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Sixteenth International Scientific Conference
SPACE, ECOLOGY, SAFETY
4 – 6 November 2020, Sofia, Bulgaria

NANOTECHNOLOGY IN MILITARY APPLICATIONS

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Keywords: *nanotechnology, military applications, nanodevices, smart weapons, nanomaterials, nanoelectronics*

Abstract: *This paper presents a brief review on some current and potential military applications of nanotechnology. Some examples of what can be created by nanotechnology are: ultra-small computers; new types of weapons and sensors; implants introduced into the body of military personnel; production of lightweight, strong and multi-functional materials for use in clothing, both for protection and to provide enhanced connectivity, etc. A critical discussion is presented. Possible future extensions of the work in this field are considered.*

НАНОТЕХНОЛОГИИ ВЪВ ВОЕННИТЕ ПРИЛОЖЕНИЯ

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Ключови думи: *нанотехнологии, военни приложения, наноустройства, интелигентни оръжия, наноматериали, наноелектроника*

Резюме: *Тази статия представя кратък обзор на някои настоящи и потенциални военни приложения на нанотехнологиите. Някои примери за това, което може да бъде създадено от нанотехнологиите, са: ултра малки компютри; нови видове оръжия и сензори; импланти, въведени в тялото на военния персонал; производство на леки, здрави и многофункционални материали за използване в облеклото, както за защита, така и за осигуряване на подобрена комуникацията и др. Представена е критична дискусия. Представени са възможни бъдещи изследвания на работата в тази област.*

Introduction

Nanotechnology (NT) can meet almost all of our needs. The words of the Polish satirist Stanislaw Jerzy Lek that "no matter what a scientist works on, the result is always a weapon", are fully applicable to nanotechnology. Currently, most experts agree that nanotechnology will shape the entire 21st century. Nanotechnology is an interdisciplinary field of applied and fundamental science and technology that deals with a set of theoretical foundations as well as practical research, synthesis and analysis, production methods and the use of products with a given atomic structure through the controlled manipulation of individual molecules and atoms. It should be noted that today in the world there is no single standard describing what nanoproducts and nanotechnologies are.

Measurement at NT level is in nanometers (nm). Fig. 1 illustrates the differences in scale that range from hair diameter down to one hydrogen atom.

Nanotechnology can be difficult to determine and define. There are different definitions of nanotechnology as: 1. NT involves research and technology development at the 1nm-to-100nm range; 2. NT creates and uses structures that have novel properties because of their small size; 3. NT builds on the ability to control or manipulate at the atomic scale. According to the “Concept for the development of nanotechnology work in the Russian Federation for the period up to 2015”, NT was understood as a set of techniques and methods that allow modification and creation of controlled objects, including components with dimensions smaller than 100 nm, which in As a result, they have acquired fundamentally new qualities that allow their integration into full-fledged systems on a larger scale. At the same time, the practical aspect of nanotechnology involves the production of various devices and their components needed to process and manipulate molecules, atoms and nanoparticles.

