Mechanics and Mechanical Engineering
Vol. 10, No 1 (2006) 21–32

NANOKNOWLEDGE – NANOTECHNOLOGY
yesterday, today, tomorrow

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Lecture from January 11th, 2006 presented at the Honoris Causa
Ceremony at the Lodz Technical University

1. Introduction

History like to repeat itself. The world has originated in nano scale. The first cells were appeared 4,5 bilion years ago. Then micro and macro organisms were created. Nowadays there exist macro organisms and macro devices which are in turn made in minature to micro scale. From the micro scale we descend to the nano scale. The sequence of theses transformations has been presented in Fig.1.

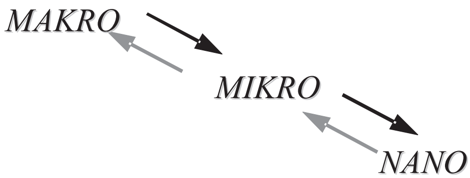

Figure 1 The sequence of transformation

<u>Milestones</u>

3,5 bilion years ago – First living cells as well as biomachines they contain and bioinformatics systems are created.

400 B.C. – Demokryt introduces the term "atom" (old Greek: indivisible).

1905 – A. Einstein publishes an article in which the diameter of the sugar molecule is estimated to 1 nm.

1959 – R. Feynman presents his famous lecture entitled ,,Lower there is still a lot of space" about the prospect of miniaturization.

1974 – N. Taniguchi creates the term ,,nanotechnology" in processing with 1 nm precision.

1985 – R. F. Curl, H. W. Kroto and R. E. Smalley discover fulerens with 1nm diameter.

1986 – K. E. Drexler publishes a book "Engines of Creation" popularizing nanotechnology.

1989 – D.M. Eigler fro IBM puts individual xenon atoms into IBM.

1991 – Sumio Lijima from NEC In Tsukuba in Japan discovers carbon nanotubes.

1998 – The Ceesa Dekker's team from The Technical University in Delft In Holland creates transistor based on carbon nanotube.

2000 – Eigler and others create quantum mirage capable of wireless information transferring.

2000 – S. Wegrzyn Nanosystems of Informatics.

The era of nanoscience and nanotechnology. The nanoscience and nanotechnology have currently been – after biomedical research (cancer treatment) and research connected witch defense (antirocket shield) – the most dynamically developing branch of science and technology in the world.

Nanomania is spreading all over the world. All Scientists believe that nanoscience and nanotechnology (molecular engineering based on designing and building devices in atomic scale) deal with objects with measurements in nanometers.

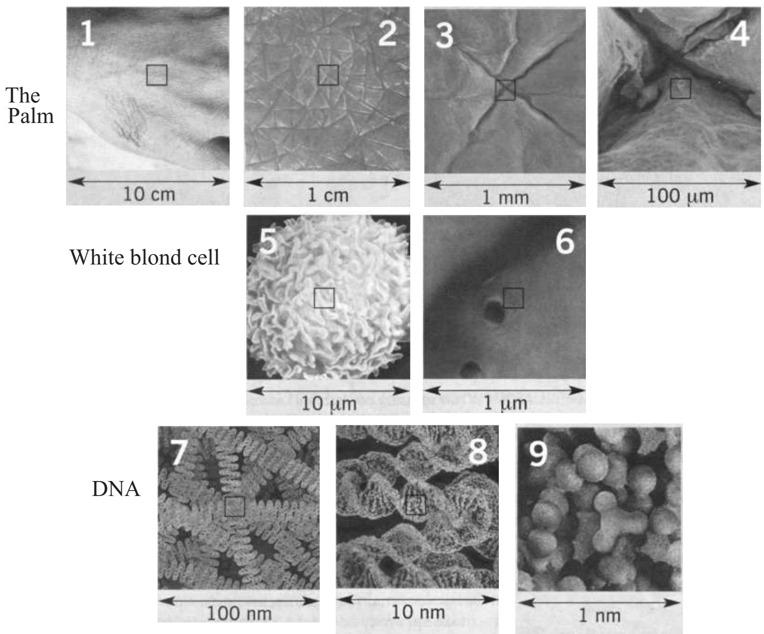

Figure 2 Diminishing the palm

How small is a nanometer?
- One billion of the meter.
- About five silicone atoms.
- About ten hydrogen atoms.
- A Hundredth part of an average bacteria.

