

Fractal analyses of porous sol-gel nanocomposites modified by fullerenol $C_{60}(OH)_n$ ($n = 22-24$)

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Abstract. In this study silicon dioxide – tin dioxide nanomaterials modified by fullerenol were obtained through sol-gel technology. The porosity changes caused by the fullerenols addition are discussed.

1. Introduction

Fullerenols are among the most important and promising fullerene derivatives which can be easily synthesized with readjusting properties by varying the number of hydroxyl groups [1-3]. The aim of this study was to investigate the influence of the fullerenols $C_{60}(OH)_n$ ($n = 22-24$) addition on features of $SiO_2 - SnO_2$ sol-gel system layers formation using the method of fractal dimension determining.

2. Experiment

In this study sol-gel method for porous layers formation was chosen [4-9]. An inorganic salt $SnCl_2 \cdot 2H_2O$ as the precursor of tin dioxide and tetraethoxysilane as the precursor of silicon dioxide were selected. Buthanol (C_4H_9OH) was used as a solvent. The modifying agent (fullerenol $C_{60}(OH)_n$ ($n = 22-24$)) was introduced at the stage of preparing the solution, i.e. sol, and the concentration of fullerenols in the alcohol was 1 mg/l. To obtain powders, 10 % aqua ammonia (NH_4OH) was added to the solutions-sols. The powders were heat-treated for 30 minutes at the temperature of 600 °C.

AFM experiments were performed using NTEGRA-Therma nanolaboratory (NT-MDT, Zelenograd, Russia). Commercial etched silicon tips NSG 01 with typical resonance frequency of 150 kHz were used as AFM probes. X-ray diffraction experiments were carried out on «DRN Farad» ($Cr-K\alpha$). The original program for the analyses of the patterns fractal dimension by the method «perimeter - square» was used [10].



3. Results and discussion

During the experiments, a series of samples of the "silicon dioxide – tin dioxide" system was obtained using the sol-gel method which was both modified and not modified by fullerenols, with different ratios of components (mol. %): 90% SiO₂–10% SnO₂; 50% SiO₂–50% SnO₂. Some technological features are discussed in [11].

The microstructure of the synthesized samples was investigated by the atomic force microscopy method in the tapping mode in the NTEGRA nanolaboratory. Figure 1 illustrates the morphology of the sample surface containing 10 mol. % SnO₂ and 90 mol. % SiO₂ without and with the addition of the C₆₀(OH)_{*n*} (*n* = 22–24) fullereneol. It has been found that the addition of the fullereneol greatly affects the morphology of the surface of the oxide composite: the density of grain distribution and their average size increases [11]. The atomic force microscopy data indicate that on the surface of the sample prepared with addition of the fullereneol aggregates of ~2 microns observed in figure 1 (a) are not formed.

