

Miniaturyzujemy!

Jacek Szczytko, Wydział Fizyki UW



1. Miniaturyzujemy III i IV.

- a. Nanorurki
 - i. Węgiel i nie tylko
 - ii. Pokrócone zasady
- b. Nanomaszyny
- c. nano+bio
- d. molekuły

Miniaturyzujemy!

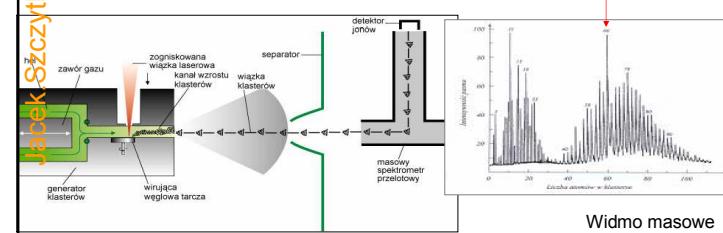
W latach 1975-1978, w zimnej przestrzeni międzygwiezdnej odkryto molekuły opisane формułą HC_{2n+1}N ($n = 2, 3, 4$ i 5)

W 1985 r. Richard Smalley, Harry Kroto i Bob Curl odkryli fuleryny (Nobel 1996)

$\text{C}_{2n}, n \geq 16$



60



Widmo masowe

P. Yam Świat Nauki 11, 16, 1993

Paweł Tomasz Pęczkowski



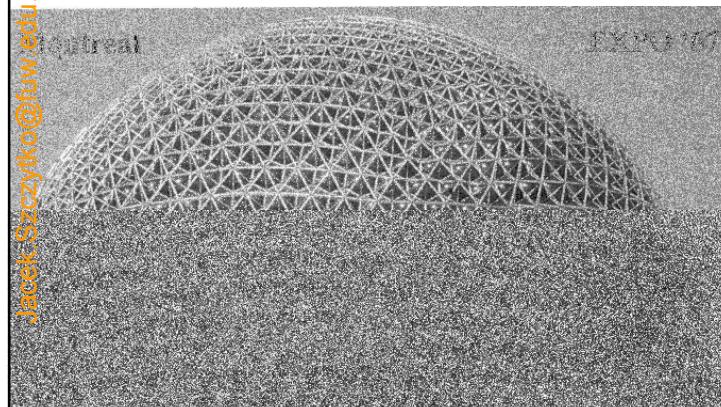
C_{60}

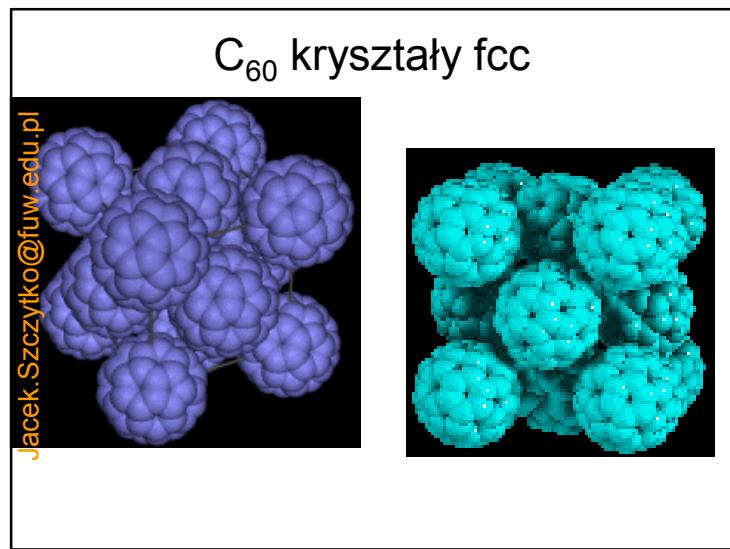
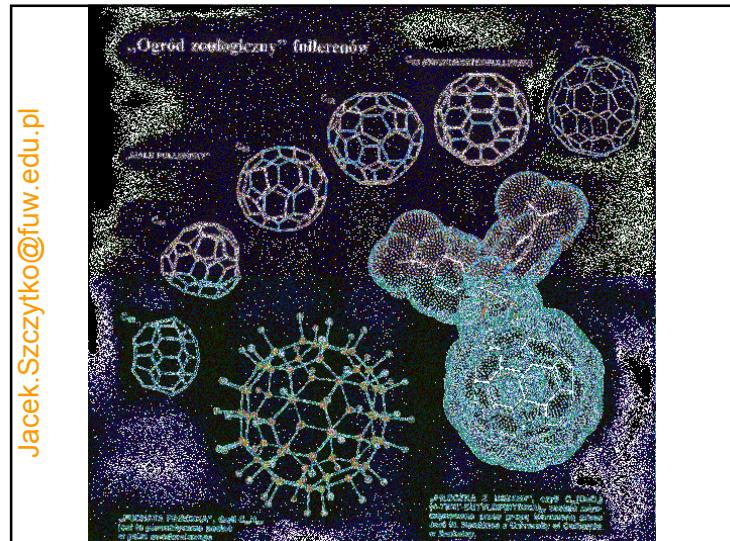
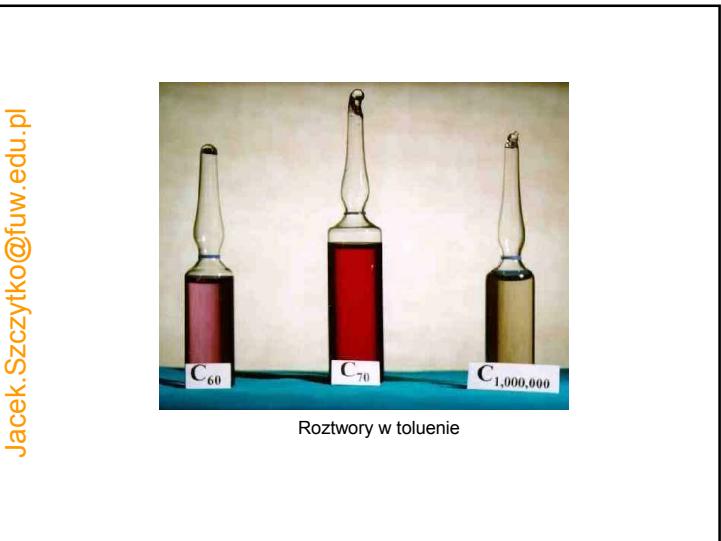
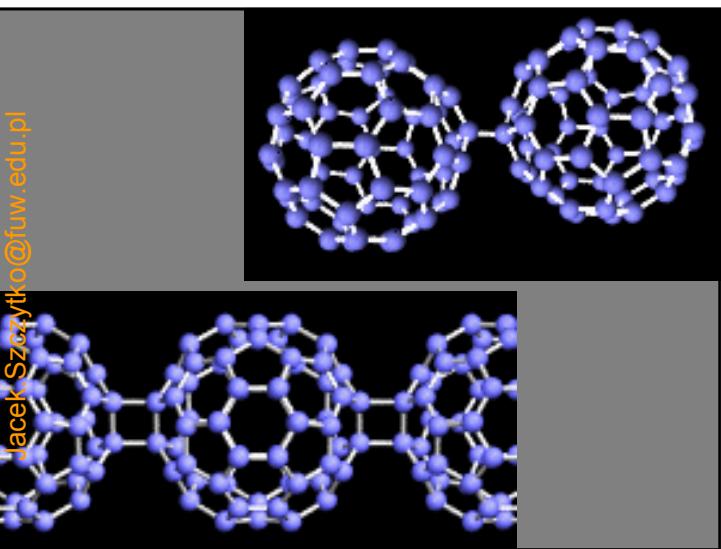
$0.71 \pm 0.007 \text{ nm}$

