DOI 10.1007/s11182-017-1085-8

Russian Physics Journal, Vol. 60, No. 2, June, 2017 (Russian Original No. 2, February, 2017)

BRIEF COMMUNICATIONS

PREPARATION OF γ-AL(OH)$_3$ AND γ-AL$_2$O$_3$ NANOPARTICLES BY THE METHOD OF PULSED LASER ABLATION OF METAL ALUMINUM IN WATER

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UDC 621.373.826+535.012.22+535.581

Keywords: pulsed laser ablation in a liquid, nanoparticles, structure, aluminum Al_2O_3.

Pulsed laser ablation (PLA) in a liquid is the unique method of preparation of *pure* nanocolloids and ultrafine powders on their basis [1]. PLA of chemically active metals allows one to initiate a large number of chemical reactions and to influence effectively on the structure and composition of the prepared nanoparticles (NP) [2, 3]. Aluminum with electrochemical potential of 1.7 V belongs to these metals. The NP of various compositions were prepared by ablation with variable solvents, including addition of precursors, at different laser radiation wavelengths [4–6]. For a number of fundamental and applied problems, of interest are nanodispersed materials based on aluminum without impurities characteristic for their chemical synthesis, in particular, $Al(OH)_3$ for use in medicine as sorbents and γ-Al_2O_3 for use in catalysts. The purpose of the present work is preparation of pure aluminum oxide and hydroxide nanoparticles by the method of pulsed laser ablation and their subsequent characterization.

The experimental conditions of PLA for preparation of NP dispersions were described in [2]. Nd:YAG-laser radiation (1064 nm, 7 ns, and 20 Hz) was used for ablation. The Al target had a purity of 99.5 %, and ablation was performed in distilled water.

Figure 1 shows SEM images of nanoparticles prepared by Al ablation. Right after the preparation of the dispersion, a large number of spherical metal aluminum nanoparticles were observed (Fig. 1*a*) that converted into hydroxide (Fig. 1*b*) within several hours. The nanodispersed hydroxide powder consisted of flat flake structures (Fig. 2*a*) and had the γ-$Al(OH)_3$ gibbsite crystal structure (curve *1* in Fig. 3). Its annealing to 120°C was accompanied by evaporation of unbound water, and from 200 to 300°C, it was accompanied by intense oxidation (Fig. 4). As a result, the oxide was formed with a low degree of crystallinity representing γ-Al_2O_3. Its subsequent annealing to temperatures exceeding 1000°C led to the formation of the thermodynamically stable α-Al_2O_3 crystal structure [6]. The γ-$Al(OH)_3$ nanopowder prepared by annealing at 500°C consisted of well faceted particles of pyramidal shape (Fig. 2*c*). It should be noted that for all samples, the presence of the metal Al phase was observed caused by the presence of an insignificant amount of large particles (<1 %) that were not oxidized during annealing to 500°C.

The oxide particles were formed by PLA in water and as a result of air purging through the solution. In this case, the particles had spherical shape (Fig. 2*d*), and a significant amount of amorphous aluminum hydroxide was present in the sample.

Thus, pure $Al(OH)_3$ and γ-Al_2O_3 nanoparticles have been prepared by the method of pulsed laser ablation in water without any precursors, and their morphology and composition have been investigated. These materials in the

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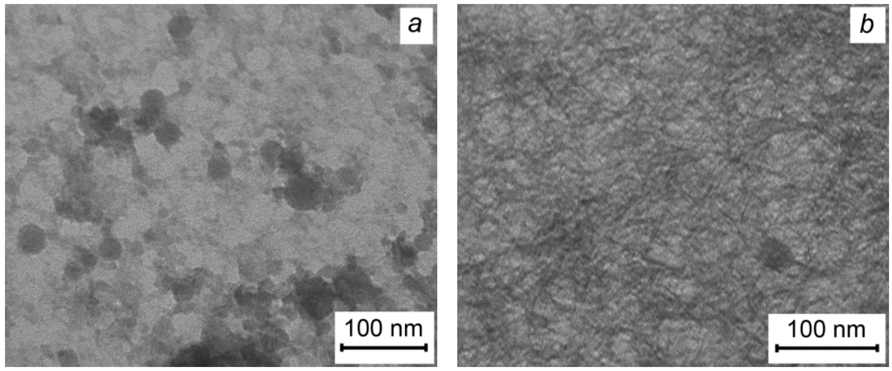

Fig. 1. SEM images of nanoparticles prepared by PLA of aluminum in water: *a*) freshly prepared dispersion and *b*) dispersion after 6 h storage.