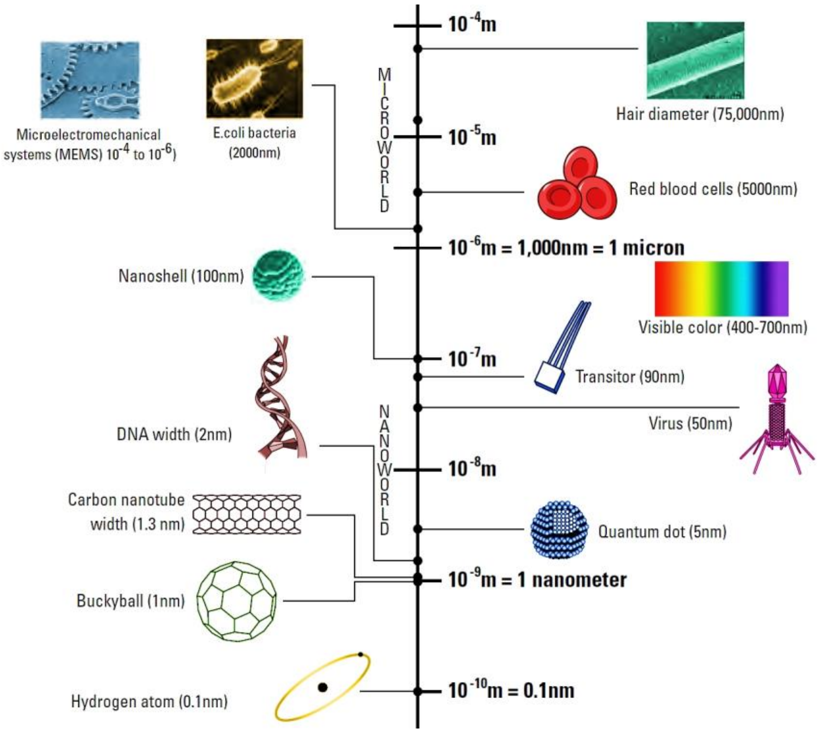

Fig. 1. Size comparisons, from hair diameter (75.000 nm) to the hydrogen atom (0.1 nm)

For example, the realm of nanoscience is not new; chemists will tell you they have been doing nanoscience for hundreds of years. Stained-glass windows found in medieval churches contain different-size gold nanoparticles incorporated into the glass — the specific size of the particles creating orange, purple, red, or greenish colors. What's new about current nanoscience is its aggressive focus on developing applied technology — and the emergence of the right tools for the job.

Corporations, universities, and military/government laboratories are all working together to further nanotechnology research because it's got so much promise in so many applications.

Many nanotechnology products [1] (e.g. nanolayered magnetic disk heads, nanostructured catalysts, nanoparticles in cosmetics, quantum well optoelectronic devices etc.) are already on the market. Today, most countries have their own NT research programs.

The first fact about the use of nanotechnology for military purposes should be considered the fact discovered by scientists from the Technical University of Dresden (Germany) when examining a sample of damask steel (known for its highest strength), from which the sword (Fig. 2, a) is made. Made in the 16th century, it is kept in the Historical Museum of Bern (Switzerland). After etching the surface of a metal sample in hydrochloric acid, the researchers found threadlike objects with nanometric transverse dimensions (Fig. 2, b). A detailed study of the surface using a scanning tunneling microscope revealed that these are multilayer carbon nanotubes, also filled from the inside with cementite - iron carbide (Fe_3C), which has a very high hardness. The distance between the layers in the studied nanotubes turned out to be close to the typical one for such systems - 0.34 nm. Since nanotubes have record breaking strength (elastic modulus is approximately equal to 10^{12} TPa), it is not surprising that the components of damask steel provide such high strength properties of the saber material [2].

The point of view that the widespread introduction of nanotechnology in the construction and development of the armed forces will make it possible to win an inhumanly rapid and destructive war is firmly entrenched in military circles. Therefore, the world is already working hard to create new weapons and protection against them, using nanotechnology [2]. Nanotechnology is concerned with materials, systems structures and components that exhibit novel and significantly improved physical, chemical and biological properties, phenomena and processes due to their nanoscale size. Nanostructures and devices have unique chemical, electrical, magnetic, optical and biological properties. Nanotechnology introduces an understanding of nanoscience to create new materials, structures or devices using nanoscale properties.

(a) (b)

Fig. 2. (a) – Damascus steel sword and (b) - Damascus steel nanostructure

Examples of some nanotechnology and nanomaterials in national defense and military applications

What can nanotechnology do for the military? NT research in the following areas can help the military [3]:

- Clothing with greater tolerance for temperature changes
- Increase surveillance for better protection
- Smaller cameras
- Cheap, small, and more effective weapons
- Exploration of the oceans
- Augmenting human performance
- Scratch resistant surfaces
- Stronger, thinner and cheaper glass
- Change shape of objects, i.e. armor-like fabric
- Coatings that don't degrade (doesn't need repainting)
- "Invisibility"
- Faster intensive medical help
- Lighter, faster aircraft which use less fuel
- Submarines and planes that can go undetected by radar
- Smart materials
- Intelligent apparel system
- MEMS and NEMS
- Explosives and propellants
- Nanorobots
- Armaments electronics
- Aerodynamics and propulsion
- Sensors and transducers