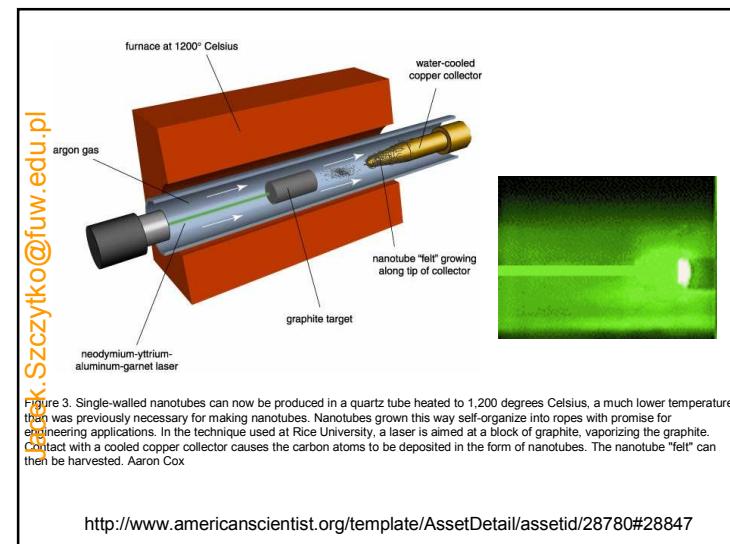
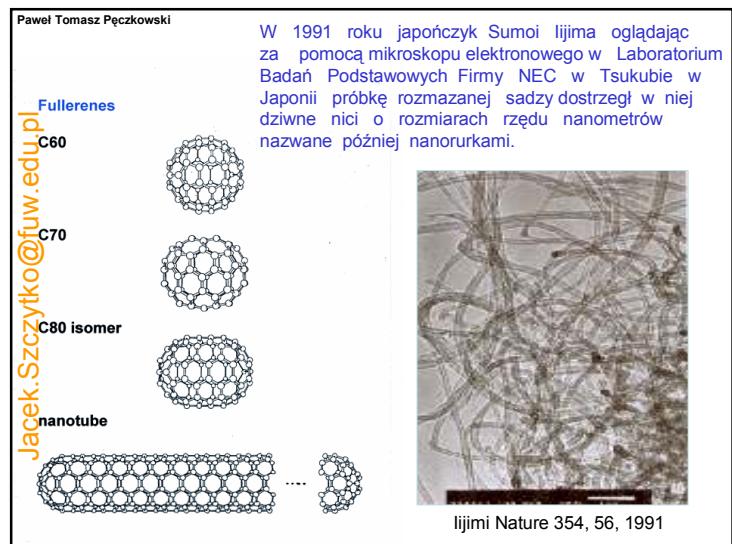
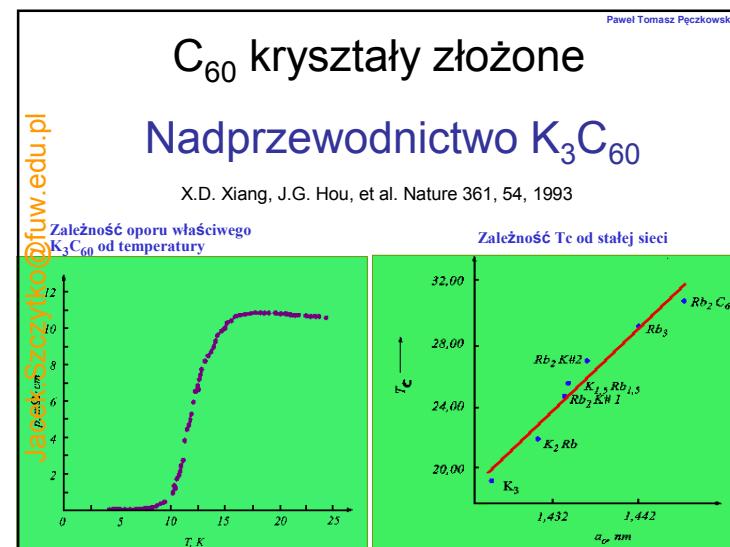
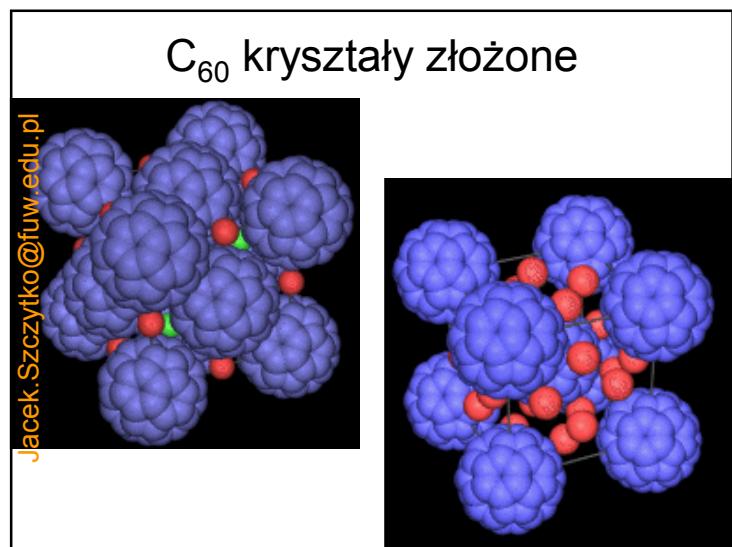


Miniaturyzujemy!

Buckminster Fuller pour un exposition en 1967 à Montréal

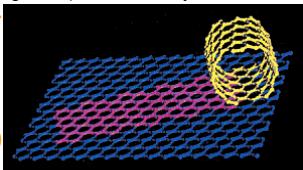






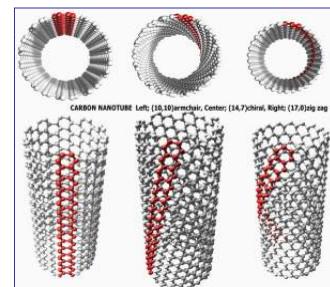
Orientacja nanorurek

Nanorurki można sobie wyobrazić jako warstwy atomów węgla (takie jak w graficach), które zostały zrolowane.



Rozróżniamy orientacje:

- Armchair
- Zig-zag
- Chiral



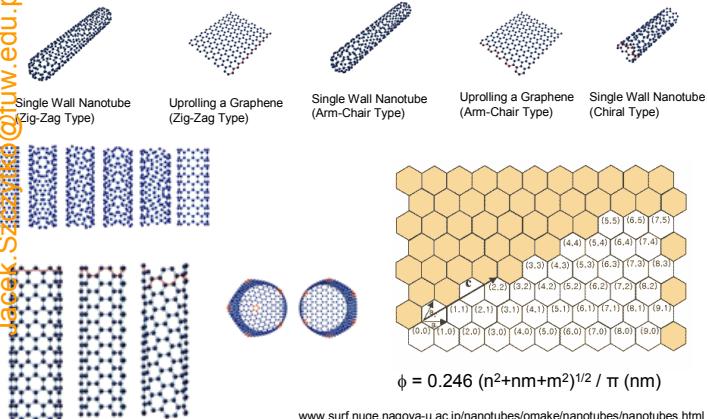
Orientacja jest zdefiniowana przez wektor chiralny (n, m)
 $c_h = n \mathbf{a} + m \mathbf{b}$

J.Basak, D.Mitra, S.Sinha „Carbon nanotube: the next generation sensors” presentation

Paweł Tomasz Pęczkowski

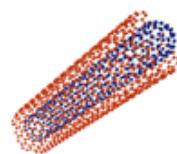
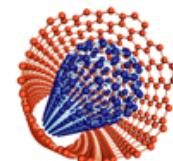
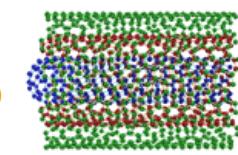
Ogród Zoologiczny nanorurek

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Ogród Zoologiczny nanorurek

Nanorurki wielościenne

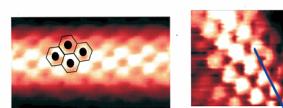
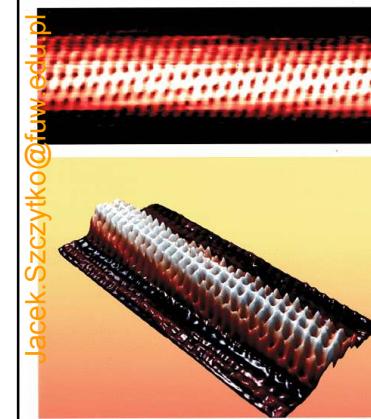