Diminishing factor by 10 we proceed from the sight of a part of upper part of the palm 1 centimeter wide to (on the level of 1 nanometer) nucleotides creating DNA. The black square circles the area of the next diminishing Fig.2.

Descending to the nanoscale of physical, chemical and biological phenomena, we can see the unknown world of molecules and we shall soon see the nanomachnes ruling there. Before this happens, important part of the work has to be done by scientists and engineers dealing with nanoscience, nanotechnology and mechanosynthesis.

Nanoscience – is the study of materials, objects and phenomena in nanoscale with the thought of application as below.

Mechanosynthesis – is a mechanically directed chemical synthesis in the scale of individual atoms and molecules – the basis of molecular production.

Nanotechnology – molecular production with the use of the techniques of nanosystems designing, analysis and production.

Nanosynthesis – is a nanorobot + nanocomputer, so studies of Electronics, Microproduction, especially systems of high integer scale (VLSI), are necessary.

Selfreplication – The prime idea of nanolechnology connected with Information Technology, the software and virtual engineering as a tool of simulation.

There exists two different approaches sympolising the present state of the discipline.

The oldest approach – top – down, proposed by Feynman: Big machines make small machines. This approach is at the top of its development in the technology of microproduction, especially of microcomputers elements (VLSI)..

The contemporary opposite approach – Bottom- up, proposed by Drexler is putting atom on atom with the use of nanomachines. It is also watching chemical, biochemical synthesis and protein engineering for creating mechanosynthesis and for bilding nanomanipulators and nanomachines called replicators and assemblers.

One of the most biggest achievements of nanoelectronics is the creation and operation of self-mounting molecular electronic elements. Self-mounting is an inevitable step on the way to self-replication – the main paradigm of nanotechnology.

2. Nanobranches

Nanoelectronics. These are nanocomputers but the nanocomputer technology apart from electronical element salso include the possibility of building biological, mechanical, and quantum elements.

Nanomaterials. It appears that diminishing the measurements of basic nanocristals of well known materials, you may receive far better physical, mechanical and electric properties. The genealogical tree of nanomaterials has been shown in Fig.3.

3. Fulerens

The fulerens are molecules consisting of many karbon atoms, creating a closed, regular, empty inside sphere. The fulerens have become a source in the synthesis of new organic and non-organic and so far unknown materials. Great hopes of producing superconductors (substances leadind electricity without resistance) are associated with fulerens. In Fig.4a fuleren containing 60 atoms of carbon has been presented. In Fig.4b fuleren containing 70 atoms of carbon has been shown.

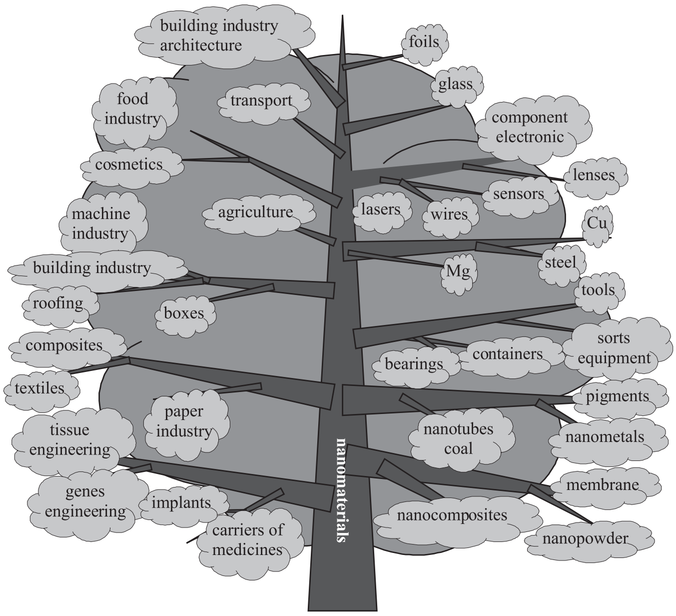

Figure 3 Branches of Nanotechnology

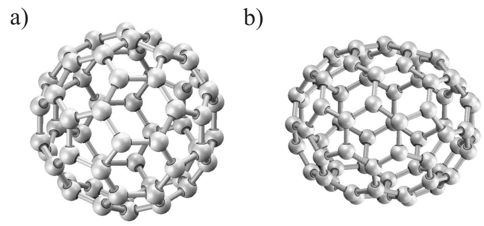

Figure 4 Structure of fuleren: a) C60, b) C70

4. Nanotubes

Nanotubes - a kind of carbon element existing in the form of stowed graphite surface. In their structure they are similar to fulerens but they have got a cylindrical shape of a diameter of several nanometers (they are ten thousands times thinner than human's hair) and their length can be million times bigger. **The Young module for nanotubes is about 3700 GPa.** Therefore they have got huge resistance to stretching. The tightest carbon fibres have rarely got more than 800 GPa.

