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Synthesis and properties of TiO_2, NiO and ZnO nanoparticles and their possible biomedical application

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ABSTRACT

Purpose: The main purpose of this publication is to bring closer method of synthesis and examining basic properties of TiO_2, ZnO and NiO nanoparticles (NPs), and investigate their possible biomedical application.

Design/methodology/approach: Nanopowders were made with sol-gel method. Surface morphology studies of the obtained materials were made using Zeiss's Supra 35 scanning electron microscope and the structure using S/TEM TITAN 80-300 transmission electron microscope. In order to confirm the chemical composition of observed nanopowders, qualitative tests were performed by means of spectroscopy of scattered X -ray energy using the Energy Dispersive Spectrometer (EDS). The DLS (Dynamic Light Scattering) method was used to analyse the particle size distribution using the AntonPaar Litesizer 500 nanoparticle size analyser. Changes in particle size distribution at elevated temperatures were also observed. The TiO_2, ZnO and NiO NPs with spherical shape were successfully produced by sol-gel method.

Findings: The diameter of the as prepared nanoparticles does not exceed 25 nm which is confirmed by the TEM analysis. The highest proportion among the agglomerates of the nanoparticles has been shown to show those with a diameter of 80 to 125 nm. The qualitative analysis of EDS confirmed the chemical composition of the material.

Practical implications: Nanoparticles (NPs) has been receiving an incrementally increasing interest within biomedical fields researchers. Nanoparticles properties (physical, chemical, mechanical, optical, electrical, magnetic, etc.) are different from the properties of their counterparts with a larger particle size.

Originality/value: The nanoparticles were prepared using sol-gel method which allows the particle size to be controlled in a simple way.

Keywords: Nanoparticles, Sol gel method

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BIOMEDICAL AND DENTAL MATERIALS AND ENGINEERING

1. Introduction

TiO_2, ZnO and NiO nanoparticles have been used for years as an addition to paints, bleaching plasters and pastes, and for self-cleaning surfaces production. Good photocatalytic properties of those materials have made them also one of the basic components of dye sensitized solar cells. Researches are being carried out on the use of several kinds nanoparticles in the areas of medicine and plant protection. Nanoparticles are gaining more and more recognition in these areas. The particle size allows reaching previously inaccessible areas of organisms, which allows for more effective distribution of drugs and other chemical substances. In addition, they also have properties that differ significantly from the solid materials [1-5].

Size is the most important property of nanoparticles for medical applications. They must be adequately small and well dispersed. Due to such small dimensions, nanoparticles have a very large specific surface area, which is why they can be used in transport and controlled release of drugs and, in the case of magnetic particles, for imaging and cancer therapy. However, a large specific surface area increases the mutual interactions between particles, which increases their tendency to agglomerate and after combining into agglomerates they lose their extraordinary antibacterial properties. In addition, the pore size between cellular barriers is about 6-10 nm depending on the tissue. Therefore, in order to be effective in the body, nanoparticles must be small enough to penetrate into the organ and after leaving the interaction without any obstacles leave it. This will prevent deposition of nanoparticles in the body and unpredictable side effects over time [6,7].

The main goal of the experiment was to produce nickel, zinc and titanium oxide nanoparticles using the sol-gel method, which allows the particle size to be controlled in a simple way. The nanoparticles were then analysed to assess chemical composition and size.

2. Materials and methods

During the work, three types of nanoparticles were produced by the sol-gel method.

2.1. Synthesis of titanium dioxide nanoparticles

Titanium oxide nanoparticles were made using titanium isopropoxide as precursor and distilled water as hydrolysis catalyst. The desired pH value of the solution was adjusted by the addition of HNO_3. While stirring with a magnetic stirrer, both substances were mixed under room temperature. Cloudy suspension was formed, which was then heated to 60-70°C and held overnight. After that, the volume of the solution was reduced to approx. 50 cm^3.