www.surf.nuqe.nagoya-u.ac.jp/nanotubes/omake/nanotubes/nanotubes.html

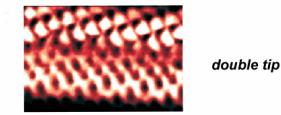
Nanorurki z bliska

Atomic resolution on the nanotubes

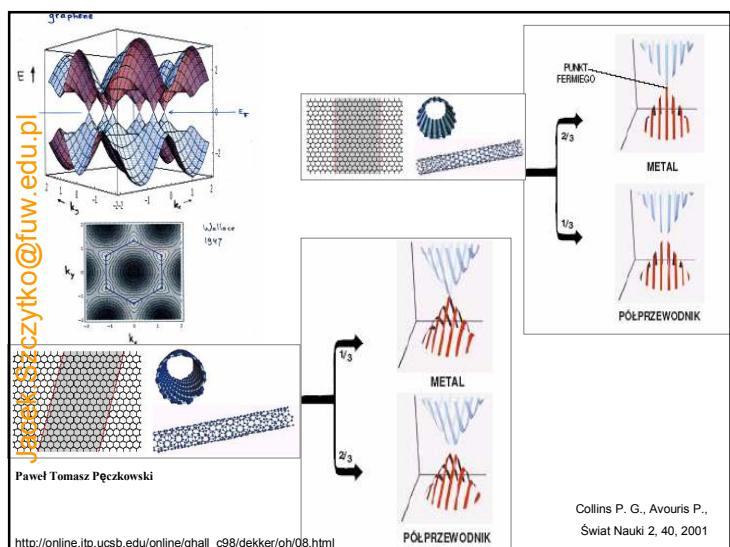
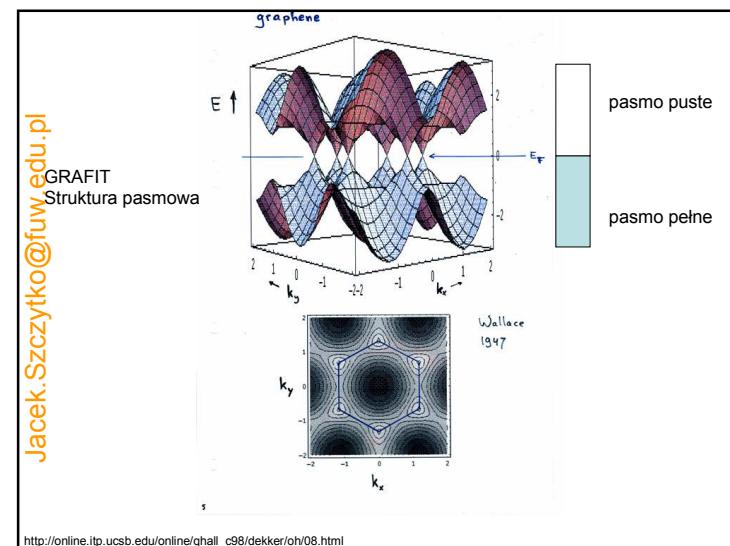
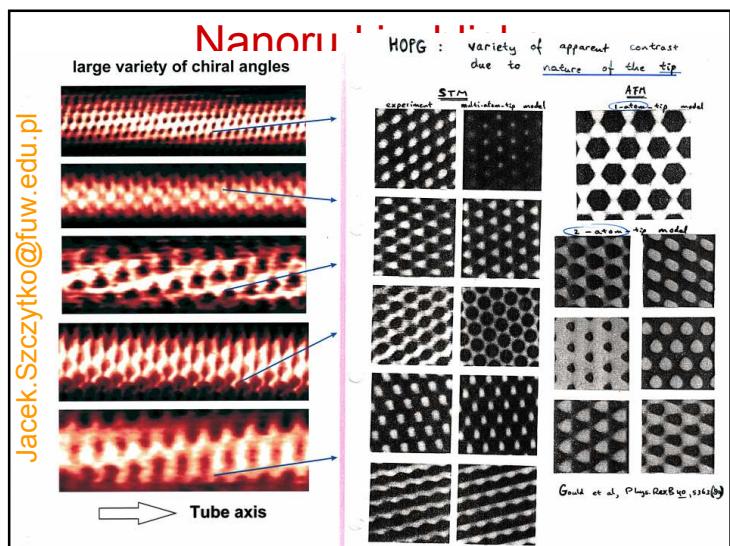
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triangular lattice:
dark dots correspond
to centers hexagons



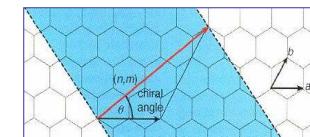
Gea Dokter
 TU Delft DIMES



Podwójna osobliwość elektroniczna nanorurek

W zależności od orientacji CNT mogą przejawać właściwości metaliczne lub półprzewodnikowe

➤ Nanorurki SWCNT o konfiguracji zig-zag są metalami gdy $\frac{1}{3} \cdot n =$ liczba całkowita



➤ Nanorurki chiralne o wskaźnikach (n,m) są przewodnikami o charakterze metalicznym, gdy spełniona jest następująca zależność

$$(2n + m) = 3 \cdot q$$

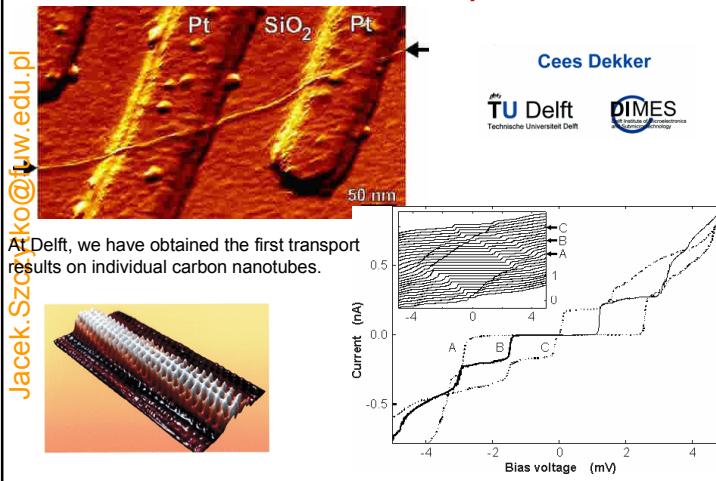
gdzie q jest liczbą całkowitą.

Gdy warunek ten nie jest spełniony, CNT jest półprzewodnikiem.

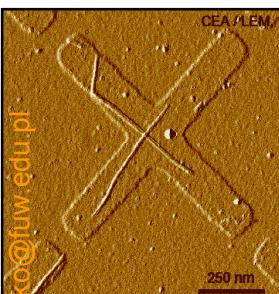
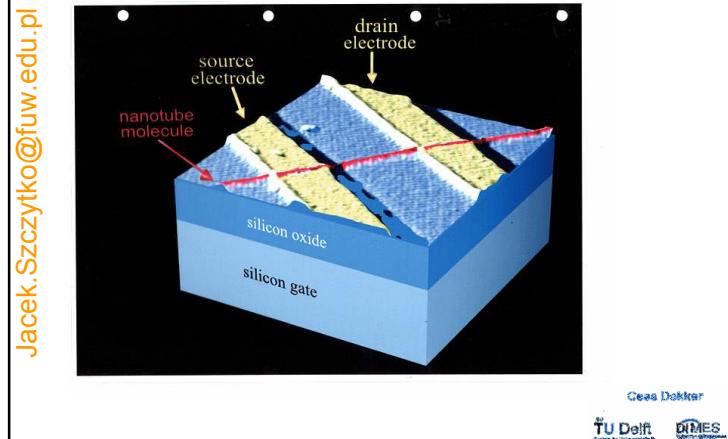
Wynika stąd, że SWCNT o wskaźnikach (n,n) wykazują przewodnictwo metaliczne

Paweł Tomasz Pęczkowski

Nanotubes as molecular quantum wires



Nanotubes as molecular quantum wires

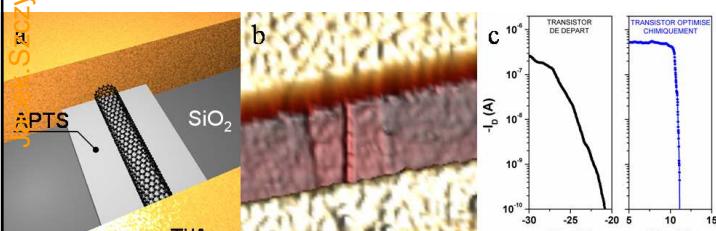


Nanotranzystory

www-drecam.cea.fr/scm/lem/LEM_eng/

AFM picture of carbon nanotubes on a silicon substrate. Nanotubes specifically adhere to pattern of amine silane (APTS) cast on the surface.

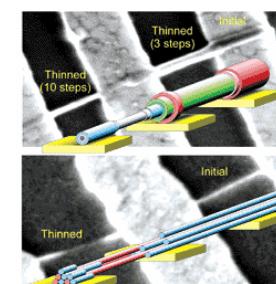
Drawing (a) and AFM picture (b) of a self-assembled carbon nanotube transistor. After sticking to the APTS pattern, the nanotube was connected with source and drain electrodes (Ti/Au). The doped silicon substrate is used as a gate.
(c) chemically optimising the performances of a carbon nanotube transistor. The current (I_d) in the nanotube is modulated by the gate voltage (V_{gs}). After optimizing (blue), the transition from passing to blocked state is a lot sharper than before (black).



Nanotranzistor IBM

"CONSTRUCTIVE DESTRUCTION"

1. The scientists deposit ropes of "stuck together" metallic and semiconducting nanotubes on a silicon-oxide wafer,
2. Then a lithographic mask is projected onto the wafer to form electrodes (metal pads) over the nanotubes. These electrodes act as a switch to turn the semiconducting nanotubes on and off,
3. Using the silicon wafer itself as an electrode, the scientists "switch-off" the semiconducting nanotubes, which essentially blocks any current from traveling through them,
- 4.. The metal nanotubes are left unprotected and an appropriate voltage is applied to the wafer, destroying only the metallic nanotubes, since the semiconducting nanotubes are now insulated,
5. The result: a dense array of unharmed, working semiconducting nanotube transistors that can be used to build logic circuits like those found in computer chips.



Yorktown Heights, N.Y., April 27, 2001 ... IBM scientists developed a breakthrough transistor technology that could preview how computer chips can be made smaller and faster than what is currently possible with silicon.

Nanoliczydła

Description: This diagram and image depict a carbon nanotube containing four carbon buckyballs. The blue dots represent electrons. Each buckyball can serve as qubit.

Source: University of Oxford

NANOTECHNOLOGIA

Fullerenowe liczby

amid z wielkimi blokami kamiennymi – wieżowymi i dzwonnymi – było bazą wznoszenia zbudowanych architektonicznych struktur, czasem jednak nie jest zasługą tych budowli, że ich skutek jest zauważalny w dzisiejszych technologiach. Wszystko, co dotyczy klocków kamiennych, jest zasadniczo znanym zabytkiem, ale zauważalne są także nowoczesne technologie, które wykorzystują właściwości tych struktur. Na przykład Hongjie Dai, pracujący wspólnie z innymi naukowcami, wykorzystał pełnowymiarowy mikroskopu sił atomowych (STM) do eksperymentu, który pozwolił na odkrycie, że kiedy jedna z czterech buckyballów, której średnica wynosi 90 nm, przejeżdża przez nich nanotubę, dochodzące do 2000 nm, pojedyncze pojawiają się dopyndzenie.