Militaries of many countries are aiming towards weapons based on nanotechnology. Weapons can be used in three different ways: (1) To massively damage the lungs. Ultrafine particles from diesel machines, power plants and incinerators can cause considerable damage to human lungs. This is because of their size (as they can get deep into the lungs) and also their ability to carry other chemicals including metals and hydrocarbons along with them; (2) To get into the body through the skin, lungs and digestive system. This helps to create free radicals that can damage the cells. There is also a serious concern that, once the nanoparticles are in the bloodstream, they are able to cross the blood–brain barrier; (3) The human body has developed a tolerance to most naturally occurring elements and molecules with which it has contact. However, it has no natural immunity to new nanosubstances and therefore is more likely to find them toxic; and; (4) The most dangerous nano-application used for military purposes is the nano-bomb, which contains engineered self-multiplying deadly viruses that can continue to wipe out a community, country or even entire civilization. Militaries all around the world are about to embark upon the use of nanomaterials, nanobots and nanotechnologies that are likely to make weapons of mass destruction. Armies of enormous strengths can be wiped out slowly without even fighting a single battle. Because of this, the soldiers may never know when they have been nanopoisoned [4].

The study of friction, wear and lubrication has been of great practical importance for a long time, since the functioning of many mechanical and electrical systems embedded in military installations depends on the corresponding processes of friction and wear. The newest repair-regeneration oil nanoadditives have an important place in the application of lubricants. Added to oils or greases they assure partial regeneration of worn surfaces under special friction conditions. Forming an antifriction protective layer during a selective transfer between the working surfaces, they decrease friction and wear, and increase the wear-resistance in the contact pairs of machines [5].

Security is a broad field, covering everything from the security of our borders to the security of our infrastructure to the security of our computer networks. Here is our take on how nanotechnology will revolutionize the whole security field:

- Superior, lightweight materials: Imagine materials ten times stronger than steel at a fraction of the weight. With such materials, nanotechnology could revolutionize tanks, airframes, spacecraft, skyscrapers, bridges, and body armor, providing unprecedented protection.

- Advanced computing: More powerful and smaller computers will encrypt our data and provide round-the-clock security. Quantum cryptography — cryptography that utilizes the unique properties of quantum mechanics — will provide unbreakable security for businesses, government, and military. These same quantum mechanics will be used to construct quantum computers capable of breaking current encryption techniques (a needed advantage in the war against terror). Additionally, quantum computers provide better simulations to predict natural disasters and pattern recognition to make biometrics — identification based on personal features such as face recognition — possible.

- Increased situational awareness: Chemical sensors based on nanotechnology will be incredibly sensitive — capable, in fact, of pinpointing a single molecule out of billions. These sensors will be cheap and disposable, forewarning us of airport-security breaches or anthrax-laced letters. These sensors will eventually take to the air on military unmanned aerial vehicles (UAVs), not only sensing chemicals but also providing incredible photo resolutions. These photos, condensed and on an energy-efficient, high resolution, wristwatch-sized display, will find their way to the soldier, providing incredible real-time situational awareness at the place needed most: the front lines.

- Powerful munitions: Nanometals, nano-sized particles of metal such as nanoaluminum, are more chemically reactive because of their small size and greater surface area. Varying the size of these nanometals in munitions allows us to control the explosion, minimizing collateral damage. Incorporating nanometals into bombs and propellants increases the speed of released energy with fewer raw materials consumed — more (and better-directed) “bang” for your buck [6].

- Robotics: However, there are a few driving forces making robotics economically feasible: defense, space exploration, and labor. In the near term, autonomous UAVs (short for Unmanned Aerial Vehicles) will keep continuous watch over our borders, and robots will dispose of roadside bombs in the battlefield. Space exploration will be done by robots, cutting the need for human involvement and thus allowing us to go farther than we’ve ever gone before.

