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TEHNIKA – materiali

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Nanotehnologija kot tehnologija prihodnosti, problematika nanoodpadkov

Nanotechnology as the technology of the future, nanowaste problems

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Povzetek: V prispevku predstavljamo nanotehnologijo kot vejo znanosti in inženirstva, ki je osredotočena na materiale z vsaj eno dimenzijo velikosti pod 100 nm. Nanotehnologija obravnava razumevanje materialov ali procesov na nano nivoju. Nanomateriali so lahko v obliki nanodelcev, nanocevi, nanopiramid idr. ter imajo drugačne lastnosti v primerjavi z materiali običajnih dimenzij. Njihove spremenjene fizikalno-kemijske lastnosti prvenstveno izvirajo iz velikega razmerja med površino in volumnom, kar se odraža v njihovi visoki površinski aktivnosti. Zaradi teh lastnosti se lahko uporabljajo na različnih področjih (elektronika, kemija, biotehnologija, medicina). Na podlagi tega dejstva je nanotehnologija širok izraz, ki zajema številna področja znanosti, raziskav in tehnologije.

Ključne besede: nanotehnologija, nanomateriali, lastnosti, nanoodpadki.

Abstract: In this paper, we present Nanotechnology, which is a branch of science and engineering focused on materials with at least one dimension below 100 nm. It involves the understanding of materials or processes on the "nano" scale. Nanomaterials, in the form of nanoparticles, nanotubes, nanopyramids, etc., have different properties compared to materials with ordinary dimensions. They have altered physical and chemical properties, which come from the large surface-to-volume ratio. This is reflected in their high surface activity and, because of this, they are useful in various fields (Electronics, Chemistry, Biotechnology, Medicine). Based on this fact, Nanotechnology is a broad term that covers many areas of science, research and technology.

Key words: nanotechnology, nanomaterials, properties, nanowaste.

1. Introduction

The Nanotechnology is a multidisciplinary field comprising a range of scientific fields, ranging from organic chemistry, molecular biology, material engineering, semiconductor physics, and manufacturing technologies **[1-6].** Nanotechnology can offer many new solutions to the current social, economic and technological challenges. Experience has shown that new materials and devices made with Nanotechnology have been used extensively in Medicine, Electronics, Energy Conversion and Storage, Water Treatment and in various consumer products **[7-10]**. As a result of the widespread of Nanotechnology, waste containing synthetic nanomaterials are consequently generated **[11]**. This means that it is necessary to ensure that the storage of such waste does not cause adverse effects on the environment and health.

Nanomaterials are materials that have at least one dimension below 100 nm (**Figure 1**). These materials are in the form of nanoparticles, nanotubes, nanopyramids, etc., and have different properties compared to materials of ordinary dimensions. Their altered physicochemical properties derived from a large surface-to-volume ratio, which results in a higher surface activity. Synthetic nanomaterials are already widely used in commercially available products, such as cosmetics (hair products, skin hydration and UV filters), paints and coatings (antistatic, anti-noise, anti-corrosion and UV filters), textiles (water repellent and antibacterial substances) and building materials (self-cleaning materials, fireproof materials). It is expected that the products based on Nanotechnology and nanomaterials will expand into other areas soon and will be used in Medicine and Pharmacology, Energy and the Environment.

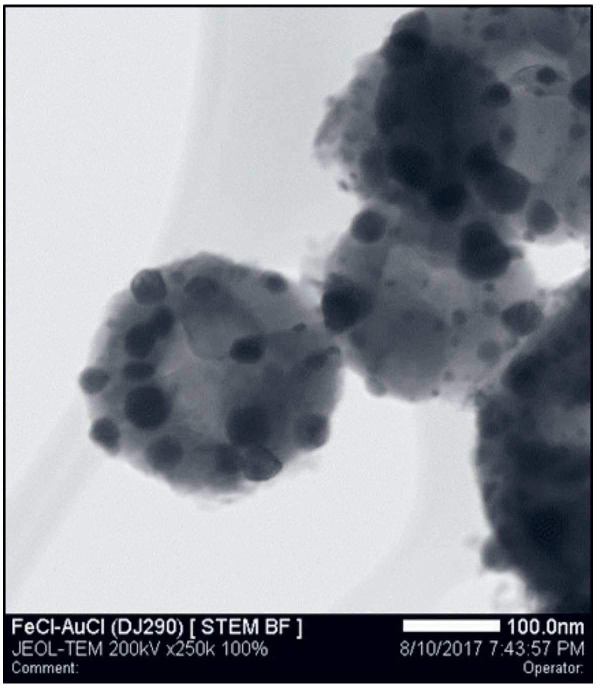

Figure 1: Nanoparticles shown by Transmission Electron Microscopy.

The most common nanomaterials include carbon compounds (carbon nanotubes, fullerenes, graphene and carbon compounds), oxides (zinc oxide, silicon oxide, titanium oxide, copper oxide, etc.), metal nanoparticles (silver, gold, platinum, etc.), polymers and biological nanomaterials (liposomes and proteins). Due to their small dimensions and different structures compared to their bulk pieces, these synthetic nanomaterials have very different physical and chemical properties. Their mechanical, optical, electrical and many other properties can differ significantly from the properties of their bulk materials. One such example is gold, which, in its bulk state, does not absorb visible light. However, as gold in nanoparticles **[12-14]**, it can be an effective light absorber that can be used for relaxation of certain chemical reactions or as a catalyst. Because of this ground-breaking finding, an increase in use of gold nanoparticles has been observed in recent years **[15-16]** – (**Figure 2**).

