SENSOR DEVICES FOR ASSESSING THE TOXICITY OF NANOMATERIALS

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Abstract. Nanotechnology and nanomaterials are produce a great interest because of their unique structural morphology and outstanding physicochemical properties. Nanomaterials open up new possibilities for the development of new technologies of sensorics and monitoring. While nanomaterials have numerous applications, and the benefits of nanotechnology are widely covered, their potential impact on human health and the environment is also being investigated. Nanosensors can be classified into two main categories: sensors, which include nanotechnology or sensors with nanotechnology support, which are nanoscale in themselves or have nanoscale materials, components; and sensors that are used to measure nanoscale properties. The first category may ultimately lead to lower material costs, lower weight and energy consumption. The second category can improve understanding of the potential toxic effects of emerging pollutants from nanomaterials, including fullerenes, dendrimers and carbon nanotubes.

1. Nanomaterials and nanotechnology for sensing.

The development of nanotechnology has led to a high level of use of nanomaterials for a wide range of devices, as well as to the discovery of new opportunities for the creation of chemical and biosensor devices. The use of nanoscale materials, such as nanoparticles, nanotube, nanoneedle, nanowire, nanosheet, nanorod, nanobelt and nanocomposites for the development and creation of new types of sensor devices is increasing.

Due to the electrical, magnetic, optical properties of nanomaterials, biosensors based on them were divided into electrochemical, optical or photoelectrochemical, magneto-mechanical and surface-plasmon resonant amplified types of sensor devices, etc. Their sizes are on the same scale as biomolecules, which opens up new possibilities for interaction with biological species, such as microorganisms, tissues, cells, antibodies, DNA and other proteins. Extensive research works and reviews have been published using nanomaterials for electrochemical bioanalysis, which demonstrates a growing interest in this area. Nanomaterials were used to build enzyme sensors, immunosensors, and gene sensors to achieve direct transfer of enzymes and relative components to the electrode surface, to stimulate a spectroelectrochemical reaction, and to enhance the bio-recognition signal.

2. Detection of metal and metal oxide nanoparticles.

Silver nanoparticles (AgNPs). Silver nanoparticles are known for their antimicrobial activity, and for this reason they have been used in water purification and other applications such as baby pacifiers and food storage containers. Their bactericidal activity depends on the shape and size, and particles less than 100 nm in size exhibit optimal antibacterial activity. Despite these beneficial uses, silver nanoparticles are toxic.

There are many excellent chemical sensors for recognizing silver ions, including ion-selective electrodes, optodes, and fluorescent sensors. Plasma emission spectroscopy, Atomic absorption (AAS), and anodic stripping voltammetric methods have been used to measure trace levels of silver. However, none of these have been applied for silver nanoparticles detection.

As for now, only one article has appeared reporting their application for AgNPs. The article has been published by Chatterjee et al. [1] on ‘‘selective fluorogenic and chromogenic probe for detection of silver ions and silver nanoparticles in the aqueous media’’. The chemistry of their sensor was based on Rhodamine B derivative 1 as the fluorogenic and chromogenic probe for Ag+/AgNPs in aqueous media (Fig. 1).

The most serious problem limiting use of ion-selective electrodes and other existing sensors is interference from other undesirable ions. Some of these sensors are not completely ion-specific; all are sensitive to other ions having similar physical properties.

Gold nanoparticles (AuNPs). Recently detection of AuNPs has been reported using Surface Plasmon Resonance (SPR) technique. Plasmon resonances in metallic nanoparticles are due to the collective oscillation of conduction electrons against their matrix. Such resonances play a central role in the optical properties of metallic nanoparticles and therefore are useful in detection metal nanoparticles such as AuNPs. Lindfors et al. [2] reported detection and spectroscopy of gold nanoparticles using super continuum white light confocal microscopy. They illuminated the sample with super continuum laser light generated in a photonic crystal fiber (PCF) through a cascade of nonlinear effects that gave rise to a spectrum extending from the visible to the near infrared. Using this technique these scientists were able to detect a single gold particle down to a nominal diameter of D ¼ 5 nm. This was the first detection of individual gold nanoparticles below 10 nm using a fully optical technique.

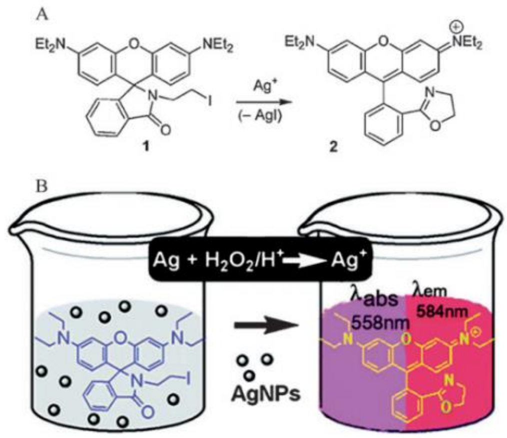

Fig. 1 - (A) Ag+ Promoted Spirolactum Ring Opening of Probe; (B) Schematic illustration of the sensing mechanism promoted by Ag+-coordination to the iodide of the probe.

Another optical technique for detecting AuNPs is the photothermal detection of gold nanoshells using phase-sensitive optical coherence tomography (OCT) as reported by Adler et al. [3] OCT is a high-resolution biomedical imaging modality that produces cross-sectional and three-dimensional images of tissue microstructure by interferometrically measuring the amplitude and echo time delay of backscattered light. Typically, at low temperature gradients the technique is suitable for in vivo use and represents a new method for detecting AuNP contrast agents with excellent signal-to-noise performance at high speeds using OCT.

In addition, microelectrode amperometry of carbon fiber is used to measure the dynamic secretion of chemical messenger molecules from cells exposed to nanoparticles. This method facilitates the detection of a specific molecular target based on the applied potential, submillisecond time resolution, and quantification of endogenous concentrations of chemical messengers released during exocytosis. In the presence of AuNPs, carbon microelectrode amperometry was used to characterize serotonin exocytosis from the peritoneal mast cells of mice cultured together with fibroblasts, and the results suggest that the nanoparticles disrupt the dense nuclear biopolymer intercellular matrix and represent a potential for systematic studies showing how exocytic function depends on the size, shape and composition of the nanoparticles.

Metal oxide nanoparticles. Metal nanoparticles such as ZnO, TiO2, CeO2, ZnO and TiO2 have been used as sunscreens for many years because of their ability to filter UVA as well as UVB light, giving broader protection than other sunscreening agents. These materials are widely used, although in theory they have been labeled as potentially toxic. A biosensor for detecting gold nanoparticles can also be used to detect nanoparticles of metal oxides (ZnO, or Fe3O4). Other methods for detecting metal oxide nanoparticles are a traditional characteristic of nanomaterials. For example, Tyner et al. [4] compared up to 20 existing conventional methods for detecting and characterizing metal oxide nanoparticles in unmodified commercial sunscreens. Their findings showed that only varied-pressure SEM, AFM, laser-scanning confocal microscopy and X-ray diffraction were found to be viable complementary methods for detecting and characterizing nanoparticles in sunscreens. However, none of these has been used to detect and characterize ENMs fully without complementary methods.

Summary and conclusions. In this article we have tried to generalize and understand the field of nanomonitoring and nanotoxicology, including the problems of monitoring nanomaterials, the possibility of combining existing analytical methods with traditional toxicity methods. Environmental monitoring of nanoparticles is an important area of research, and it will greatly benefit from new approaches to detecting the presence and characterization of the properties of nanomaterials.

References:

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