The nano-crystal of a diamond and carbon nano-tubes In Argonne National Laboratory the most resistant of all known materials, consisting of diamond nano-crystals and carbon nano-tubes (two form sof the same element-carbon- Fig.5.) has been achieved. The hardest material- diamond has been joined with the tightest material- carbon nanotubes. The newly created composite material has got features of both joined materials.

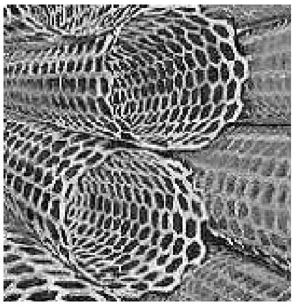

Figure 5 The nanocrystal of diamod and carbon nanotubes

It is used among others in:
- abrasion-resistant clothes
- catalysts for efficient fuel elements
- chemical hydrogene store-rooms
- elements of energy saving nanoelectronics et al.

5. Examples of nano-devices

Nano TV While examining nanotubes application, the researches have used them in the construction of ultra-thin monitors .Due to their build the tubes may serve as light fibres delivering the light quantum to the screen surface. The scale in which they are made allows for receiving resolution thousands times better than this of the best LCD panels.

Scientists have always been searching for an alternative material capable of acting in a similar way as the muscles, yet more efficient, stronger and more flexible. It seems that the carbon nanotubes fulfill all these requirements (apart from the fact that they are extremely expensive).

They maybe an excellent base for the mechanical systems of the robots working in space, high radiation conditions as well as under water (there where the circumstances exclude the possibility of human work).

Gears K. Eric Drexler and Ralph C. Merkle, have run a number of nanometrical simulations of gears Fig.6.of manipulators and othermoecular subsystems. They emphasise that these computer images have been created without taking into consideration the complex forces of in chemical bonds.

In such systems the rules of macroscopic physics cannot be applied and it is necessary to apply the rules of quantum mechanics.

Nanorotor The researchers from the University in Colorado have worked on the first, computer generated model of a molecular rotor presented in Fig.7. The rotor is rotating in one direction with different velocities as a respond to the changes of oscillating electrical field forces. The Synthetic molecule is an axis with 2 elements carrying opposite electrical charges, mountedin a parallel way to the ground made of gold – explains prof.Josef Michl from the scientific team.

Mobile Nanorobot The scientists from Dartmouth College in Hannover built the smallest in the world controller mobile robot, presented in Fig.8. They prepared a sworm of 200 nanorobots, each of which is as wide as the width of a human's hair

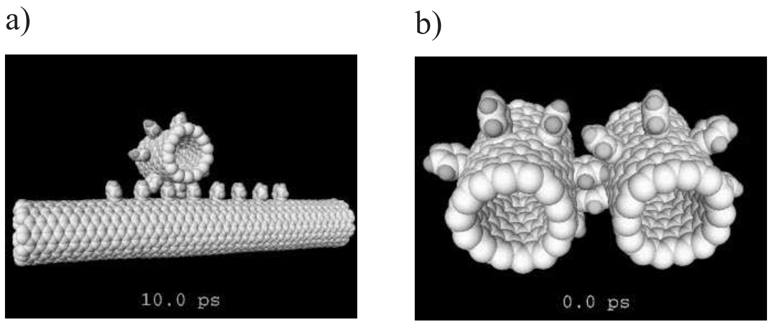

Figure 6 Nano-gear created from individual atoms

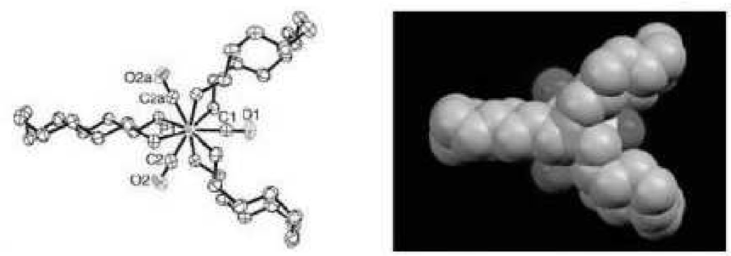

Figure 7 Microscopic rotor

and is capable of moving on small distances. It "creeps" like a caterpillar using silicone microelements.This device makes thousands of steps per second, each of which is 10nm long. The robot turns like a motorcyclist.