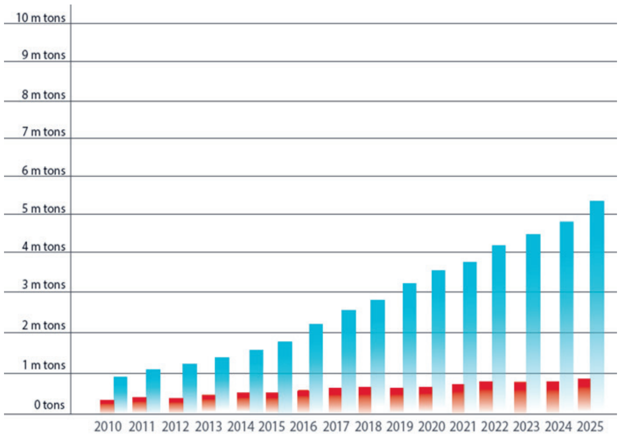

Figure 2: Increase in use of gold nanoparticles from 2010 and a forecast to year 2025 **[17].**

2. Problematics

Unfortunately, the increased use of nanomaterials may also cause an increase in the risk of toxicity and chemical reactivity. This, however, needs to be monitored. The effects of many purpose-produced nanomaterials on human health and the environment are not yet well understood, and not all nanomaterials have hazardous properties. A literature review shows that studies conducted on the same type of nanomaterials are inconsistent; some studies indicate the biocompatibility of nanomaterials **[18]**, while others demonstrate a potentially hazardous nature (e.g., carbon nanotubes) **[19]**. The potential risks of these materials thus depend on their solubility, size, shape and degree of agglomeration, as well as on other physicochemical parameters. The disposal of nanomaterials and nanomaterials containing products should be carried out with special care to ensure that nanomaterials are harmless to human health and are not released into the environment. Furthermore, potentially hazardous, toxic or chemically reactive nanomaterials should be neutralized. Wherever possible, recycling procedures should be followed.

Nanowaste can be the result or by-product of industrial or commercial processes. Due to the wide variety of existing nanomaterials, a single removal process will not be sufficient for all nanomaterial's classes. It will be necessary to develop the safety measures and processes for the decomposition of nanomaterials into ionic form, which will be required for processing at the next production stage (into a new product). All processes will need to be based on a sound knowledge of scientific issues and professional practices, while respecting existing legislation. Decomposition processes will need to ensure that the nanowaste is stable and free from hazardous properties later after use. Due to this, it will be necessary to study different types of nanomaterials processing, from thermal to chemical or physical processes, with the introduction of new innovative technological degradation solutions.

3. Opportunities

The lack of strict policies and regulations related to the use of Nanotechnology and the degradation of nanomaterials through recycling are key issues. Nanowaste will be difficult to store, separate or further monitor; due to its small size, it will be able to expand directly into water systems or hover in the air, which can be harmful to human health and the environment. On this basis, it will be necessary to regulate EU legislation, which will also be related to the regulation of the sale of products containing nanomaterials, including nanocomponents. Efforts will need to be made to ensure that, wherever possible, the recycling of nanomaterials is implemented.

Governments and policies will need to develop assessments, regulations and monitoring measures for Nanotechnology manufacturers. Large-scale environmental and health impact studies will need to be prepared before placing nanomaterial-based products on the market; these studies will need to include studies on the toxicity and chemical reactivity of new nanomaterials. Only then the safe methods of disposal and recycling will be established. Nanomaterials manufacturers (or independent bodies) will need to determine whether these substances or manufacturing techniques could endanger public health or the environment. The products will be marketed only if there is no risk or if the risk can be controlled by safeguards. Concentrated industrial nanowaste will need to be diluted and deactivated after use. In addition, companies producing such nanowaste as a by-product of their industrial activities will have to prove that they are not harmful to the environment and human health. We believe that newly developed nanomaterials should not be placed on the market without proper recycling or storage procedures. Newly developed storage and recycling processes for nanomaterials will need to be reviewed and approved by government agencies based on undisputed evidence from the claiming organization. To provide sufficient evidence, manufacturers will be able to carry out the tests themselves; in individual cases they will be able to rely on existing scientific procedures and claims in the field of nanoparticles.

4. Conclusions

Consumers and the wider community will need to understand that, although Nanotechnology can solve many of the current challenges, if it is used improperly or irresponsibly, it can have serious, often irreversible, consequences for human health and the environment. Campaigns to raise awareness, communication and education are vital to building understanding and preventing dangerous situations in the field of Nanotechnology. State funding, industry funding and research grants should be allocated to accredited research institutions in order to continually evaluate existing protocols and develop new disposal and recycling processes for nanowaste and/or nanomaterial-containing products.

The European Commission and the Smart Specialization Strategy of the Republic of Slovenia have ensured a significant and rapidly growing amount of Nanotechnology funding for the development of new nanomaterials, but so far, insufficient attention has been paid to the development of nanowaste disposal processes. Many scientists and international organizations are currently studying this growing problem in order to develop appropriate and effective regulations and policies. However, addressing this growing and potentially very dangerous issue requires a more unified and collaborative approach at all levels. Sharing experience and knowledge, coordinated research activities, developing guidelines for manufacturers, users and facilities for the processing of nanowaste, and examining existing guidelines or policies are just some of the ways in which the nanowaste management plan can be successfully moved forward.

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