Research of materials for porous matrices in sol-gel systems based on silicon dioxide and metallic oxides

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Abstract. In this study silicon dioxide – stannic oxide and silicon dioxide – zinc nanomaterials oxide were obtained through sol-gel technology. The results of nitrogen thermal desorption measurements, atomic force microscopy measurements and particle sizes measurements are discussed.

1. 1. Introduction

Currently, the “quantum dots – poromeric inert matrices” hybrid systems have become broadly used. The advantage of quantum dots in porous inert matrices is stability of sizes; in systems with quantum dots the density of radiating centers can be significantly higher than that in polycrystalline materials. Porous matrices must be optically transparent when photoluminescent particles are introduced into them. To develop electroluminescent structures, it is necessary to form highly-conductive wide-gap layers. In this respect the materials of sol-gel systems based on silicon dioxide and metallic oxides are most promising.

The purpose of this study is researching different stages of sol-gel synthesis of materials in silicon dioxide – stannic oxide and silicon dioxide – zinc oxide systems [1-4].

2. Experiment

In this study an inorganic salt $Zn(NO_3)_2 \cdot 6H_2O$ as the precursor of zinc oxide, $SnCl_2 \cdot 2H_2O$ as the precursor of stannic dioxide and tetraethoxysilane as the precursor of silicon dioxide were selected. To control properties of the synthesized nanomaterial surface, the nitrogen thermal desorption and atomic force microscopy were used.

AFM experiments were performed using NTEGRA-Therma nanolaboratory (NT-MDT, Zelenograd, Russia). Commercial etched silicon tips NSG 01 (NT-MDT, Zelenograd, Russia) with typical resonance frequency of 150 kHz were used as AFM probes. Specific surface area measurements were made using Sorbi № 4.1 (CJSC «META», Novosibirsk, Russia) that realizes physical adsorption of noble gas by the sample to be studied [5].


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3. Results and discussion

In the course of this study the samples of xerogels in the "silicon dioxide – stannic oxide" and "silicon dioxide – zinc oxide" systems were obtained, and specific influence of sol-gel synthesis conditions on the specific surface area and morphology of samples surface was investigated. As an example figure 1 presents AFM images of 85% SiO_2 – 15% SnO_2 layer obtained with various centrifuge speeds.

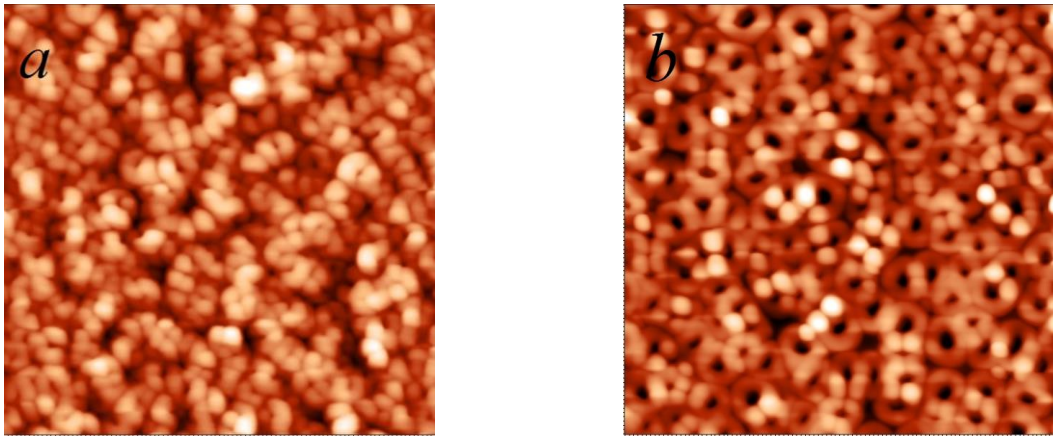

Figure 1. AFM images of 85% SiO_2 – 15% SnO_2 layers obtained with various centrifuge speeds: a – 5000 rpm , b – 1000 rpm (scan size area is 5 * 5 μm)

As it can be seen from figure 1 the reducing of centrifuge speed leads to formation of porous structure with a large pore size. This structure may be promising for deposition of the quantum dots. So by varying the centrifuge speed we can change the porous matrix and the sizes of deposited quantum dots.

Analysis of adsorption-desorption, capillary condensation and study of the pore size distribution were carried out on powders. Figure 2 presents the full adsorption/desorption isotherm for the sample of 85% SiO_2 – 15% SnO_2 powder. A relative error of the method is 6 %. The features of method are discussed in [6]. The results are shown in table 1.