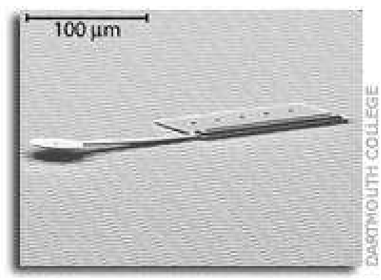

Figure 8 Mobile nanorobot

Nanocar The nanocar presented in Fig.9 is the result of over eight – year work of scientists under the direction of professor Jamesa M. Tour. The vehicle consists in 95 percent of carbon molecules with slight amounts of hydrogen and oxygen. The car is 2 nm long and 2 nm wide, so you can park over 20,000 such a cars on one human's hair. It moves on wheels consisting of 60 molecules of pure carbon formed in a sphere. The direction and velocity of this car are controlled by electrical field

Figure 9 Nanocar

6. Nanotechnology in medicine

Nanodoctors of the future. A nanomachine can be designed so as to make it move with the blood current without starting the defence organism reactions, and to fulfill tasks such as:
- cancer cells elimination
- carrying oxygen
- replacing cell elements
- taking photos of a living organism

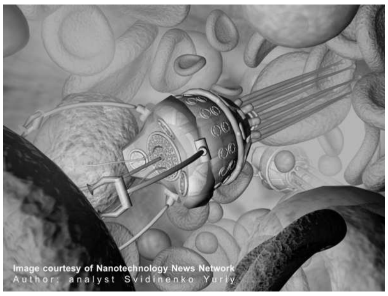

Figure 10 Nanorobot in blood circulation

DNA in medicine. DNA – existing in chromosomes is the carrier of genetic information. A DNA molecule consists of 2 chains which turn around common axis making the so called right-turning double helix (Fig.11). Scientists from the University in Ruhr work on being able to control DNA. If the experiments are successful we shall avoid side-effects of cancer treatment.

7. Nanotechnology in the space

Nanospace ideas. Nanorobots fixed in white blood cells (leucocytes) of the astronaut will monitor organism, to spot damages made by radiation. Nanorobot will consist of fluorescent chemical fluid, which will flash when radiated (Fig.12).

Space lift. The mode of facilitating and low cost of space traveling is nanotechnology. It consists in joining the satellite on the geostationary orbit with the earth with the use of a wire. This construction gives us a possibility to lift vehicles to

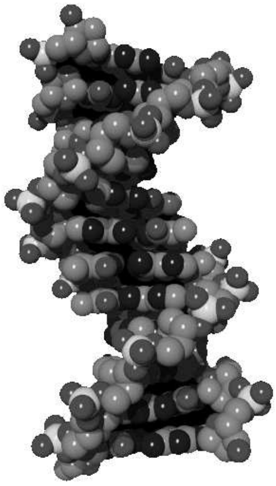

Figure 11 DNA modification by nanodoctors

space on the wire for the price much lower than with the use of rockets. It would have to be wire extremely resistant, light and of at least 35,000 kilometers. An ideal material for the construction of such a lift would be carbon nanotubes (Fig.13).

8. Nanotechnology in motorization

The future or the present? In new cars with petrol engines there are already catalysts made from thin nanotubes. In Volkswagens mirrors have wolfram net inside. This chemical compound changes its colour depending on the amount of electrical charge. It may replace special glasses for drivers. Soon colour-changing windscreens will be available. Works on special roof surfaces which will help to spare energy are carried out.

At the end of 2003 special kinde of lacquer much more resistant than an ordinary one has entered serial production (Fig.14). Nanomolecules increase laqueure resistance to scratches and the shining effect. Laboratory tests have proved that the laquer shiness according to DIN was 40 percent points bigger than when using traditional ones. The firs car mark which offers nanolaquer is Mercedes-Benz.

