SELECTED ENGINEERING PROBLEMS
NUMBER 5

INSTITUTE OF ENGINEERING PROCESSES AUTOMATION
AND INTEGRATED MANUFACTURING SYSTEMS

Piotr SAKIEWICZ[1*], Ryszard NOWOSIELSKI, Rafał BABILAS, Wirginia PILARCZYK, Katarzyna CESARZ-ANDRACZKE,

[1] Institute of Engineering Materials and Biomaterials, Faculty of Mechanical Engineering, Silesian University of Technology, Gliwice,
[*]piotr.sakiewicz@polsl.pl

WEEECONTAININGNANOWASTE -RISKFORENVIRONMENT AND HEALTH&SAFETY

Abstract: The quantities of waste electrical and electronic equipment (WEEE) will increase in the near future and the importance of its recycling has become more evident. This waste are mixture of materials and components that because of their hazardous content, can cause major environmental and health problems. In order to minimize risks two legislation acts have been put in place; the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive) and Directive on waste electrical and electronic equipment (WEEE Directive). It has led to a reduction of hazardous substances which often are replaced by new ones for example nanomaterials. Actually, existing processes for the recycling of used electronic equipment focuses on separation of metals but there is not procedures taking into account the presence of nanowaste. It is significant subject not only from the point of waste treatment and the recovery of valuable materials but also from the risk for environment and health.

1. Introduction

Nanotechnology has developed in very short time in an uncontrolled manner in all areas of life including electronic and household goods industry. Waste electrical and electronic equipment (WEEE) is considered to be one of the fastest growing waste torrent in the EU, growing at 3-5 % per year. In 2005 it was generated 9 million Mg, and expected to grow to more than 12 million Mg by 2020 [1,2]. The advances is driven by revolution in material sciences. The electric and electronic equipment has been developed, applied, and consumed worldwide at a very high rate and its give an opportunity for the use of nanotechnologies in electronic components and products. Nanotechnology in electrical and electronic equipment is encountered as nano thin-films, nanofibers, nanowires, nanotubes, nanoparticles, nanopowders, nanocapsules, fullerens, dendrimers, quantum dots, nanostructures, nanocoatings, nanoparticles, nanostructured films, nanofibers used in e.g.;

- displays,
- nanocomposites,
- organic electronics,
- optoelectronics and photonics,

- energy storage and generation devices e.g. batteries, solar cells, capacitors, fuel cells,
- heat management systems,
- nanosensors,
- memory and storage devices.

The WEEE and electronic industry waste include: products containing nanoparticles, pure nanomaterials, nano thin-films, nanofibers, nanowires, nanopowders, nanostructures, liquid suspensions containing nanoparticles, items contaminated with nanomaterials and solid matrixes with nanomaterials.

2. Risk for environment and health & safety

The importance of smart waste electrical and electronic equipment recycling has become more evident over the last years. WEEE are inhomogenous and complex in terms of materials and components. In order to develop a cost effective and environmental friendly recycling system, it is important to identify and quantify of materials and hazardous substances to understand the physical characteristic of this waste stream [2]. The restriction in use of hazardous substances in electrical and electronic equipment entered in 2003 cause necessity of replacing old materials by new. The maximum tolerated amount of the substance permitted in any homogenous material from which the application is comprised. At present the list of substances including e.g. : lead, mercury, cadmium, polybrominated diphenyl ethers (PBDE), hexavalent chromium, polybrominated biphenyls [3].

It has led to a reduction of hazardous substances, which often are replaced by new materials often containing nano solution. The industry produces ever smaller electronics devices improving costs, properties and performance often using nanotechnology. Development of nanotechnology causes miniaturization and the current electronic products tend to be smaller and more integrated. This impede reparability and shorten the product life cycle causing more amount of waste. The WEEE Directive has ten categories of electrical and electronic equipment and they are categorized as follows [4]:

- large household appliances ,
- small household appliances,
- it and telecommunications equipment,
- consumer equipment,
- lighting equipment,
- electrical and electronic tools with the exception of large scale stationary industrial tools,
- toys, leisure and sports equipment,
- medical devices with the exception of all implanted and infected products,
- monitoring and control instruments,
- automatic disperses.

The structure and chemical composition of the WEEE depends on the type and the age of the equipment. For example WEEE from IT contain a higher amount of precious metals and nanomaterials than scrap from household. In older devices the amount of nanowaste is low but content of valuable metals and hazardous substances is higher [1]. Due to their hazardous material contents, if WEEE are not correctly treated may cause environmental and health problems during the waste management, recycling or landfill phases. Commonly, the mechanical separation, electrochemical treatment, thermal treatment and hydrometallurgical treatment methods are used for the treatment of electrical and electronic waste [5]. None of this method takes into account the prevalence of a variety of nanowaste.

