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FUTURE DEVELOPMENT OF NANOTECHNOLOGY AND HUMAN HEALTH

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Abstract: *The first use of the distinguishing concepts in ‚nanotechnology' a talk given by physicist Richard Feynman at an American Physical Society meeting at Caltech on December 29, 1959. Feynman described a process by which the ability to manipulate individual atoms and molecules might be developed. In the coming decades nanotechnology could make a supercomputer so small it could barely be seen in a light microscope. Fleets of medical nanorobots smaller than a cell could roam our bodies eliminating bacteria, clearing out clogged arteries, and reversing the ravages of old age. Low cost solar cells and batteries could replace coal, oil and nuclear fuels with clean, cheap and abundant solar power. New inexpensive materials could open up space and material abundance for all the people of the earth could become a reality.*

Key words: *nanophysics, nanomaterials, human health, nanomedicine, science, technology, education*

1. Introduction

The conceptual underpinnings of nanotechnologies were first laid out in 1959 by the well known physicist Richard Feynman (Fig 1). In his lecture „There is plenty of room at the bottom" he explored the possibility of manipulating material at the scale of individual atoms and molecules [1].

Fig 1. Richard Feynman

The term „nanotechnology" was used in 1974 by Norio Taniguchi [2] (University of Tokyo, Japan) and the primary driving force for miniaturisation came from the electronic industry, which aimed to develop tools to create smaller electronic device on silicon chips (at IBM, USA has been developed technique called electron beam litography). By means of this method were created nanostructures and device as small as 40–70 nm in the early 1970s.

Nanoscience and nanotechnologies are widely seen as having huge potential to bring benefits to many areas of research and applications. They are attracting rapidly increasing investments from governments and from business in many parts of the world. Their application may rise new chalenges in all branches of science, technology, medicine, biology and so on.

2. Nanoscience and nanotechnology

Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties digger significantly from those at a larger scale.

Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale [3].

A nanometer (nm) is one thousand millionth of a metre. For comparison, a single human hair is about 80 000 nm wide, a red blood cell is approximately 7 000 nm wide and a water molecule is almost 0,3 nm across (Fig. 2). People are interested in the nanoscale because the properties of materials can be very different from those at a large scale. In some senses, nanoscience and nanotechnologies are not new. Chemists have been interested in polymers, which are large molecules made up of nanoscale submits, for many decades.

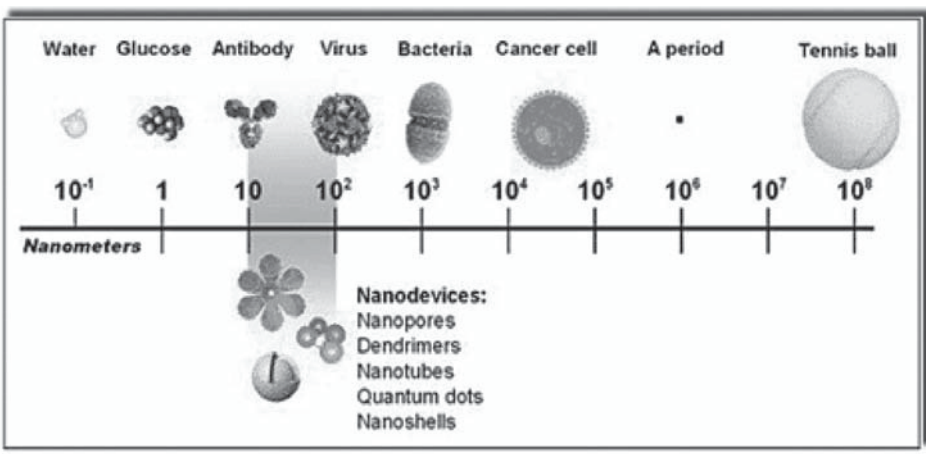

Fig. 2. Nanoscale [4]

Nanotechnologies have been used to create the tiny features on computer chips for the past 20 years. However, advances in the tools that now allow atoms and molecules to be examined and probed with great precision have enabled the expansion and development of nanoscience and nanotechnologies.

3. Nanomaterials in science

Two principal factors cause the properties of nanomaterials to differ significantly from other (bulk) materials: increased relative surface area and quantum effects. These factors can change or enhance properties such as reactivity, strength and electrical characteristics. Nanoparticles have much greater surface area per unit mass compared with bulk materials. As chemical reactions occur at surfaces, this means that a given mass of material in nanoparticulate form will be much more reactive than the same mass of bulk material.

