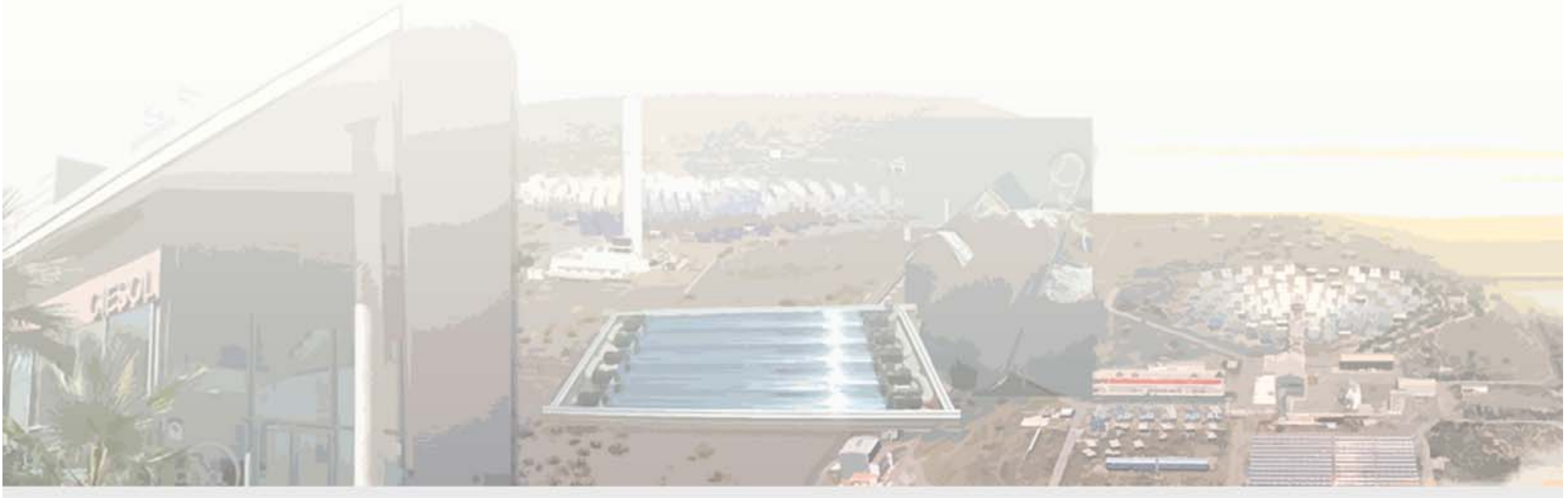

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Photocatalytic Materials and Technical Solutions for Production of Pure Indoor Air

P187

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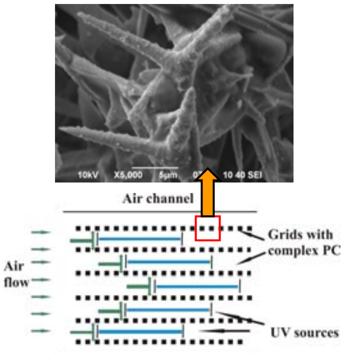

In this study we propose the composite materials with a complex impact and method for increasing the probability of contacts between the contaminants (bacteria) and the catalyst by using the complex methodic: mechanical interactions bacteria with ZnO tetrapods spikes, photocatalytic process on ZnO nanoparticles and disinfection by Ag nanoparticles, moreover all these methods will be united in one device. Ag and ZnO nanoparticles have been deposit on ZnO tetrapodes and this complex material have been deposit on different substrates, such as glass, grid and fabric. Two types of design of air purifier system are proposed.

Introduction

It is known many traditional methods for air purification methods such as adsorption, separation or disinfections, but they have the same weakness: pollutants just move from one place to another without being thoroughly resolved. At the same time it can lead to the formation of toxic by-products. Lately, the photocatalytic method using nano-TiO_2 material has been discovered and used for air purification. Photocatalyst air purifier systems have many benefits and may kill the bacteria and increase the overall air quality. Traditionally a photocatalytic air purifier is a specialized air filtration device and UV illumination source. In some cases the plasma assistant system may be used for increasing the efficiency of air purification [1].