9. Nanotechnology in electronics

In recent years computational possibilities have increased very fast, doubling on average every 18 months – it is noun as the Moore's law. The electronic industry has approached the barrier of possibility. The layer of silicone dioxide used as a gate isolation in integrated circuits cannot be thinner than 2 nm. The thinner the layer the bigger the speed achieved.

Nanotube transistors (Fig.15) made by Intel in the new process are only 50 nm long, and are the smallest and the fastest of all CMOS transistors made in the world.

Nanocomputers. Such a computer exists in every cell of a living organism,

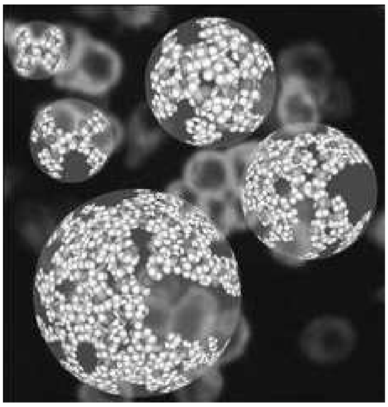

Figure 12 Artistic vision of nanorobots in action

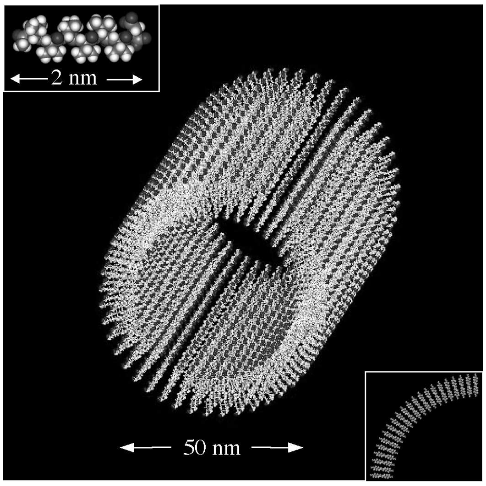

Figure 13 Nanotube model

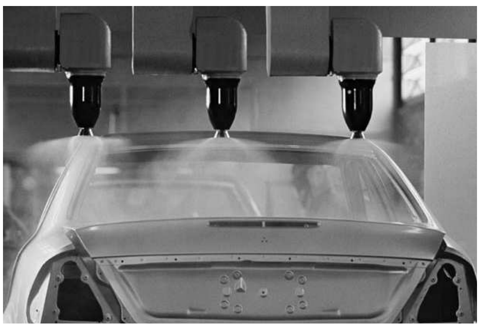

Figure 14 The process of nanolaquer application in the factory of *Mercedes-Benz*

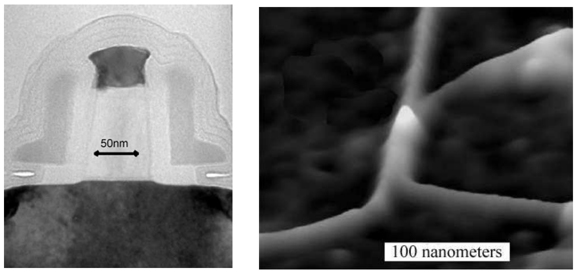

Figure 15 Transistors made in new Intel proces

because each cell contains DNA or RNA. A DNA molecule is a bank of information. This information is coded in the sequence of four bases – adenine, cytosine, guanine and thymine. It has all been packed by the organism in a tiny nucleus. Data operation in the cell is made by enzymes. The "software" and I/O inputs of this computer is the DNA molecules. The enzymes and software molecules together influence the input molecule, which leads to creation of the output molecule. In this way a simple calculator called automaton is achieved.

The first calculations with the use of DNA. Leonard Adleman was the first man to solve mathematical problem using a reaction of DNA molecules. In 1994 he presented an experiment solving the problem of Hamilton's routes, that is finding the best sequence of visiting a town from a given list. Shapir's team went further. Using DNA they created in a test-tube the simplest kind of a computer called finite automaton. It means that computer generating answer yes or no.

10. Recent news

Medal – Innovations 2005 has been given to scientists from the Lodz Technical University for their work on fluid cooling for applications in micro and nanoelectronics.

MENiS prize also for the scientists from the Lodz Technical University for inventing a new method of making nano and micro fluids based on polimer.