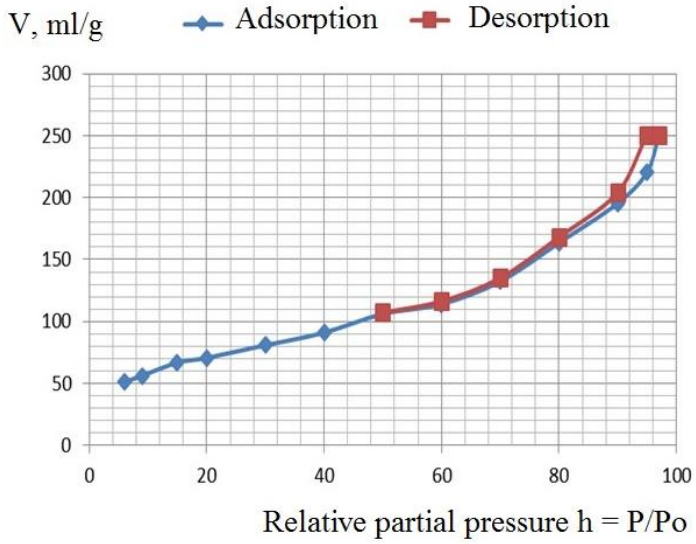

Figure 2. Full adsorption/desorption isotherm for the sample of 85% SiO_2 – 15% SnO_2 powder

Table 1. Sizes of pores of the 85% SiO_2 – 15% SnO_2 powder taken by full adsorption isotherm

D_i, nm	V_i/V_{total}, %
2.5	7
3	17
4	30
7	29
15	17

It was determined that the lion's share of pores in SiO_2 – SnO_2 materials has average dimensions of 3 nm, and 15 nm. Such systems can be perspective for injection of lead chalcogenide and cadmium chalcogenide quantum dots.

In case of silicon dioxide – zinc oxide system, the dependence of the heating temperature on layer structure was analyzed. Figure 3 presents AFM images of the surface of 80%ZnO-20%SiO_2 nanocomposites obtained at different annealing temperatures: a - 300°C, b - 400°C, c- 500°C,d - 600°C.

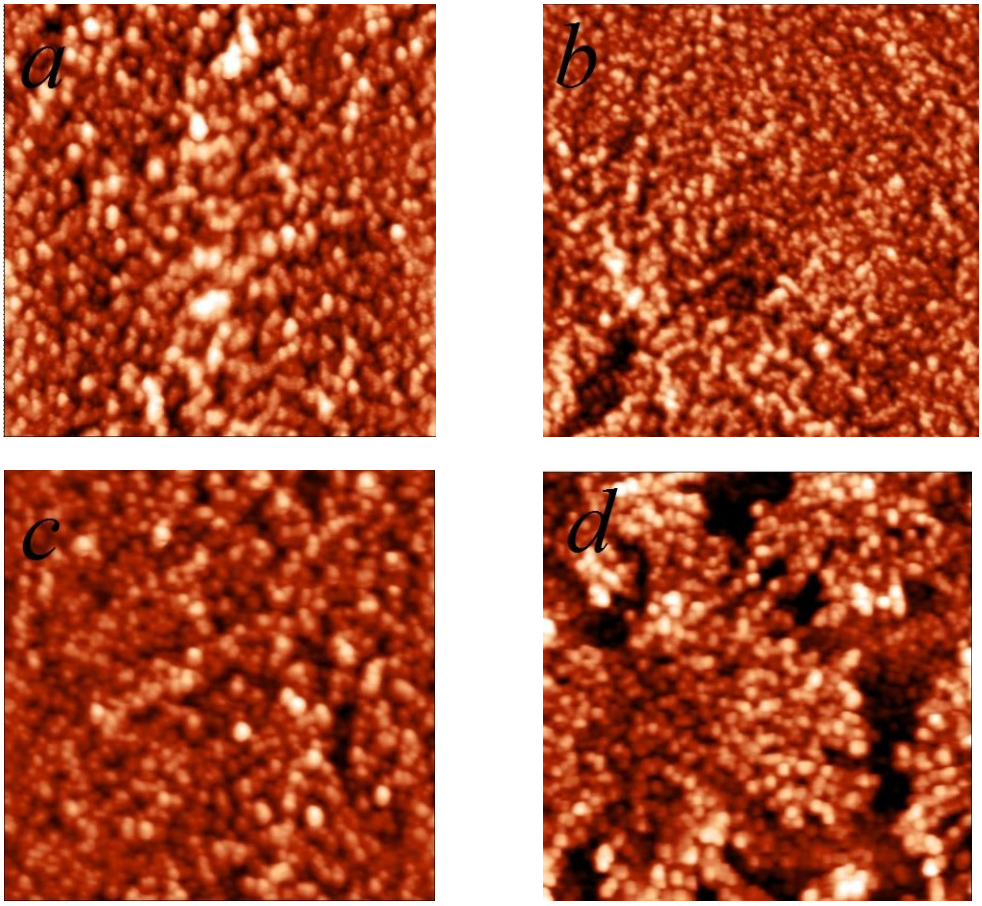

Figure 3. AFM images of 80%ZnO-20%SiO_2 layers obtained at different annealing temperatures: a - 300°C, b - 400°C, c- 500°C, d - 600°C (scan size area is 10 * 10μm)

As it can be seen from figure 3, the annealing temperature directly affects the distribution and size of the particles formed. Increasing of the annealing temperature leads to the reduction of particle sizes. The most uniform distribution of the particles is observed for the sample annealed at 500°C.

Conclusions

The experimental results show that by varying the synthesis parameters (such as centrifuge speed, annealing temperature) we can change the porous matrix and the sizes of deposited nanoparticles, for example quantum dots. The obtained results are perspective for optimizing the conditions of production of xerogels with required parameters.

Acknowledgments

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