TiO_2 under UV irradiation creates an excited-state of electron (e^-) and hole (h^+) pairs, which are able to react with O_2 and water vapor in the atmosphere to produce superoxide ions (O^{2-}) and hydroxyl radicals (OH•). Both O^{2-} and OH• are extremely powerful agents in destroying chemical compounds as well as bacterial cells to form CO_2 and H_2O. But the destruction of bacteria membrane by photocatalytic process, that can lead to killing the bacteria (can be not) is the multistep process. It consist of presence of water molecules in the air, production of ROS by photocatalysis, interaction ROS with bacteria membrane, etc. So, the effectiveness of photocatalytic system in case of high air rates in air duck or the probability of contact between the contaminants and the catalyst should be very high. For increasing the effectiveness of photocatalytic filters the antibacterial filter with Ag nanoparticles are used [2, 3].

In this study we propose the materials and method for increasing the probability of contact between the contaminants (bacteria) and the catalyst by using the complex methodic: mechanical interactions bacteria with spikes, photocatalytic process on ZnO nanoparticles and disinfection by Ag nanoparticles, moreover all these methods will be united in one device.

Experimental

ZnO nanoparticles were synthesized using a precipitation technique from $ZnCl_2$ salt. As a precipitant the water solutions of oxalic acid were used. All used chemicals were of chemical purity. A precipitate was obtained by the addition of an aqueous solution of $ZnCl_2$ in oxalic acid water solution with continuously stirring using a propeller stirrer for 30 min. The value of the pH was more than 8. The precipitates were recovered by suction filtration using a vacuum pump. The sediments were washed several times with distilled water before drying in a microwave furnace (P = 700 W, f = 2.45 GHz). The dried precipitates were calcined in a resistive furnace at 500 and 700°C with a dwell time of 2 h.

The ZnO tetrapods, as substrate for ZnO, Ag and other NPs, were produced by CVD method. In the

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present studies the coatings on a glass, grids, and carbon fabric were made by spin coating technique or by painting. In presented examples, the slip prepared from zinc oxide tetrapods, boric acid on water or alcohol. After coating procedure the samples were dried at room temperature and the heated in the temperature region 400-700°C. In case of creation of carbon/ZnO coating a glycerol was added in the slip. For creation of Ag/ZnO NPs composite the chemical reduction of silver was used by silver mirror reaction.

The powders were characterized by means of X-ray diffraction (Dron-3) with Cu-K$_\alpha$ radiation for crystallite sizes and quantitative phase analyses. Morphology of synthesized particles and coatings were studied by means scanning electron microscopy (JSM 6490 LV, Jeol, Japan).

The photocatalytic activity of the ZnO particles was tested by photodegradation of phenol used as model pollutant in water with concentration of 50 ppm under UV illumination.

The optical properties of ZnO nanopowders were measured on a Cary 5000 UV-Vis-NIR spectrometer with Internal Diffuse Reflectance sphere (Agilent Technologies, USA).

Result and discussion

Synthesised ZnO tetrapods and ZnO nanoparticles are shown on Fig. 1. According to XRD data ZnO tetrapodes and ZnO NPs are crystallized in the wurtzite structure P63mc.

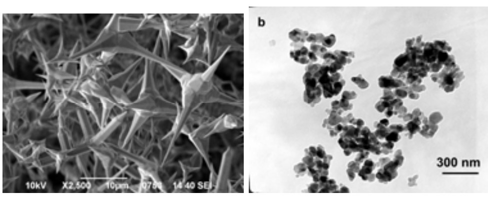

Fig. 1 SEM image of ZnO tetrapods – a) and TEM image of ZnO nanoparticles – b).

ZnO nanoparticles demonstrate the high level of photocatalytic activity determined by monitoring of concentration of phenol in water/phenol (50 ppm) suspension of ZnO NPs (Fig. 2).

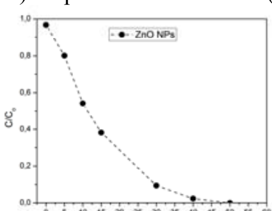

Fig. 2 Photocatalytic degradation of phenol in presence of ZnO nanoparticles.

According to the mention above experimental procedure the coatings from ZnO tetrapodes and ZnO NPs, ZnO tetrapodes and Ag NPs, ZnO tetrapodes and carbon were prepared on glass substrate (Fig. 3) and grid (Fig. 4).