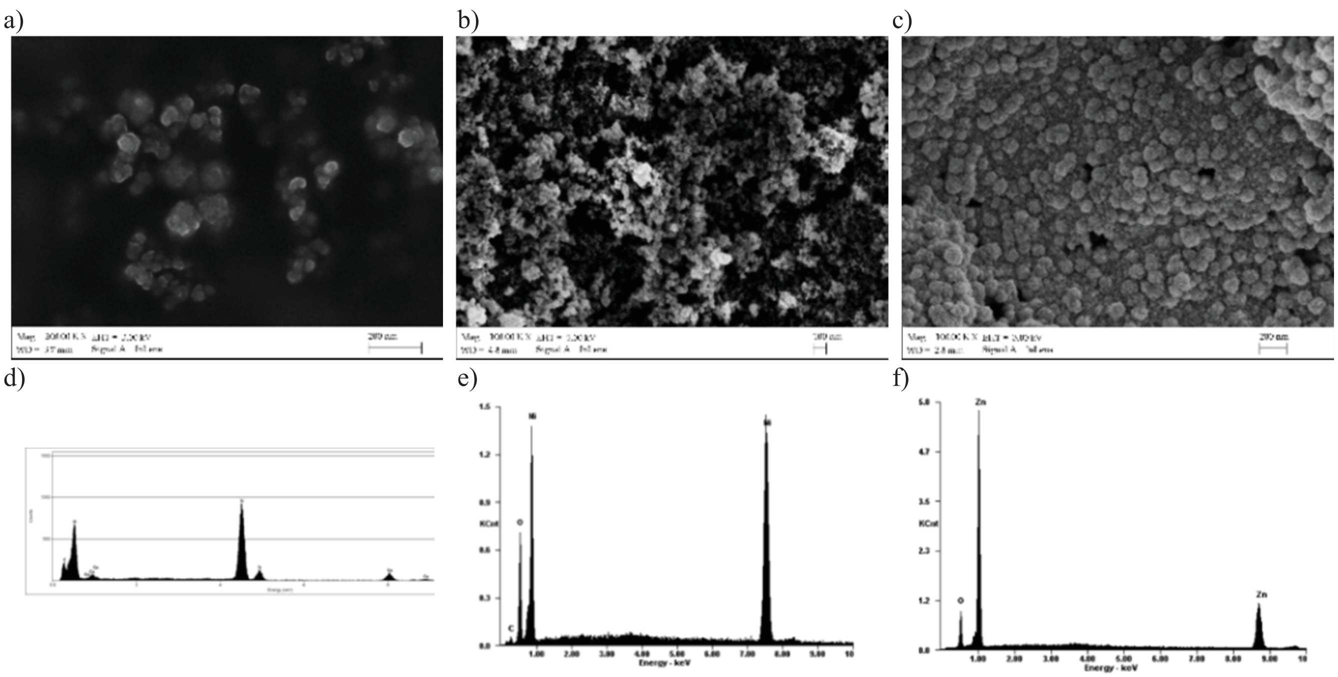

Fig. 1. SEM Images of TiO_2 (a), NiO (b) and ZnO (c) nanoparticles and EDS spectrum of TiO_2 (d), NiO (e) and ZnO (f) nanoparticles

After the reaction had completed, the solution was dried in furnace. The resulting material was then annealed. The produced precipitates were next washed with ethanol and dried. As a result, a yellow-white powder was obtained, which was further ground in an agate mortar.

2.2. Synthesis of nickel oxide and zinc oxide nanoparticles

Nickel oxide and zinc oxide nanoparticle were prepared also using sol gel method and nickel (II) nitrate hexahydrate for NiO NPs, and zinc acetate dehydrate for ZnO as a precursor. For ZnO NPs citric acid was also added.

2.3. Characterisation techniques

To observe particle surface morphology, SEM imaging was performed using a Zeiss's Supra scanning electron microscope operated at 3 kV. S / TEM imaging using TITAN 80-300 transmission electron microscope was used to analyse the structure. In order to confirm the chemical composition of the obtained materials qualitative tests were performed by means of spectroscopy of scattered X-ray energy using the Energy Dispersive Spectrometer (EDS). The DLS (Dynamic Light Scattering) method was used to analyse the particle size distribution using the AntonPaar Litesizer 500 nanoparticle size analyser.

3. Results and discussion

On the SEM imaging agglomerates of all types of nanoparticles with sizes up to 500 nm were registered (Figs. 1a-c). The qualitative analysis of EDS (Figs. 1d-f) confirmed the chemical composition of the material produced, no additional contamination of the samples was found. Cu on TiO_2 EDS spectre was caused by background.

The size distribution of nanoparticles was checked using the DLS method (Fig. 2).

The highest proportion among the agglomerates of the nanoparticles has been shown to show those with a diameter of 80 to 125 nm. This study showed the large tendency of this material to agglomerate. TEM imaging showed that the size of the nanoparticles did not exceed 25 nm (Fig. 3).