Cybernetyczne wielokrotnie fulleryny, zwane nanorunkami, zdobudowane są z koncentrycznych pierścieni atomowych, a ich średnica jest zazwyczaj mniejsza niż 10 nm. W związku z tego cyfrowa pokójka cząstek fullerenowej otrzymuje wyjątkową gęstość chemiczną. Te niewielkie rurki rzeczywiście niezwykle elastyczne, mogą bowiem średnicę zwiększać do 200 nm, mając jednocześnie średnicę 5–20 nm. Główne uwagi dotyczą możliwości wykorzystania nanorunków do celów technologicznych, takich jak np. do produkcji nowego typu kolorów, Daniel Cobert, jeden z członków zespołu, mówi: „Wysokość elastyczności pozwala nam zmieniać nanorunki, są one nieskazitelnie elastyczne i po zgodzie wracają do początku swojego kształtu”.

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simtubem2.mpg

Nantero

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Nano-anteny

Receiving and transmitting light-like radio waves: Antenna effect in arrays of aligned carbon nanotubes

Y. Wang^{a)} and K. Kempa
Boston College, Chestnut Hill, Massachusetts 02467

(a) SEM image of a random array of MWCNTs. **(b)** SEM image of a scratched array of MWCNTs.

FIG. 1. Aligned (a) and scratched (b) random arrays of MWCNTs. In this study we use only the random arrays, to reduce the internanotube diffraction effects. Scale bars, 1 μ m.

FIG. 2. (a) Fluorescence color from the random array of MWCNTs. The positions A₁–A₇ are selected for the length effect measurement. (b) Light intensity vs wavelength measured at the selected points in (a).

Color nanotube display

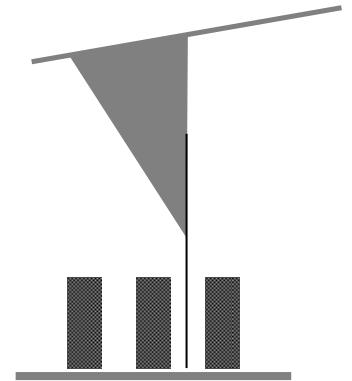
Jacek.Szczytko@fuw.edu.pl

(above): A field-emission display using carbon nanotubes.

(above): A cross section image, made with a scanning electron microscope, of a carbon nanotube cathode. The nanotubes are aligned perpendicular to the substrate and are embedded into a metal electrode. (Courtesy, Samsung Advanced Institute of Technology, Korea)

Scanning Probe

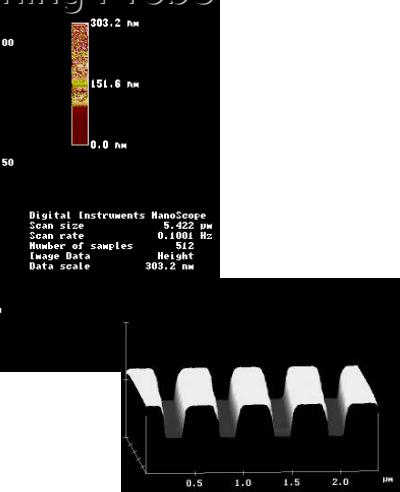
M. Meyyappan
Director, Center for Nanotechnology
NASA Ames Research Center
Moffett Field, CA 94035
meyya@orbit.arc.nasa.gov
[web : http://www.ipt.arc.nasa.gov](http://www.ipt.arc.nasa.gov)



Scanning Probe

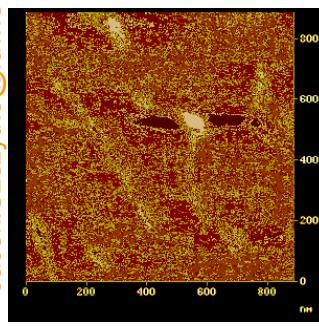
A scanning electron micrograph (SEM) showing a dense, layered structure of nanowires on a substrate. The image is taken at 193nm scale.

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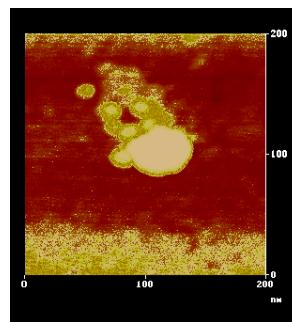


Scanning Probe

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DNA

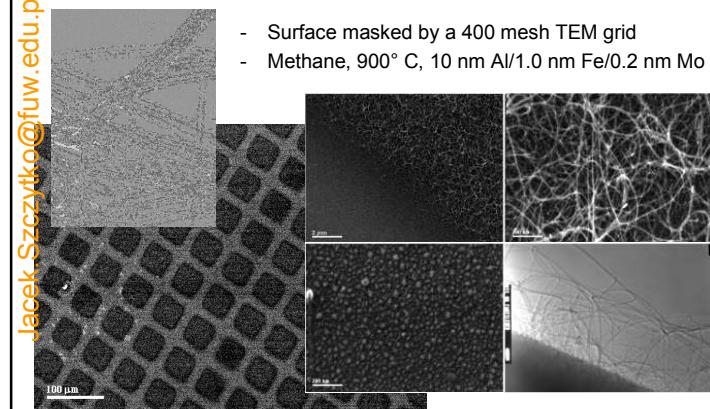


PROTEIN

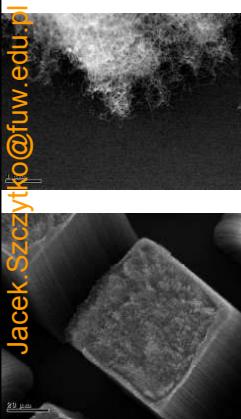
Wzrost kontrolowany

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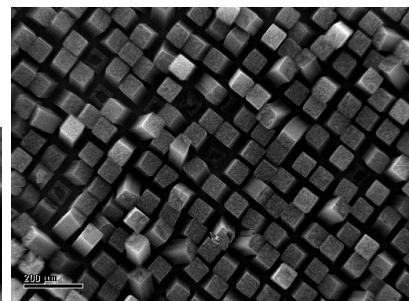
- Surface masked by a 400 mesh TEM grid
 - Methane, 900° C, 10 nm Al/1.0 nm Fe/0.2 nm Mo



Wzrost kontrolowany



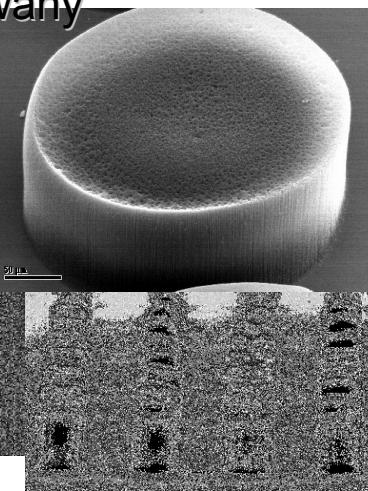
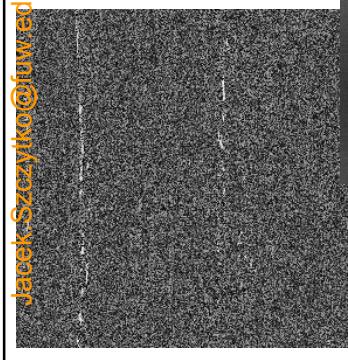
- Surface masked by a 400 mesh TEM grid; 20 nm Al/ 10 nm Fe; nanotubes grown for 10 minutes



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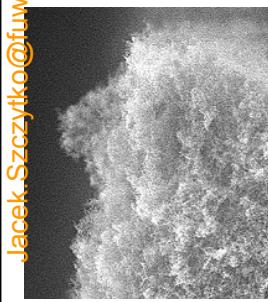
Wzrost kontrolowany

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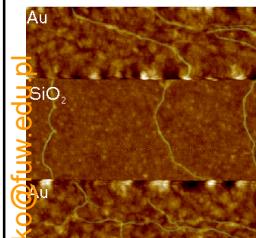
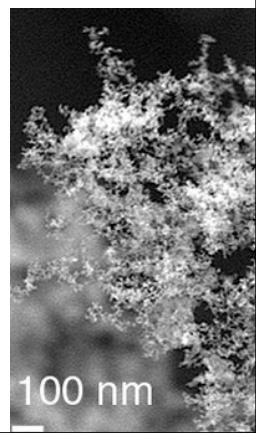


Nanopianka

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Nanopianka węglowa jest... magnetyczna!
Physics News 678, March 26, 2004



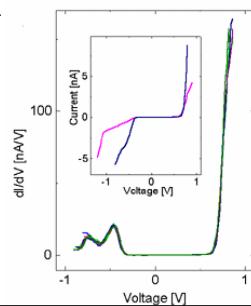
Dr Andrei Rode , Australian National University



Jacek.Szczytko@fuw.edu.pl

Conductance measurements on lambda DNA fragments

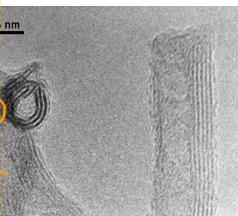
Fragments of lambda DNA with a length of 1.5 micron (4500 base pairs) were deposited on gold electrodes spaced by about 250 nm. By AFM imaging single DNA molecules were found between the electrodes. The measured resistance between the electrodes was found to be larger than 200 GOhm. Below is an AFM image of DNA over gold electrodes.