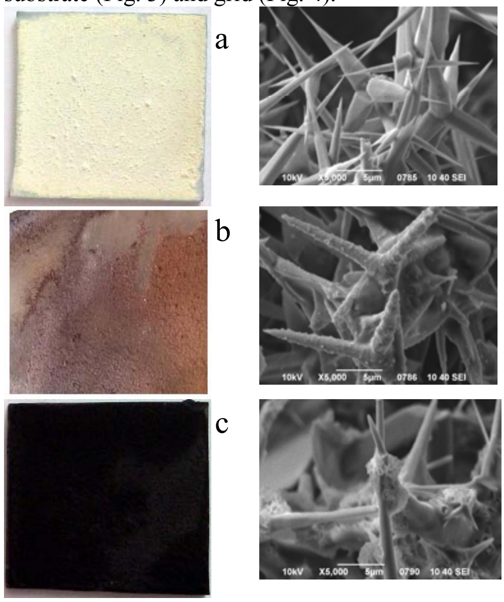

Fig. 3 Different types of coatings and their microstructures. ZnO tetrapodes and ZnO NPs – a), ZnO tetrapodes and Ag NPs – b), ZnO tetrapodes and carbon – c)

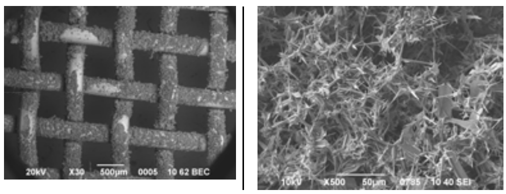

Fig. 4 Composite ZnO tetrapodes and ZnO NPs on a grid substrate.

According to the best practice for UV reactors for air purification the reactor the reactor should have: high specific surface for a large reaction surface area, support small pass through channels and low air velocity for a high mass transfer, and have the UV source irradiate directly on the reaction surface. On a base of these conclusions we proposed the two types of simple reactor. First type of reactor consists from two sub modules – working module and UV module (Fig. 5a). These modules angled to the flow of air. The substrate in the working module may be produced from glass, stainless still grid, carbon fabric, etc. These planar substrates covered on both side the complex composite/photocatalytic materials. Second type of reactor consist from grid substrates is parallel to the air channel axis and plate-like air swirlers located perpendicular to the air channel axis (Fig. 5b). On the swirlers block also UV sources are mounted.

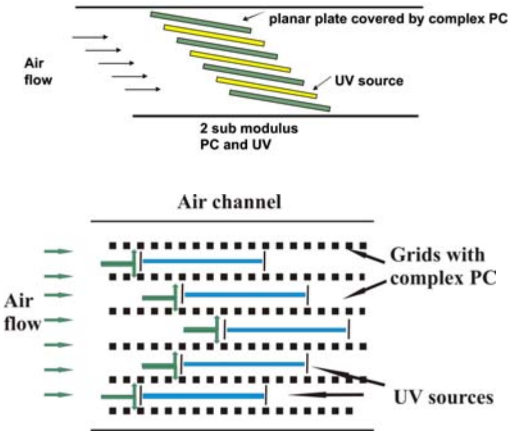

Fig. 5 Two type of reactor for air purification.

These both reactors consist from two independent blocks and can be easy mounted in the air channel as well as remounted from them and working block can be sending to recovery.

The catalytic properties of powders in air can be examined by degradation of fullerene C_{60} studying the disappearance the anisotropic $\bullet O^{2-}$ signal and appearance the isotropic ESR signal C_{60}^{+} paramagnetic center with ***g***-factor 2.0021, which correspond to oxidized form of C_{60}, due to the interaction of C_{60} with atmospheric oxygen (Fig. 6).

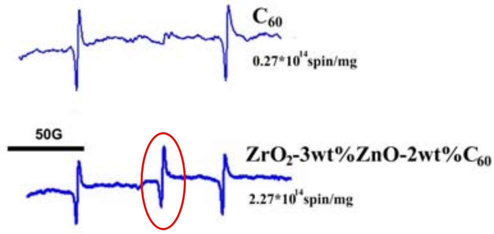

Fig. 6 ESR spectra of irradiated UV light PC nanopowder with fullerene.

The interaction of fullerene with the oxygen-rich surface of PC nanoparticles generates the intense (in tens time higher in comparison with pure C_{60}) isotropic ESR signal with ***g***-factor of about 2.0021±0.0002.

Keywords: photocatalyst, complex action, doped ZnO, coatings, design
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References

[1] S. O. Hay, T. Obee, Z. Luo, T. Jiang, Y. Meng, J. He, S. C. Murphy, S. Suib. *Molecules,* 20 (2015) 1319.
[2] T. S. Le, T. H. Dao, D. C. Nguyen, H. C. Nguyen, I. L. Balikhin. *Adv. Nat. Sci.: Nanosci. Nanotechnol.* 6 (2015) 015016
[3] V. Sambhy, M. M. MacBride and B. R. Peterson *J. Am. Chem. Soc.* 128 (2006) 9798