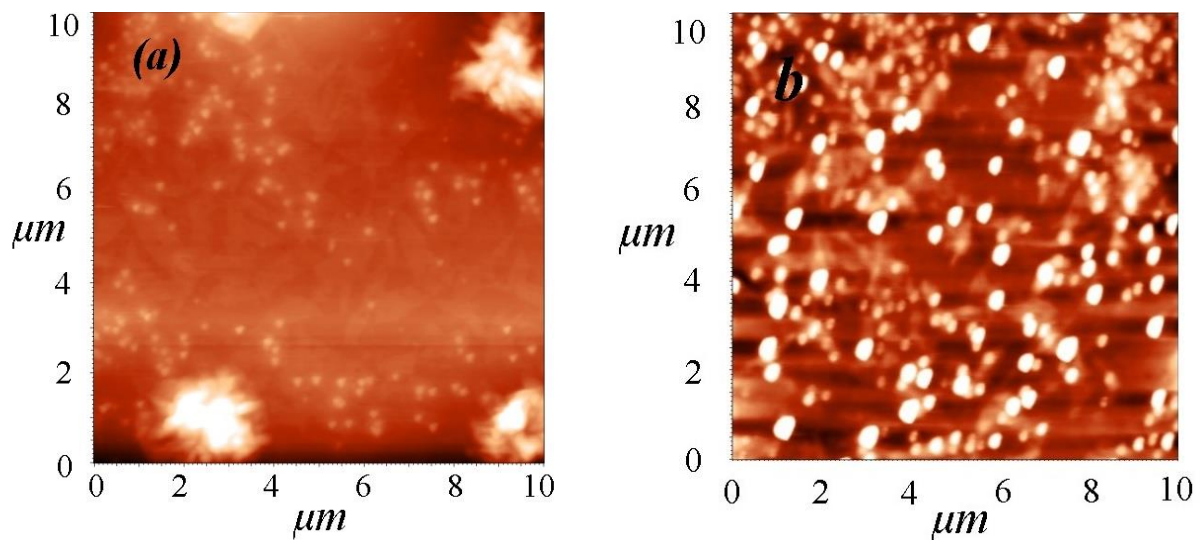


Figure 1. AFM images of the sample containing 90 SiO₂–10 SnO₂ (mol. %) synthesized without adding the fullereneol: (a) and synthesized with the addition of the fullereneol (b) (scan space size - 10 × 10 μm²)

In the figures 2 (a, b) the dependences $S_c(\delta) = f[P_c(\delta)]$ in logarithmic coordinates for the patterns shown in the figures 1 (a, b).

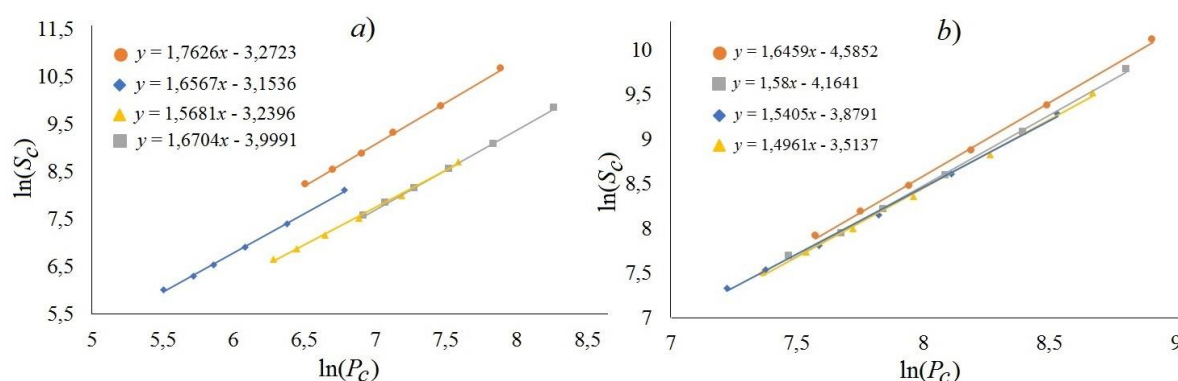


Figure 2. The dependences $S_c(\delta) = f[P_c(\delta)]$ for 4 horizontal cross-sections of the patterns 90 SiO₂–10 SnO₂ (mol. %) synthesized without adding the fullerene: (a) and synthesized with the addition of the fullerene (b)

The slope coefficient reducing for all the lines corresponds to rising of the height at that the cross-section was made. It can be seen from the figures that the addition of fullerenols in initial solution results in the reducing of the line's slope coefficient (fractal dimension meanings are $D_f=1.83$ for the first image and $D_f=1.78$ for the second one).

4. Conclusions

Porous nanocomposites based on silicon dioxide – tin dioxide both modified and not modified by fullerenols were obtained using sol-gel method. It was determined that the introducing of fullerene $C_{60}(OH)_n$ ($n = 22-24$) in silicon dioxide – tin dioxide nanocomposites results in reducing of fractal dimension, that argues for new porous system formation. It is shown that the method of fractal dimension determining «perimeter - square» can be used for analyses of porosity changes caused by the fullerenols addition.

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