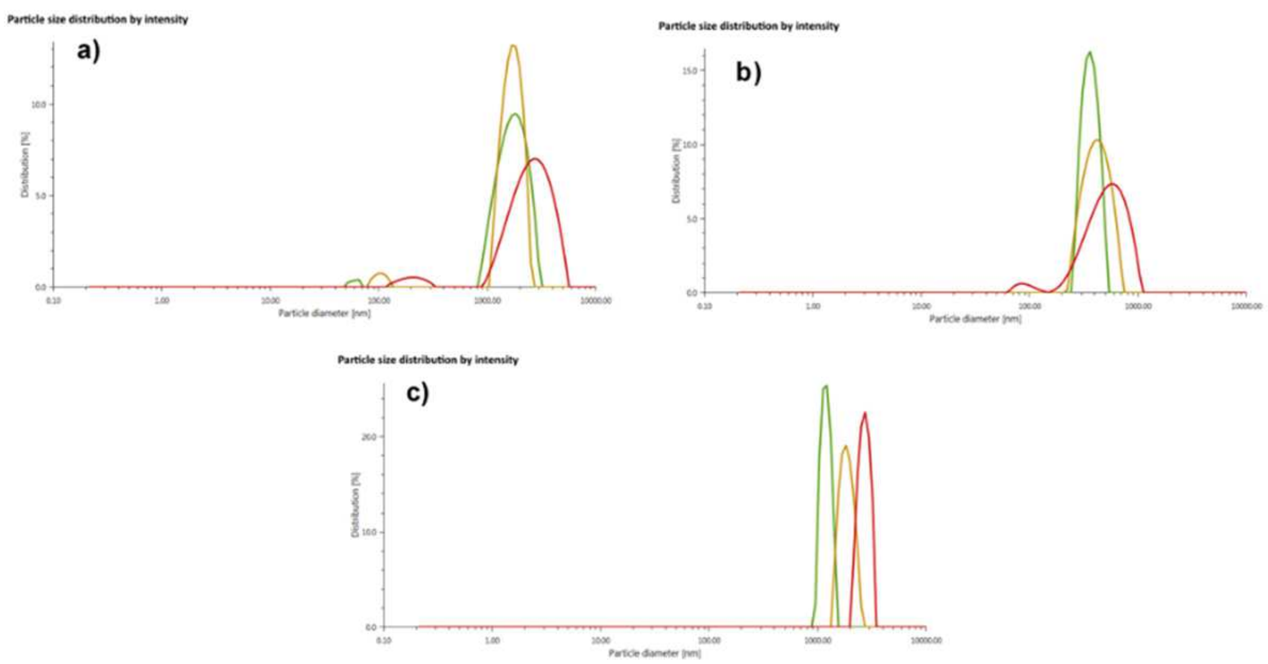

Fig. 2. Size distribution curves of TiO_2 (a), NiO (b) and ZnO (c) nanoparticles in room temperature

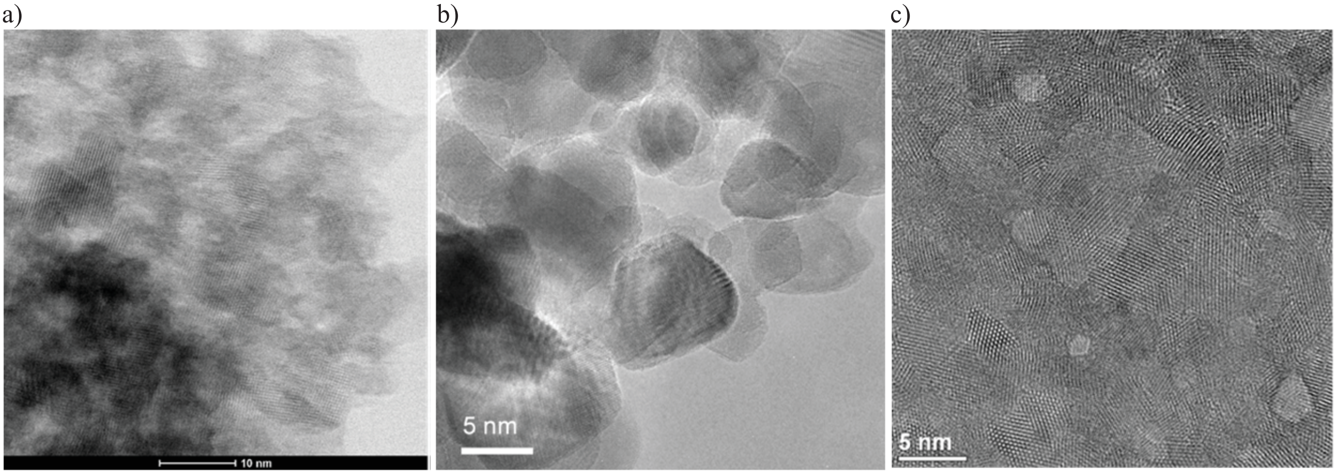

Fig. 3. TEM Images of TiO_2 (a), NiO (b) and ZnO (c) nanoparticles

4. Conclusions

Nanoparticles were created as a result of the experiment. Comparing the results obtained with the use of different research techniques, a strong tendency of particles to agglomerate was learned. The size analyser of the nanoparticles additionally rounds the particles to the sphere, which affects the inflated result. The EDS study confirmed the chemical composition of nanoparticles. Further studies on the antibacterial properties of nano-particles are planned.

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