Together with surface area effects, quantum effects can begin to dominate the properties of matter as size is reduced to the nanoscale. These can affect the optical, electrical and magnetic behavior of materials. Materials that exploit these effects include quantum dots and quantum well lasers for optoelectronics.

Here are some examples of nanomaterials:

a) Thin films, layers and surfaces. Such materials have been used in electronic devices, chemistry and engineering (silicon integrated circuits), monolayers are used in chemistry. Engineered surfaces such as large surface area are used in applications such as fuel cells and catalysts.

b) Nanotubes and nanowires – *carbon nanotubes* are extended tubes of rolled grapheme sheets (Fig. 3). They area few nanometers in diameter and several micrometres to centimeters long. They are mechanically very strong (Young´s modulus is over 1 TPa – as shift as diamond), flexible and can conduct electricity extremely well.

Inorganic nanotubes – are based on layered compounds such as molybdenum disulphide and have excellent tribological (lubricating) properties, catalytic reactivity and high capacity for hydrogen and lithium storage.

Oxide-based nanotubes (titanium dioxide) are being explored for their applications in catalysis, photo-catalysis and energy storage.

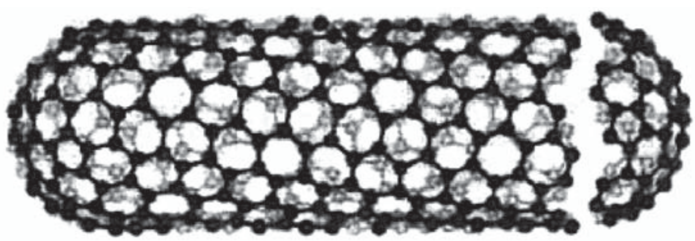

Fig.3. Nanotube [5]

Nanowires are ultrafine wires or linear dots, formed by self-assembly. They have remarkable optical, electronic and magnetic characteristics (for example they can bend light around tight corners). Nanowires can be used also as high-density data storage media.

c) Biopolymers such as DNA molecules offer a wide range of opportunities for the self-organisation of wire nanostructures into much more complex patterns. They offer opportunities for example biocompatible sensors and small, simple motors (Fig. 4).

Fig.4. Nanomotors [5]

d) Nanoparticles are often defined as particles of less than 100 nm in diameter. They exist widely in the natural world for example as the product of photochemical and volcanic activity and created by plants and algae. They have also been created as products of combustion, food cooking and from vehicle exhaust. Nanoparticles have a range of potential applications: in new cosmetics, textiles and paints, in targeting of drug delivery (where they could be to used deliver drugs to a specific site in the body). Nanoparticles can also be arranged into layers on surfaces, providing large surface area and hence enhanced activity, relevant to a range of potential applications such as catalyst.

Fullerens (carbon 60 – Fig. 5) – new class of carbon material are spherical molecules about 1 nm diameter, comprising 60 carbon atoms arranged as 20 hexagons and 1ěpentagons. Several applications are envisaged for them, such as miniature ball bearings to lubricate surfaces, drug delivery vehicles and in electronic circuits.

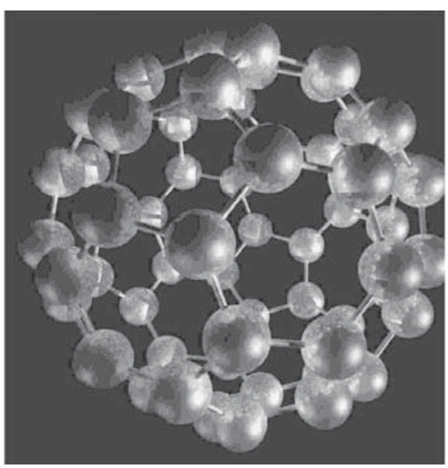

Fig. 5. Fulleren molecule [6]

Quantum dots (nanoparticles of semiconductors). If that particles are made small enough, quantum effects come into play. Thus particles can be made to emit or absorb specific wavelengths (colours) of light (optical properties of the particle is depending on their size). Quantum dots have found applications in chemistry and biology (fluorescent biological labels to trace a biological molecules)

4. Nanotechnology and medicine.

Advances in medical technology depend on our understanding of living systems. In the age of nanotechnologies we should be able to explore and analyse living systems in greater detail than ever before considered possible.

Diseases are caused largely by damage at the molecular and cellular level. Today´s surgical tools are at this scale large and crude. From the viewpoint of a cell, even a fine scalpel is a blunt instrument more suited to tear and injure than heal and cure. Modern surgery works only because cells have a remarkable ability to regroup, bury their dead and heal over the injury.