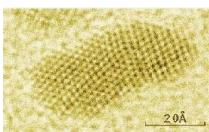
Inne nanorurki i nanowąsy

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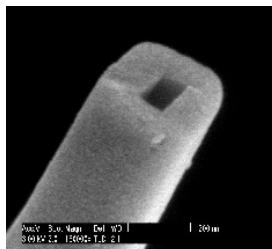
TiO₂ nanotube materials



ZnO



nanocząstka Au



Nanorurka Si
www.ee.leeds.ac.uk/nanomsc/modules1.php

ZnO



Wydział (nano)Chemii UW

<http://www.chem.uw.edu.pl/labs/elektrochemia/Nanogaleria/nanogaleria.htm>



The screenshot shows a web page titled "Pracownia Elektrochemii". On the left, there is a sidebar with links: "Strona główna", "Aktualności", "Pracownicy", "Przedmioty", "Aparatura", "Studenti", "Wydział", and "Nanogaleria" (which is highlighted). The main content area is titled "Nanogaleria" and contains a grid of 12 images, each with a caption:

- Nanocząstki z polidiolem otrzymane w membranach polietylenowych.
- Nanocząstki z polidiolem otrzymane w membranach polietylenowych.
- Nanocząstki z polidiolem otrzymane mikroskopem APM.
- Mikrocząstki z polidiolem.
- Nanodżetery jajka w masyce z pol(1,3-dimetylalanolem).
- Nanorurki palakowe.
- Róż. partyczki z pol(1,3-dimetylalanolem).
- Mikrocząsteczki z polidiolem odcinkowane w dekoracjach mosiężnych.
- Nanodżetki z polidiolem otrzymane metodą termiczną.
- Nanocząstki ze srebra na powierzchni grafitu.
- Słojki nanosąjet ze srebra na powierzchni grafitu.
- Nanoplaki z polidiolem otrzymane metodą termiczną.

Nano i bio (gekon)

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Nano i bio (gekon)

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50x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Nano i bio (gekon)

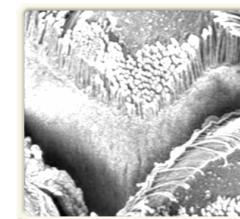
100x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Nano i bio (gekon)

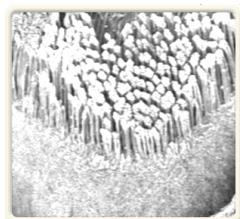
200x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Nano i bio (gekon)

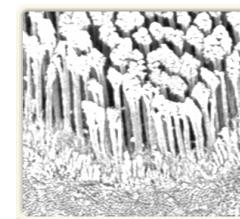
400x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Nano i bio (gekon)

800x

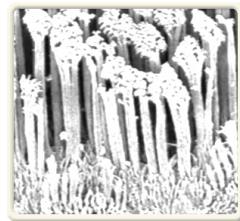


<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Jacek.Szczytko@fuw.edu.pl

Nano i bio (gekon)

1500x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Nano i bio (gekon)

3000x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Jacek.Szczytko@fuw.edu.pl

Nano i bio (gekon)

6000x



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

Jacek.Szczytko@fuw.edu.pl

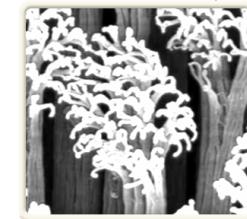
Nano i bio (gekon)

6000x

Wysokość włosów 2 mm, średnica 200 nm
 $cm^2 = 10^6$ włosów może utrzymać ciężar 1 kg

Pałek Tomasz Pęczkowski

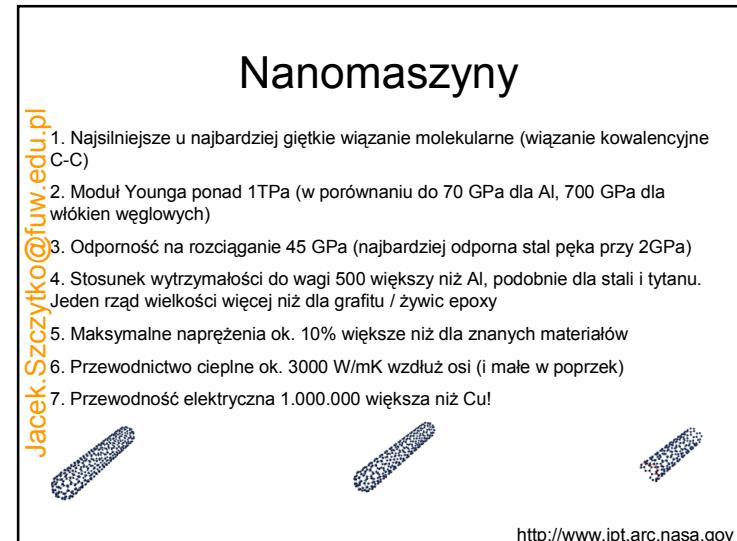
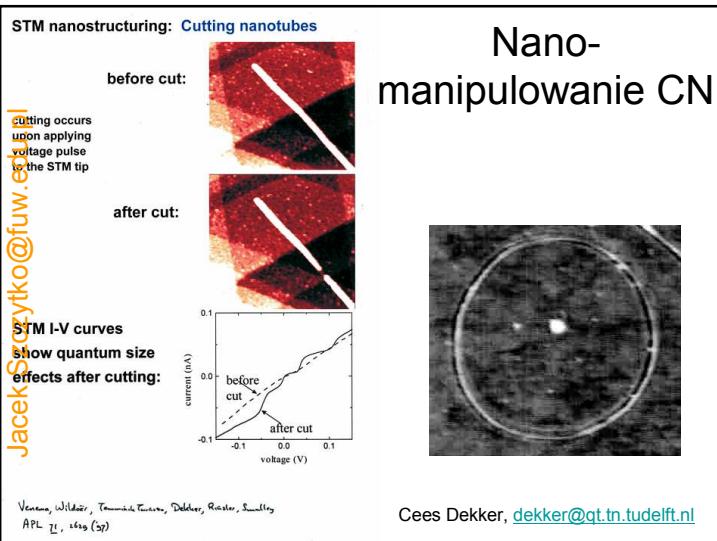
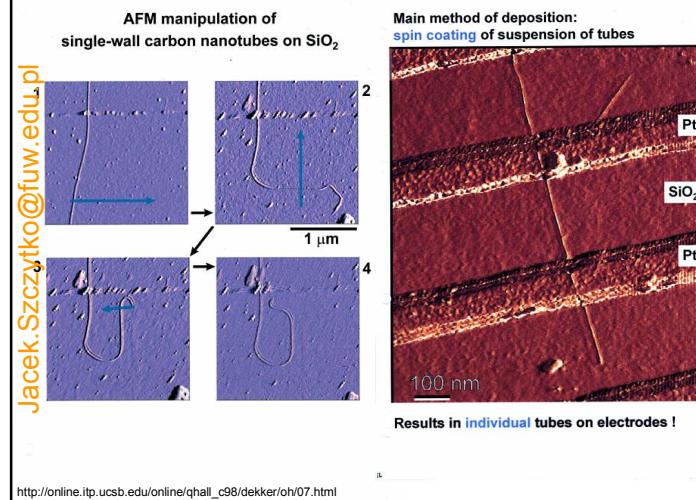
1 μm



