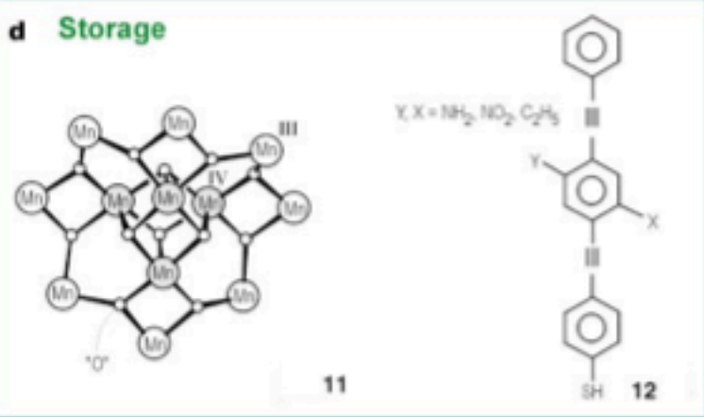
b Switches



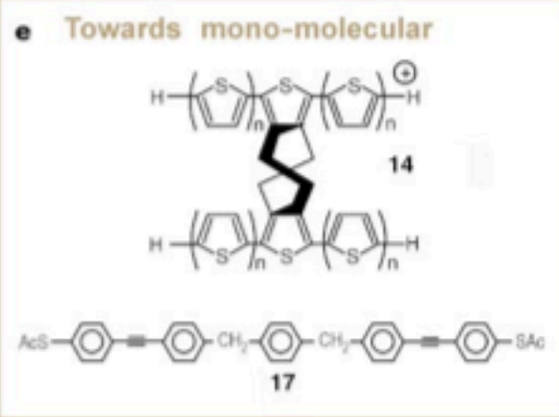
c Rectifiers



d Storage



e Towards mono-molecular



+

- molekule so majhne
- elektroni so ujeti v molekulah
- prevodne
- mehke: spremembe konformacije
- enake!
- možnost samourejanja

-

- problem kontaktov
- skaliranje proizvodnje

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Schön scandal

From Wikipedia, the free encyclopedia

The **Schön scandal** concerns German physicist **Jan Hendrik Schön** (born August 1970 in Verden an der Aller, Lower Saxony, Germany) who briefly rose to prominence after a series of apparent breakthroughs with semiconductors that were later discovered to be fraudulent.[1] Before he was exposed, Schön had received the Otto-Klung-Weberbank Prize for Physics and the Braunschweig Prize in 2001, as well as the Outstanding Young Investigator Award of the Materials Research Society in 2002, both of which were later rescinded.[2][*dubious – discuss*]

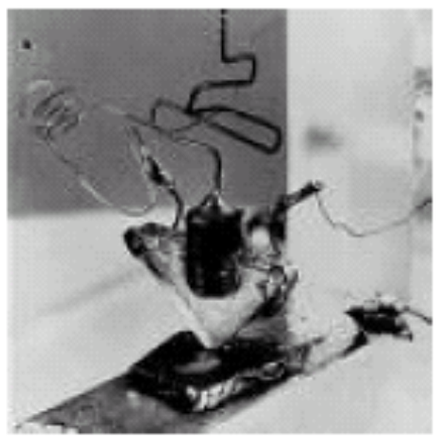
The scandal provoked discussion in the scientific community about the degree of responsibility of coauthors and reviewers of scientific articles. The debate centered on whether peer review, traditionally designed to find errors and determine relevance and originality of articles, should also be required to detect deliberate fraud.

Contents [hide]

Vacuum Tubes

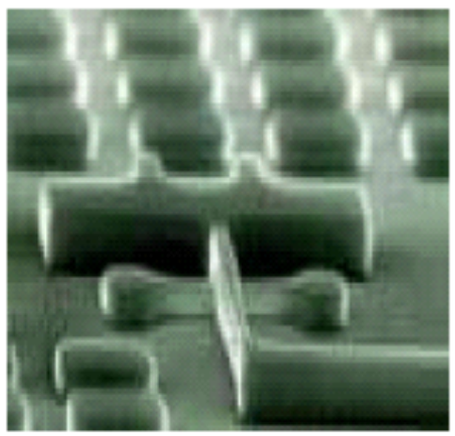
1906-1950s

Bipolar



1947-1980s

MOSFET



1960-until now

Now ??

Spintronics

Bio Sensors

Displays ….