In 2006 scientist from University of Poznan have built a modern nanobiodetector, allowing for detecting biological pollution in liquids within only 15 secounds.

Also in 2006 it has been annouced that a nanometer (Fig.16) detecting minimal temperature changes has been build in the University Michigan. It can be applied for anti-cancer therapy and for genetic analyses.

11. Potential applicatio of nanotechnology

1. Programmed positioning of molecules with 0,1 nm precision
2. Mechanosyntchesis and mounting with speed 106 operations per secound
3. Computer memory with information density 1015 bits / cm^2.
4. Computer with the speed 1016 operations / secound.
5. Materials of 50 GPa mechanical durability
6. Invasive and non-invasive sensor sin Biology and Medicine
7. Miniature analytical devices in Biochemistry.
8. Cardio-surgical and neurological equipment.

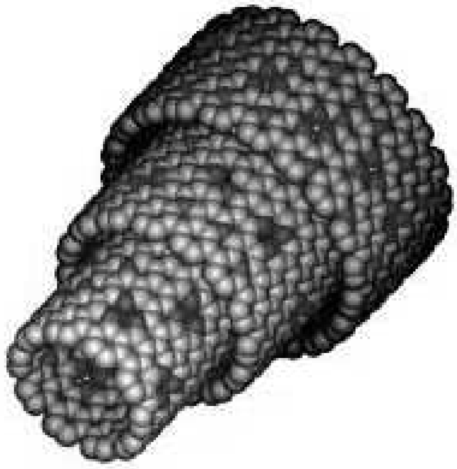

Figure 16 Measuring nanometer size 30 nm

9. Various military applications.

If self-replication, self-mounting and self-mending of nanomachines becomes reality, we shall expect in the nearest future:
1. TV screens of unlimited surface
2. Walls and windows changing shapes, colour and transparency upon request
3. Odour, dampness and dust absorbers
4. Temperature and dampness- sensitive clothes automatically reacting on weather changes.
5. nano-food for medicine but also (sadly) for the terrorists.
6. Recycling rubbish for energy and materials, environmental renewal.
7. Nano-medicine(nano-diagnosis, nanodentists, nano-surgery, nano-pharmacy, nano-cosmetcs, nano-immunology).

12. Nanoscience and nanotechnology in Poland

These problems are dealed with by scientific units in PAN (Polish Academy of Science) as well as the Universities such as the Technical University of Łódz, departments of Chemistry, Electrotechnics and Electronics and Mechanics. "Information Technology is not only about computers and methods of calculation but also such processes in living organisms, owing to which these organisms exists, develop and replicate", says prof. Stefan Wgrzyn from IITiS PAN, the leader of scientific team designing the bases of nanoinformatics. It consists in replacing codes written in letters by codes made from chemical molecules.

The operating system of the nanocomputer will compute molecules and the effect of this work apart from the resulto of computations shall be a useful product being created like a tissue of human being.

If we are able to build an artificial system operating similarly to the cells of human organism, we will be able to program it in such a way that instead of muscle protein it shall produce parts of plastics and organize them into ready made products of artificial cytoplasm.

The basis of a solution shall be another chemical compound, like DNA being able to selfreplicate and to store information. This will not be genetic but technological information.

The products will be created in the process of selforganization of matter starting with simple molecules and indiwidual atoms. We will be able to do without invisible nanorobots called assemblers.

The IITiS concept excludes assemblers. Molecular matrices operating like cell chromosomes and RNA molecules shall replace them.

Artificial organisms called by the students of the professor "nanosynthetic wegrzynowce" shall be planted on the old 20th-century waste dumps. There roots will grove into rubber, glass and plastics dissolve them and reorganize into useful products.

13. Summary

Currently we can observe a dynamic development of molecular nanoscience and nanotechnology in physics, chemistry, biology. Many scientific and industrial Institutes and labolatories have been created in the USA and JAPAN. The same movement has started in Europe with a slight delay and countries such as England, Germany, France, Denmark, The Switzerland and others including Poland are making up for the delays in this field.

It seems that the biggest level of self-consciousness is applied to the team dealing with nanomatrials.

From the short report, drawn out of necessity from the review of research of nanoscience and nanotechnology, we may conclude about the research in this field. It is impossible to summarise all the results of the research in such a short lecture.

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