As nanotechnology develops better sensors and processors and the energy revolution provides abundantly cheap energy, robots will be in demand as cheap manual labor, increasing our overall standard of living. Not only will we have robotic dogs and vacuum cleaners but also assembly-line industrial labor, bringing money back to Western nations. Perhaps a “robotic arms race” will emerge, not as a mighty military machine but as a productivity machine — each nation trying to make the cheapest goods as quickly as possible. All this will gradually grow over the next few decades — but once the hardware is in place (around 2030), the software and artificial intelligence will soon follow.

For example VMRAM (Vertical Magnetoresistive Random-Access Memory) is so robust that it resists change even from hard radiation — great for military and space applications. No wonder it’s being researched by the Navy.

Additionally, adaptive optics (AO) may revolutionize all sorts of sporting and military optics. If the computer components were adapted, AO technology could work on binoculars and similar equipment. The aforementioned universities have already shown that an observer’s recognition of shapes and orientations improve when looking at AO-enhanced images. Everybody from Army snipers to birdwatchers will be able to get a better idea of what they’re looking at.

Bell Lab micro mirror technology improves the modulation of beams used in projection optics. This could be used to improve military and other communications.

In the long term, it seems likely that most military technology depends on nanomaterials. Some of the more speculative applications in this area include:

- Nano-machines for simulating the action of human muscles in an exoskeleton
- Stealth coatings
- Self-healing (self-healing) material
- Smart leather materials
- Adaptive camouflage
- Responsive structures

There is a wide range of applications of NT and it is expected to increase. Some potential military applications of nanotechnology are already mature enough to come into force much earlier than others. Sensors are one example of this - many sensors have already been developed that take advantage of the unique properties of nanomaterials to make them smaller and more sensitive than traditional technologies.

Portable and efficient sensors are extremely valuable for the military, for example:

- Highly sensitive infrared thermal sensors
- Small lightweight accelerometers and GPS for motion and position detection
- Miniature high quality camera systems
- Biochemical sensors
- Sensors for health monitoring and drug / nutrition delivery systems

Materials have always played an important role in the design and development of applications. Therefore, the development of new materials is an important area of research for all areas of science [7]. In military operations, advanced material systems play a crucial role in the success of an operation and military organization from the tactical to the strategic level. Some modern materials are used to reflect or absorb radar and infrared radiation, providing stealth or deception for detection and tracking systems. For sensor technologies such as detectors and electronic card components such as chips, microprocessors and diodes, various materials have been developed from the nano to the macro level. Advanced electronic devices such as processors or nano / microchips are needed for high-speed data and imaging, computing and networking, especially for big data processing and optimization. 2D materials are one of the most popular areas of advanced materials research in the last decade, and well-known 2D materials are graphene, MoS_2, hBN, WS_2, WSe_2. They can also be combined to create new materials with improved thermal, electronic, mechanical, or optoelectronic properties called heterostructures.

Future of NT in military industry and conclusions

The potential NT military applications are largely unlimited. This brief overview of some of NT's military applications can improve the overall understanding of some modern and up-to-date knowledge and materials.

Last but not least, both experimental and theoretical research on NT is very important and should be developed to look for unknown and possible properties for new potential military applications of NT. Future applications require materials with exceptional mechanical, electronic and thermal properties that can withstand a variety of environmental conditions and are readily available at reasonable prices.

State-of-the-art materials will be key to the future development of modern devices, where 2D materials play an important role in this development process. Sensors, MPE, electronic devices on diodes, microcircuits, transistors; and energy storage systems such as batteries and fuel cells will be more efficient with 2D materials than traditional ones. Modern sensors and detectors based on 2D materials will provide a significant opportunity to obtain the accurate data required for planning, optimization and decision-making, which are fundamental factors in the management of military operations. It is necessary to carry out interdisciplinary work between the basic sciences and related engineering fields; that is, mechanical engineers, electrical engineers, electronic engineers and industrialists in the development of advanced 2D systems for military materials [7].

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