Nanotechnology – the manufacturing technology of 21th century, should offer us molecular machines, much smaller than a human cell and built with the accuracy and precision of drug molecules. Such tools will let medicine, for the first time, intervene in a sophisticated and controlled way at the cellular and molecular level. They could remove obstructions in the circulatory system, kill cancer cells, or take over the function of subcellular organelles.

Autonomous molecular machines (Fig. 6), operating in the human body, could monitor levels of different compounds and store that information in internal memory. They could determine both their location and the time. Thus, information could be gathered about changing conditions inside the body. These molecular machines could then be filtered out of the blood supply and the stored information and samples could be analysed. This would provide a picture of activities within healthy or injured tissue. This new knowledge would give us new insights and new approaches to curing the sick and healing the injured.

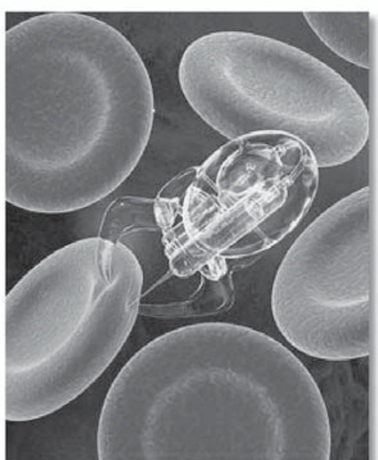

Fig. 6. Nanorobot and blood cells [6]

But there is a growing body of specific evidence which demonstrates the potential for some nanomaterials to be *toxic* to humans or environment. The smaller a particle, the greater its surface area to volume ratio and the higher its chemical reactivity and biological activity. The greater chemical reactivity of nanomaterials results in increased production of ROS (reactive oxygen species), including free radicals (for example fullerenes, carbon nanotubes, nanoparticle metal oxides). The extremely small size of nanoparticles are able to cross biological membranes and access cells, tissues and organs. Nanoparticles in blood stream can be transported around the body and are taken up for example by the brain, heart, liver and kidneys. Studies demonstrate that nanomaterials may be taken up by cell mitochondria and cell nucleus and also cause DNA mutation and induce structural damage of cell.

Size is not the only important factor . Other properties of nanomaterials that influence toxicity include: chemical composition, shape, surface structure, aggregation solubility and presence or absence of functional groups of other chemicals. It means that each new material must be assessed individually and all material properties must be taken into account.

5. Conclusion

Nanotechnology has also broader societal implications and poses broader social challenges. Social scientists have suggested that nanotechnology´s social issues should be understood and assessed not simply. Many of them suggested that technology assessment and governance should also involve public participation [7].

Some scientists suggest that nanotechnology will build incrementally, as did the 18–19th century industrial revolution, until it gathers pace to drive a nanotechnological that will radically reshape our economies, labour markets, international trade and relations, social structures, civil liberties and our relationship with the natural world [8].

Other suggest that it may be more accurate to describe change driven by nanotechnology as a „technological tsunami“. It means that rapid nanotechnology-driven change will necesarilly have profound disruptive impacts. Nano optimists, including many governments (Fig. 7), see nanotechnology delivering [6–8]:

- environmentally benign material abundance for all providing universal clean water supplies;
- atomically engineered food and crops resulting in greater agricultural productivity with less labour requirements;
- nutritionally enhanced interactive „smart“ foods;
- cheap and powerfull energy generation;
- clean and highly efficient manufacturing;
- radically improved formulations of drugs, diagnostics and organ replacement;
- much greater information storage and communication capacities;
- interactive „smart“ appliances and increased human performance through convergent technologies.

Fig. 7

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ROZVOJ NANOTECHNOLOGIÍ A LIDSKÉ ZDRAVÍ

Souhrn: Za průkopníka nanotechnologie lze pokládat významného amerického fyzika Richarda Feynmana, který se ve svém příspěvku „There's Plenty of Room at the Bottom“, předneseném dne 29. 12. 1959 pro účastníky shromáždění Americké fyzikální společnosti, zabýval možností ovládání jednotlivých molekul a atomů [1]. Je téměř jisté, že v nadcházejících dekádách dojde právě na základě nanotechnologie kromě jiného k vytvoření superpočítačů, sotva viditelných v optickém mikroskopu. Nanoroboty, menší než buňka, budou v lidském těle ničit bakterie, čistit cévy a omlazovat celý organismus. Levné solární články a baterie nahradí uhlí, ropu a nukleární palivo. Nové levné materiály zlevní cestu do Vesmíru a zajistí blahobyt pro všechny občany Země.

Klíčová slova: nanofyzika, nanomateriály, lidské zdraví, nanomedicína, přírodní vědy, technické vědy, výuka