<http://www.microscopy.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

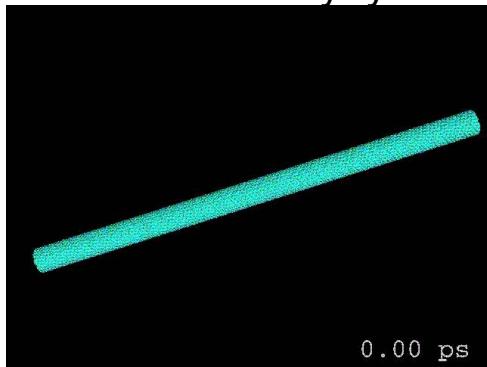
nano-Manipulowanie nanomaszyny

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Jacek.Szczytko@fuw.edu.pl

Nanomaszyny

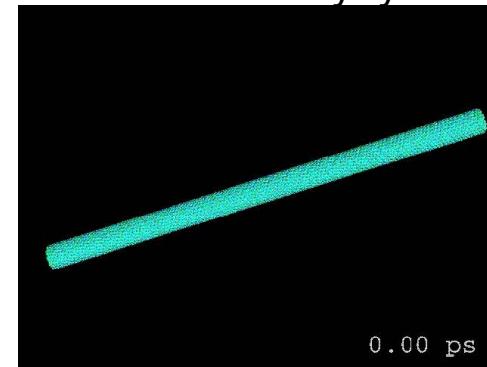


0.00 ps

Single – twist

<http://www.ipt.arc.nasa.gov>

Nanomaszyny



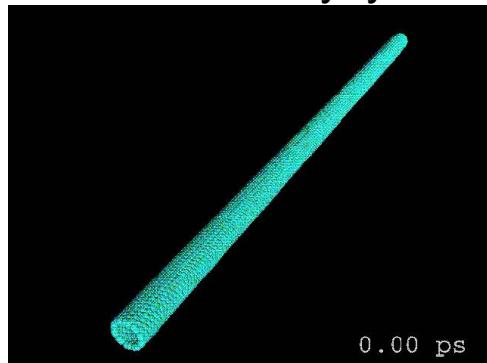
0.00 ps

Single – bend

<http://www.ipt.arc.nasa.gov>

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Nanomaszyny



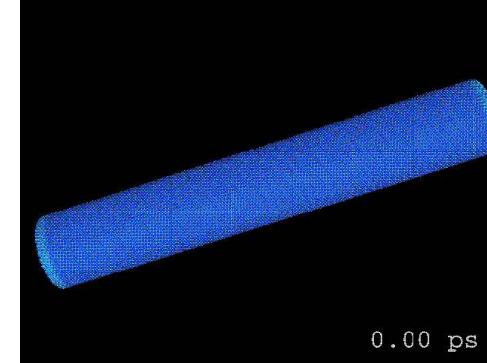
0.00 ps

Single – compress

<http://www.ipt.arc.nasa.gov>

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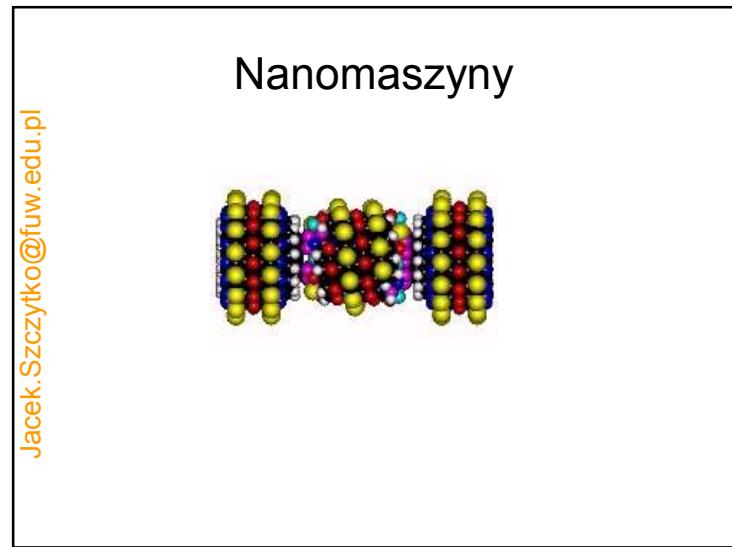
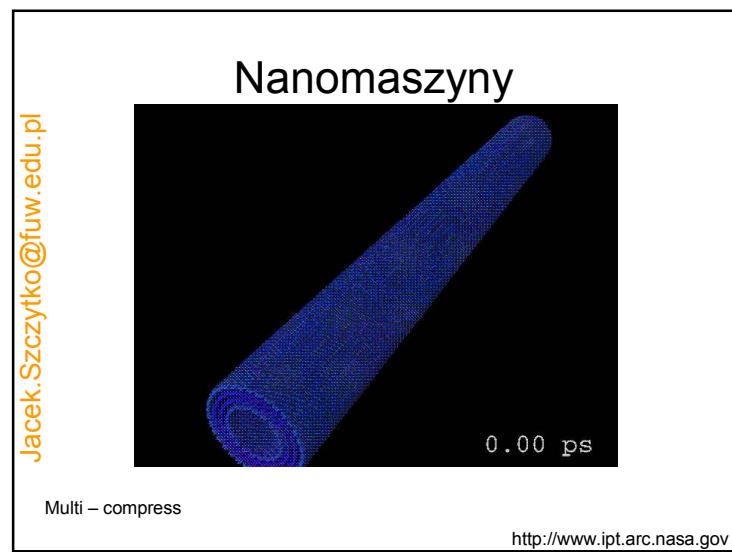
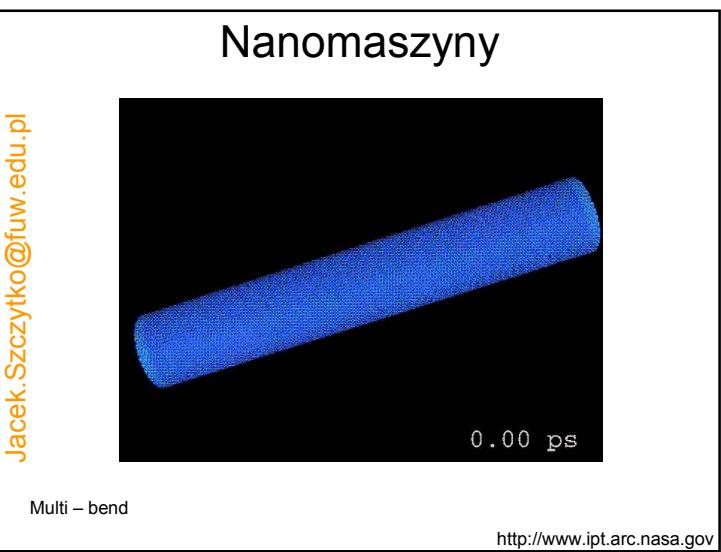
Nanomaszyny

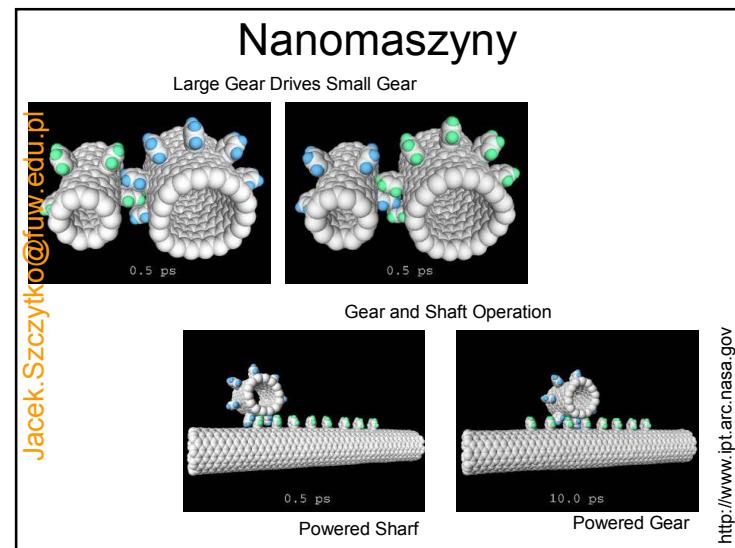
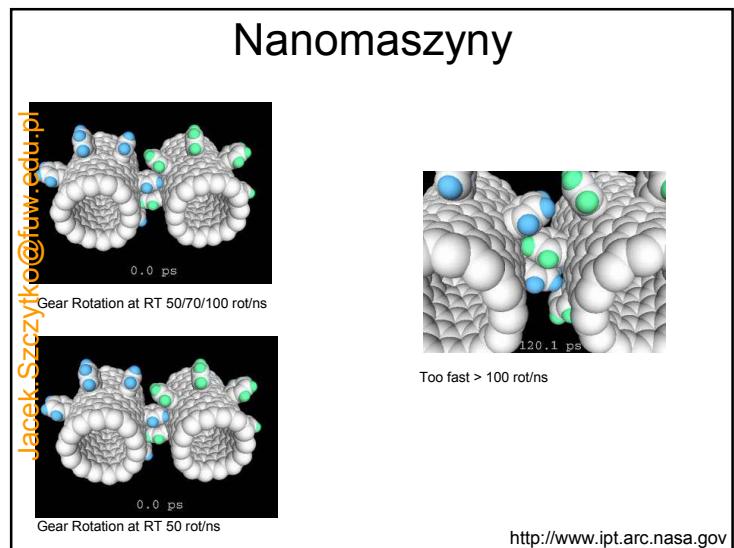
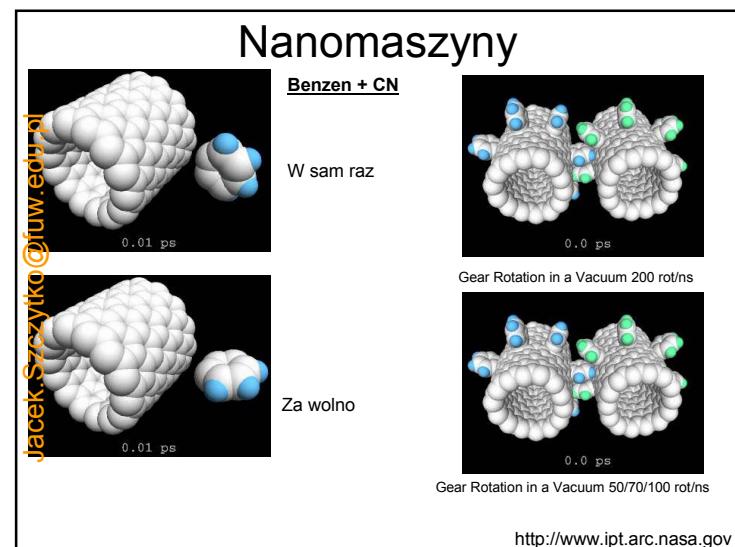
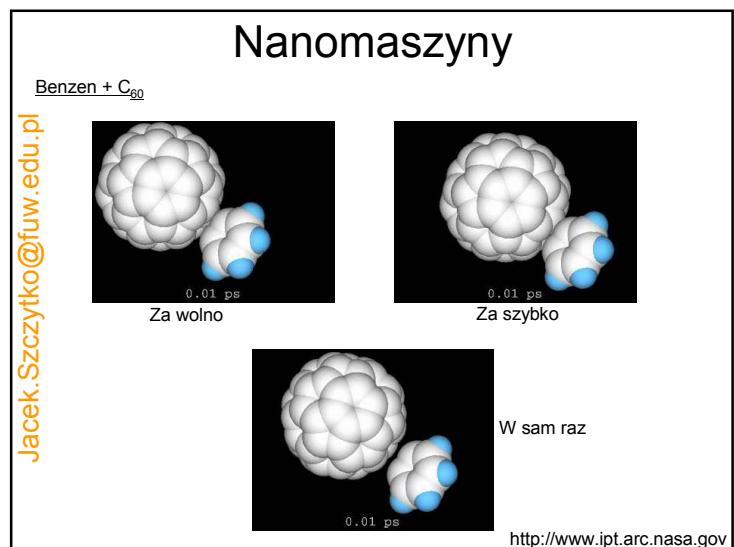