The worst way of recycling WEEE with nanotechnology seems to be mechanical separation because of dust and nanoparticles formation. This nanowaste cause water, air and soil pollution leading to risk for environment and health & safety. After segregation the obtained fractions have to be treated further in other processes or have to be landfilled as it is done at present with plastic fractions (e.g. at the world's poorest countries). Very important aspect is that this nanowaste are inhomogeneous, it means that this material can’t be mechanically disjointed or separated into different materials, by use of actions such as cutting, crushing, grinding and abrasive processes.

It is expected [2] that quantities of WEEE contain nanowaste will increase rapidly in the near future. Usually nanowaste are generated during the product end of life operations (e.g. recycling, landfill incineration etc.). The nanowaste are generated also during the usage of products containing nanomaterials or nanotechnology (e.g. abrasion, degradation, etc).

A useful tool may be establishing classification standards of nanowaste operation. Managing risk and uncertainty should be primarily on authority draws attention to the need to develop research in the area of dealing with nanowaste. In order to avoid the potential risks of uncontrolled and unexpected impact of nanowaste into the environment and health and safety EU supports many R&D programs (tab. 1).

Table 1. Selected nano - projects in the EU.

NANoREG	A common European approach to the regulatory testing of Nanomaterials
eNanoMapper	A Database and Ontology Framework for Nanomaterials Design and Safety Assessment
ENNSATOX	Engineered Nanoparticle Impact on Aquatic Environments: Structure, Activity and Toxicology
GUIDENANO	Assessment and mitigation of nano-enabled product risks on human and environmental health
LICARA	Life cycle approach and human risk impact assessment, product stewardship and stakeholder risk/benefit communication of nanomaterials
ModNanoTox	Modelling nanoparticle toxicity: principles, methods, novel approaches.
NANODEVICE	Novel Concepts, Methods, and Technologies for the Production of Portable, Easy-to-Use Devices for the Measurement and Analysis of Airborne Engineered Nanoparticles in Workplace Air
NANOMMUNE	Comprehensive Assessment of Hazardous Effects of Engineered Nanomaterials on the Immune System
NanoPolyTox	Toxicological impact of nanomaterialsderived from processing, weathering and recycling of polymer nanocomposites used in various industrial applications
Scaffold	Innovative strategies, methods and tools for occupational risk management of manufactured nanomaterials (MNMs) in the construction industry
Nephh	Nanomaterials Related EnvironmentalPollution and Health Hazards Throughout their Life Cycle
NanoMILE	Engineered nanomaterial mechanisms of interactions with living systems and the environment: a universal framework for safe nanotechnology

A wide range of nanotechnology applications and lack of comprehensive knowledge on social and health consequences of its use made politicians in many countries to take steps to prepare the relevant regulations associated with the development of new technologies.

3. Conclusion

The RoHS and WEEE directive requirements force constructors and manufacturers a need to use new materials for example nanomaterials. These materials are being used as possible replacements for traditional materials. Each manufacturer have to take into account managing risks and uncertainties associated with the use of materials with not fully known properties. Especially risk for environment, health and safety associated with waste electrical and electronic equipment and the process of their recycling. The omnipresence of electronic devices in people's everyday lives requires the introduction of procedures taking into account these aspects already at the product design stage. This also applies to industrial design which use both applied science and applied art to improve the aesthetics of design products, new materials and technologies offer new opportunities. Nanotechnologies in future electronics development will play a key role. The commercialization of nanotechnology incomplete knowledge will be today profitable for industry, but in the future would be costly for all of us.

Legislation does not yet cover nanowaste. It is very important to remember that nanotechnology has many advantages, but there is also many unpredictable risks for environment, health and safety. Interdisciplinary character of nanotechnology forcing scientists from many disciplines to develop rational procedures. People should be informed about advantages and disadvantages of nanotechnology applications to reduce hazards and risk of new technology and nanowaste quantity. Nanowaste are a new kind of waste containing nanoscale materials and appointment of entirely new standards of the waste treatment is a new challenge for scientists and lawyers. The majority of nanomaterials do not exist in the natural environment and nobody is able to determine the long term effects of its creation. Intensive industrial development of nanotechnology and lack of environmental standards caused penetration of natural environment by waste also WEEE containing nanowaste.

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