Effect of extra laser irradiation on the photocatalytic properties of TiO_2 obtained by pulsed laser ablation

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Abstract— in this work we study the effect of extra laser irradiation during the preparation by pulsed laser ablation in water on the structure and physicochemical properties of titanium dioxide. Extra laser irradiation leads to a decrease in particle size, a change in structure, and as a result, a change in optical and photocatalytic properties.

Keywords— TiO_2, pulsed laser ablation, nanoparticles, extra irradiation, photocatalysis

I. Introduction

The nanosized titanium dioxide is currently widely used in photovoltaic devices, heterogeneous photocatalysis and bactericidal materials. However, the synthesis of materials based on titanium dioxide, which have absorption in the visible region of the spectrum without reducing photoactivity is still relevant today. One of the promising methods of obtaining is the method of pulsed laser ablation (PLA). The processes occurring during PLA are high-energy, which leads to the production of a substance in a highly dispersed and highly defective state, which certainly affects its physical-chemical and optical properties. Earlier, we prepared titanium dioxide by the PLA method, which has absorption in the visible spectral region [1]. In this work, we study the effect of extra laser irradiation during the synthesis of TiO_2 by the PLA method on the structure and properties of particles.

II. Synthesis and Study

The synthesis of materials was carried out in two stages. At the first stage, a colloidal solution was obtained, by using Nd:YAG laser (LOTIS TII, model LS2131M-20, wavelength of 1064 nm, frequency of 20 Hz, pulse duration of 7 ns). After an hour of ablation, the solution was divided into two parts, one of which was subjected to extra irradiation for an hour at the same laser radiation parameters. At the second stage, both colloidal solutions were dried at a temperature 60 °C until completely dry. After, the powders were annealed for further research. The following identifiers were assigned to the samples: TiO2_ini for the sample without irradiation, and TiO2_hv for the extra irradiated sample.

The powder has a dark blue color for TiO_2_ini and a gray for TiO_2_hv, which changes after heat treatment. Transmission electron microscopy (TEM) shows that the average particle size of non-irradiated material is 5-10 nm, with presents of large particles up to 80 nm in size (Fig. 1). The specific surface area is 223 m^2/g and after irradiation the specific area slightly increases to 253 m^2/g, which may indicate that extra irradiation leads to a decrease in the size of large particles.

X-ray diffraction data shows that the samples have an amorphous structure, however, after heat treatment at 250 °C, the anatase crystalline phase begin to form in the structure of TiO_2_hv.

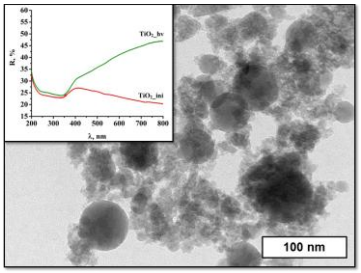

Fig. 1. TEM image of TiO_2_ini particles and DRS spectra.

The TiO_2_ini sample in the diffuse reflection spectra (DRS) showed intense absorption in the entire visible range, which can be attributed to the presence of different nature of defects in the structure (Fig. 1, insert). The spectrum of the extra irradiated TiO_2_hv sample has less absorption in the long-wavelength region, but the absorption edge becomes more clear. It can be assumed that this is a consequence of the disappearance of some defects in the structure of the material. The photocatalytic activity of the samples was studied using the photodegradation of organic pollutants phenol and Rhodamine B under visible light irradiation. The results showed better efficiency for TiO_2_hv sample compared to non-irradiated sample. For phenol and Rhodamine, the percentage of decomposition increased by 2 times. Thus, extra irradiation during the synthesis of TiO_2 by the PLA method leads to changes in the structure and, as a result, the optical properties of materials, which also favorably affects the photocatalytic behavior of the material.

Acknowledgment

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References

[1] E. Fakhrutdinova, A. Palatova, V. Svetlichnyi, “Structure and Optical Properties of Nanocrystalline Titanium Dioxide Prepared via Pulsed Laser Ablation in Liquid”, IEEE Proc., Vol. 2018, No. 8434990, pp. 3-7, 2018.