0.00 ps

Multi – twist

<http://www.ipt.arc.nasa.gov>





Nanomaszyny

Rotation of Gears with Two Off-line Rows of Teeth

Zbyt szybko

Long Gear Rotation at Room Temperature

Startup Rotating

<http://www.jpt.arc.nasa.gov>

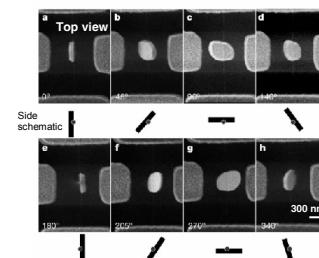
Jacek.Szczytko@fuw.edu.pl

First Synthetic Nanomotor

<http://www.jpt.arc.nasa.gov>

<http://www.jpt.arc.nasa.gov>

http://www.lbl.gov/msd/Pls/Zettl/03/07_nanomotor/03_7_nanomotor.html Alex Zettl, 03-7



Schematic (top) and scanning electron microscopy (SEM) image (bottom) of LBNL's synthetic nanomotor. A 300 nm Au plate rotor (*R*) is attached to a multi-walled carbon nanotube (MWNT) which acts as a support shaft and is the source of rotational freedom. Electrical contact to the rotor plate is made via the MWNT and its anchor pads (*A*₁, *A*₂). Three stator electrodes, two on the SiO₂ surface (*S*₁, *S*₂) and one buried beneath the surface (*S*₃), provide the control elements.

Nano-motor

<http://www.jpt.arc.nasa.gov>

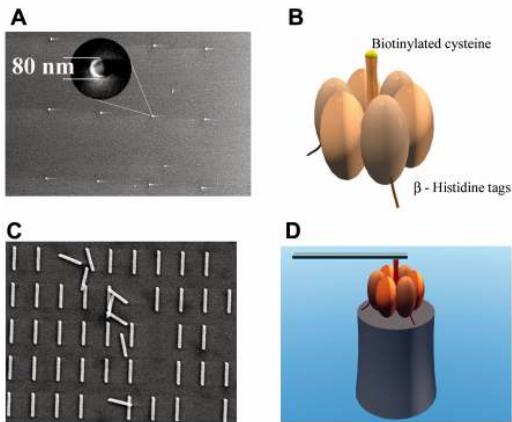
Jacek.Szczytko@fuw.edu.pl

Nano i bio (ATPaza)

<http://www.foresight.org/Conferences/MNT6/Papers/Montemagno/index.html>

<http://www.linkclub.or.jp/~hiikoyosd/ryohei/papers.html>

Nano i bio (ATPaza)



<http://www.foresight.org/Conferences/MNT6/Papers/Montermagno/index.html>

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Model for the Kinesin Mechanism

http://valelab.ucsf.edu/research/res_mec_overv.html

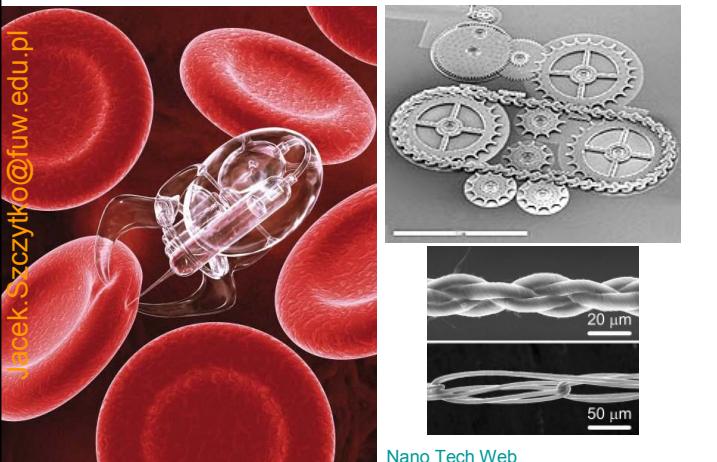
[mov-muscmysinmotrev6.mov](http://valelab.ucsf.edu/research/mov-muscmysinmotrev6.mov)

[mov-procmotconvkinrev5.mov](http://valelab.ucsf.edu/research/mov-procmotconvkinrev5.mov)

Kinesin is a dimeric motor protein that travels processively towards the microtubule plus end by taking 8 nm steps, which corresponds to the distance between adjacent alpha/beta tubulin binding sites. We have sought to define the structural changes in the motor that explain the direction of movement and the basis of head-head coordination during processive motility.

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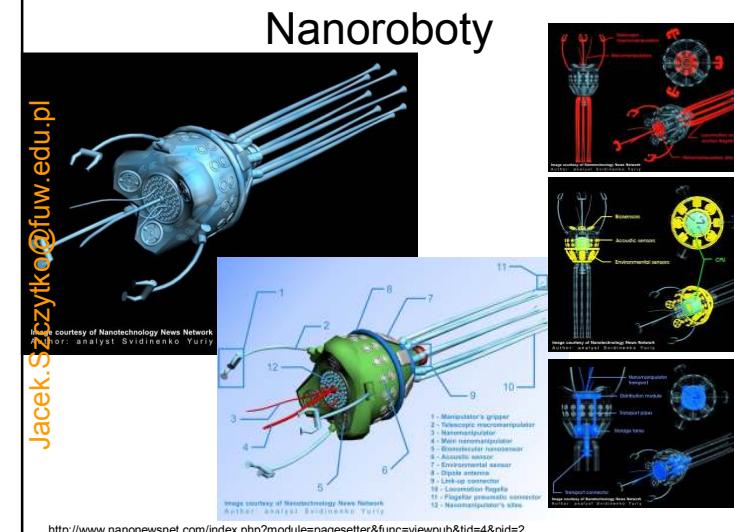
Nanorobota



[Nano Tech Web](http://nanotechweb.org/resources/insights/features/nanorobots)

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Nanorobota



<http://www.nanonewsnet.com/index.php?module=pagesetter&func=viewpub&tid=4&pid=2>

Nano-samochód

RICE UNIVERSITY
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Y. Shira/Rice University

They found the nanocar was quite stable on the surface remaining parked until the surface was heated above 170 °C - presumably because of strong adhesion between the fullerene wheels and the underlying gold. Flat gold surface was used to prevent the nanocar actually roll around on its fullerene wheels, rather than slip like a car on ice. Between 170 °C and 225 °C, the researchers observed that the nanocar moved around by translational motion and pivoting. The translational motion was always in a direction perpendicular to the handcar's axle, indicating that it moves by rolling rather than sliding.