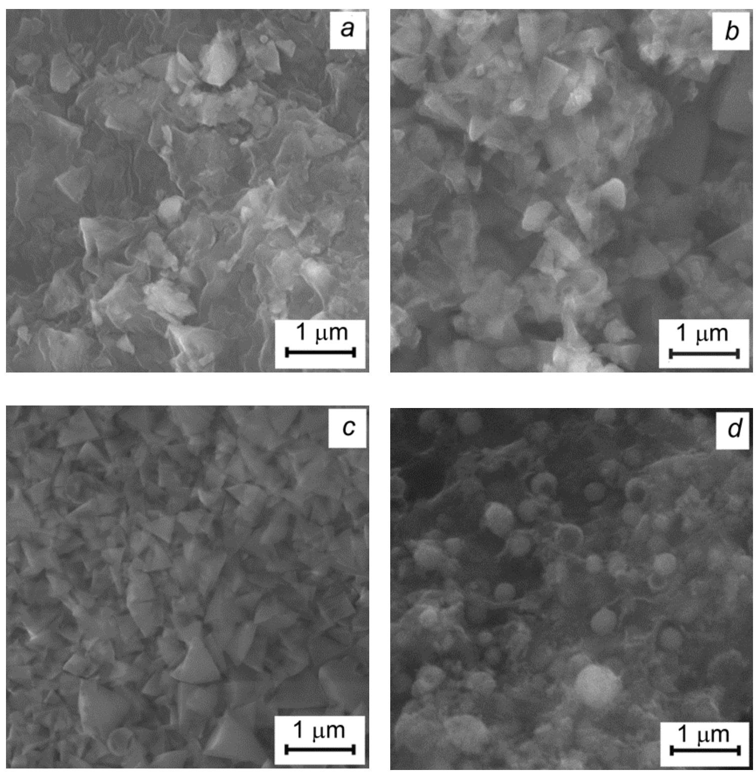

Fig. 2. SEM images of nanopowders prepared by PLA of aluminum in water: *a*) initial powder after drying; *b*) after annealing in air at temperatures of 300 and 500°C, respectively; *c*) initial powder prepared by PLA with air purging through the solution.

form of dispersions and powders will be used as components for preparation and investigation of catalysts for carbonic oxide oxidation.

This work was supported in part by the Russian Foundation for Basic Research (Project No. 16-32-50076_mol_nr).

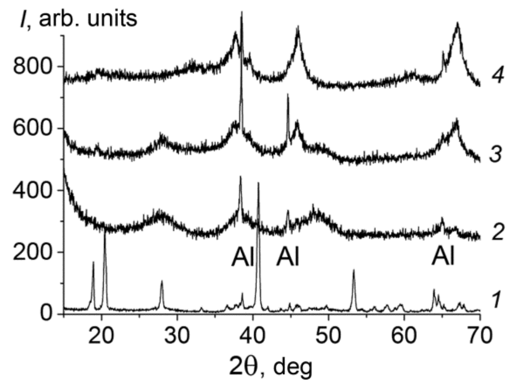

Fig. 3

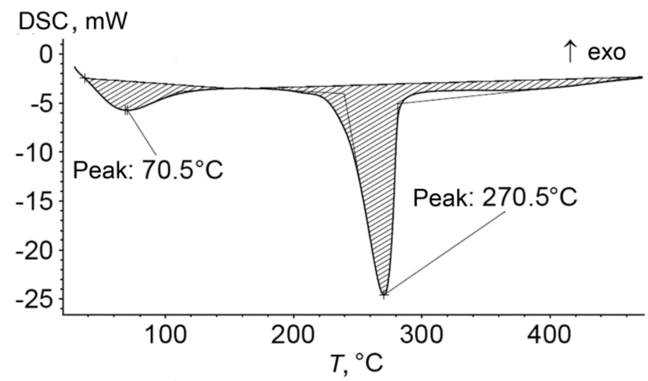

Fig. 4

Fig. 3. X-ray diffraction patterns of powders prepared by PLA of Al in H_2O: curve *1* is for the initial sample, curve *2* is for the same sample with air purging during PLA, curve *3* is after annealing at 300°C, and curve *4* is after annealing at 500°C.

Fig. 4. Thermogram of the aluminum hydroxide powder prepared by PLA of aluminum in water and drying of the dispersion.

REFERENCES

1. G. Yang, ed., Laser Ablation in Liquids: Principles and Applications in the Preparation of Nanomaterials, Pan Stanford Publishing Pte. Ltd., Singapore (2012).
2. V. A. Svetlichnyi and I. N. Lapin, Russ. Phys. J., **56**, No. 5, 581–587 (2013).
3. T. Sasaki, Y. Shimizu, and N. Koshizaki, J. Photochem. Photobiol. A., **182**, 335–341 (2006).
4. G. Viau, V. Sollière, L.-M. Lacroix, and G. A. Shafeev, Chem. Phys. Lett., **501**, 419–422 (2011).
5. S. Lee, J. H. Shin, and M. Y. Choi, J. Nanopart. Res., **15**, Art. No. 1473, 1–8 (2013).
6. M. A. Gondal, T. A. Fasasi, A. Mekki, *et al*., Nanosci. Nanotechnol. Lett., **8**, No. 11, 953–960 (2016).