<http://www.nanonewsnetwork.org/index.php?module=pagesetter&func=viewpub&tid=4&pid=2>

Nano i bio (DNA)

Jacek.Szczytko@fuw.edu.pl

(a) (b)

DNA

Filmik [protein_nanotubes.mov](#)

Nano i bio (RNA)

Jacek.Szczytko@fuw.edu.pl

These images show some of the shapes formed of RNA in the lab of Purdue's Peixuan Guo. The first three abstract shapes - monomers, dimers and trimers - are further illustrated with the analogy of human figures grasping each others' arms (see inset illustrations in figures A, B and C). Guo's team has found a way to make these elementary shapes form more complex, 3-D structures such as the array in figure D. Such arrays might form tiny scaffolding on which to construct nanotech devices. (Purdue University graphic/Guo Laboratories)

<http://www.nanotech-now.com/Purdue-release-08112004.htm>

RNA

Right hand loop
Left hand loop

A. Monomer B. Dimer

C. Trimer D. Array

State-of-the-Art: Electronic Circuits

Kees Hummelen - University of Groningen

From macroscopic copper ($\sim 1 \mu\text{m}$) to nanoscale electronics organic molecules ($\sim 0.3\text{--}3 \text{ nm}$)

Jacek.Szczytko@fuw.edu.pl

wire:

diode:

transistor: (FET)

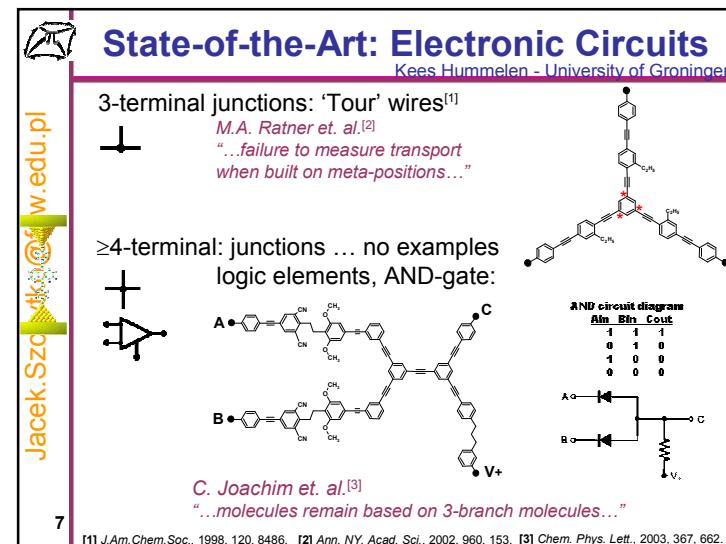
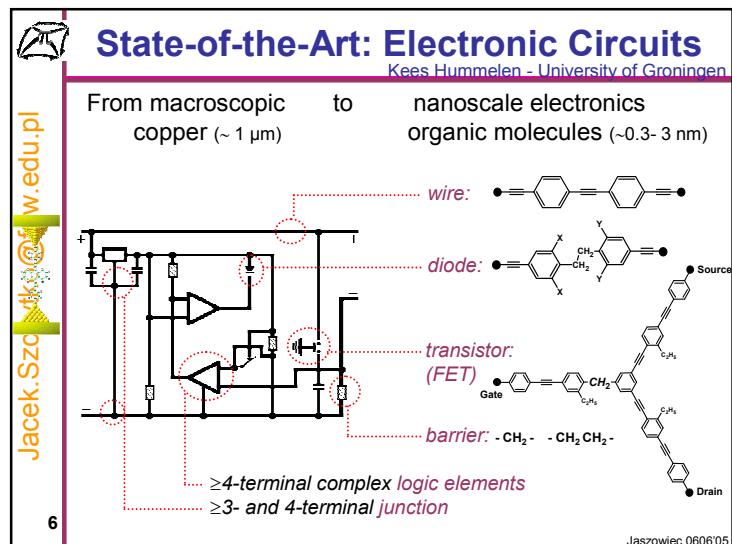
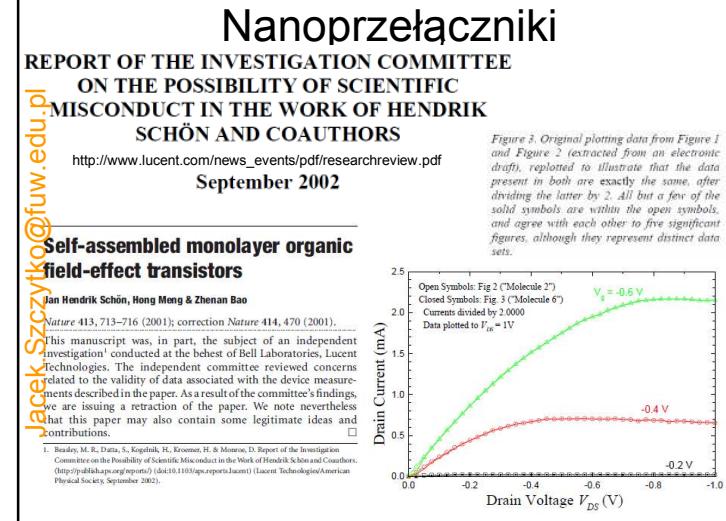
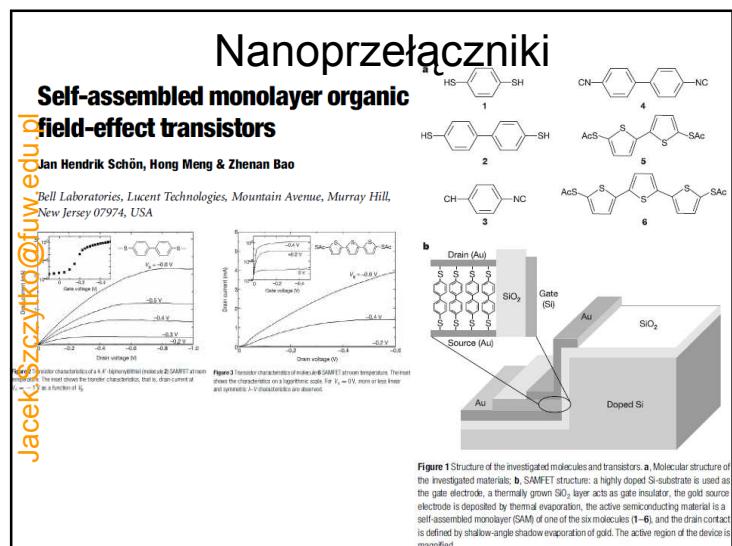
barrier:

≥ 4 -terminal complex logic elements

≥ 3 - and 4-terminal junction

6

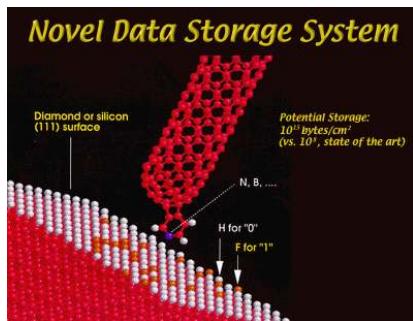
Jaszowiec 0606'05



Pamięć atomowa

<http://www.ipt.arc.nasa.gov/datastorage.html>

A novel data storage system capable of 10^{15} bytes/cm² is being explored.
In this system, H atoms would be designated as 0 and F atoms as 1.
A tip that can distinguish between 0 and 1 rapidly and unambiguously
is being investigated.



Ile bitów na atom?

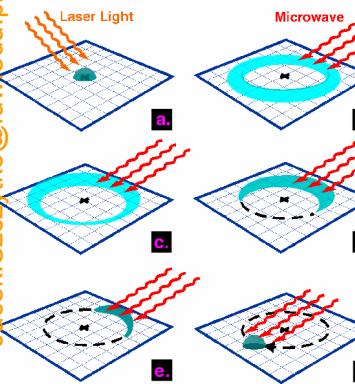


Illustration showing how to transform an electron from its usual state in an atom (a), in which it exists in a cloud of possible positions surrounding the positively charged nucleus (indicated by a plus sign), to a "Trojan state" (f), in which the electron orbits the nucleus like a planet around the sun. The name comes from Trojan asteroids, the asteroids which orbit the sun in the same orbit as Jupiter but in a place either ahead or behind the planet. To create a Trojan electron, researchers would first use laser light to put the electron into a "circular Rydberg state" in which the electron exists in a thin donut of possible positions (b). Then, a microwave beam would subsequently change the shape of the donut (c-e), shrinking the range of possible positions for the electron and ultimately causing the electron to shrink into a small droplet (or alternatively, a shortened sausage) of possible positions. This droplet then orbits the nucleus like a planet around the sun. Although not yet achieved experimentally, researchers believe that current technology could be applied to create Trojan electrons. The figure is not to scale—the circular Rydberg and Trojan states are actually hundreds of thousands of times farther away from the nucleus. In addition, the figure essentially shows just the top half of the probability cloud for the Trojan electron.



In recent computer simulations, researchers formed the word "optics" by calculating the electron cloud for a specially prepared $n=50$ state. In the image above, the intensity of the letters represents the relative probability for finding the electron at that place, and the color denotes the phase (relative point in the cycle) of the electron wave associated with that point in the cloud. (Image courtesy Carlos Stroud, University of Rochester, and Michael Noel.) This research is described by Carlos Stroud and Michael Noel in the April 1999 issue of [Optics and Photonics News](#).

Kwantowa kryptografia i teleportacja. Splątanie kwantowe

- a. Popłatane stany.
 - i. Eksperyment EPR.
 - ii. Eksperyment Bella
- b. Star-Trek, czyli teleportujemy mnie!
 - i. Co właściwie teleportujemy
 - ii. Ile kosztuje ubezpieczenie
- c. Kryptografia kwantowa
 - i. Czy są szyfry nie do złamania
 - ii. Klucze duże i małe
 - iii. Alice i Bob w świecie kwantów
 - iv. Ewa chce posuchać



Dialog z przyrodą musi być prowadzony w języku matematyki, w przeciwnym razie przyroda nie odpowiada na nasze pytania.

Michał Heller