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USING THE IMAGEJ SOFTWARE FOR DETERMINING PARAMETERS OF MICROSTRUCTURE OF NANOPOROUS MATERIALS BY THE RESULTS OF SEM IMAGE PROCESSING

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Abstract. The results of studies of the microstructure parameters of nanoporous materials using the ImageJ program are presented. Pore diameter of the nanoporous anodic aluminum oxide was determined from the results of processing the SEM images of the film surface. An algorithm for processing images for determining the pore diameter in nanoporous materials was proposed. The results obtained for the nanoporous structure of the materials under investigation are in a good agreement with those available in the literature.

Key words: nanoporous materials; surface morphology; microstructure; SEM images, ImageJ.

Advances in the development of science and technology are inextricably linked with the development of new materials for various industrial applications. In the last decade in the field of science and technology, a new direction, such as nanotechnology, has been actively developed. Nanotechnologies are aimed at the creation and application of nanostructured materials, the main properties of which are determined by a special structure, including ordered elements ranging in size from 1 to 100 nm. The size and structure of nanoparticles have a significant effect on the physic-chemical characteristics and properties of nanomaterials. Therefore, an important task is the development of special methods and techniques of research aimed at studying the structural, morphological, topological, mechanical, electro-physical, optical, biological characteristics of nanomaterials and nanosystems, analyzing the quantities of nanoparticles and measuring nanoscale for individual elements.

One of the promising materials for use in nanotechnology is anodic aluminum oxide with a nanoscale structure. At present, the study of the properties of anodic aluminum oxide is of great interest because of its unique physico-chemical properties: an array of nanosized pores, a self-organized highly ordered cellular-porous structure, and the ability to control the properties of the porous structure at the formation stage [1]. The special properties of the material allow the use of nanoporous anodic aluminum oxide for such purposes as molecular separation (chemical and biochemical filtration), the manufacture of sensors and biosensors, the synthesis of various nanomaterials (nanodots, nanotubes, nanowires) and as memory elements with high data recording density. To expand the areas of application of anodic aluminum oxide and increase the reproducibility of the parameters of its microstructure, it is necessary to know the patterns of formation of a nanomaterial structure and to accurately control their geometric parameters [2,3].

Since the basic properties of nanoporous anodic alumina depend on the pore size, it becomes

necessary to use statistical analysis methods to process large arrays of nanosized pores and develop a methodology and algorithm to study the features of morphology and nanoscale structure and automate the measurement process.

For digital processing of SEM images of the nanoporous surface of anodic alumina films, the ImageJ program was used. This program includes all the necessary functions for digital image processing. For the processing and analysis of the characteristics of the nanoporous structure of anodic alumina, the following algorithm was used in the program ImageJ:

1 Convert an image into 8 bits to enhance the contrast and simplify the subsequent analysis;

2 Elimination of random noises (which appears due to surface defects and random pore bonds) using the filter function;

3 Segmentation of the image (separation of the background from important nanoscale structures) to find the threshold value (threshold) in order to fully determine the object;

4 Analysis of selected objects.

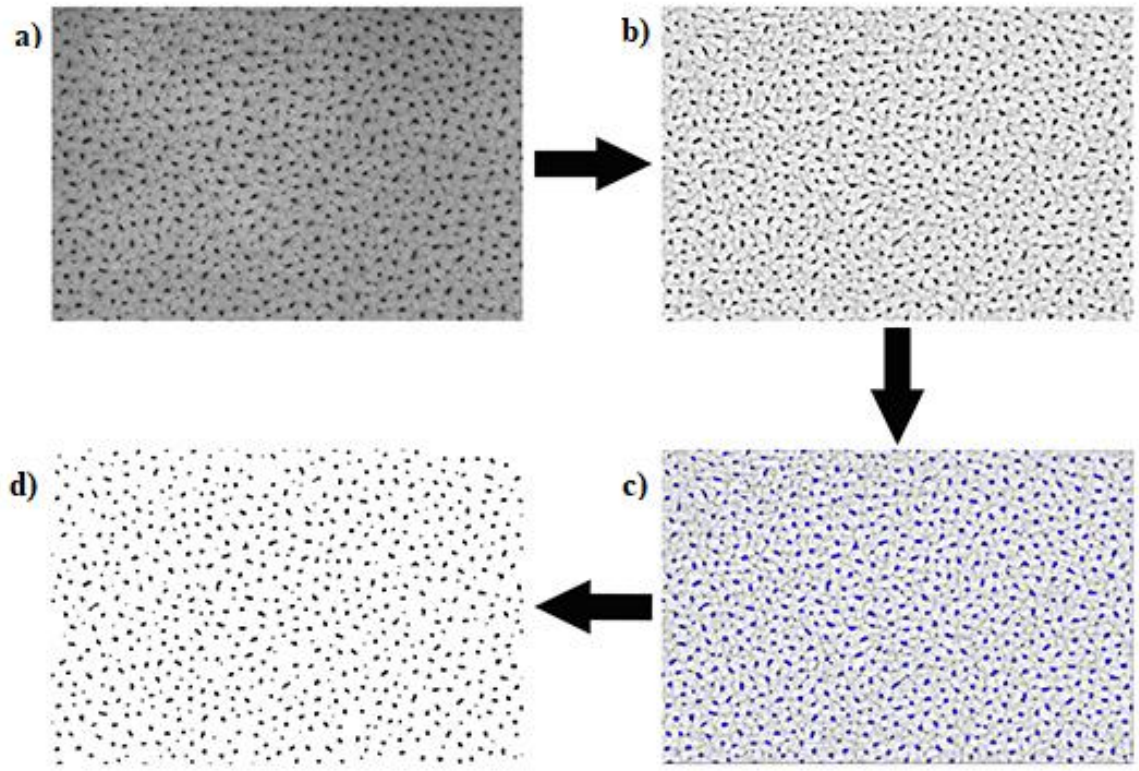

Figure 1. The processing scheme of SEM images of the nanoscale objects using ImageJ software: a) original SEM image, b) contrast enhanced image, c) thresholded image, d) final image

The ultimate task of image analysis is statistical processing of the results obtained by measuring the characteristics of a material with a porous structure, determining the average values of pore diameters, and also plotting graphs to visualize the analysis process. The pore diameter distribution and the mean pore diameter were calculated from the SEM images using the ImageJ image processing software.

As an object of investigation, anodic alumina films with large and small pores were used. The main pore diameter was calculated from the SEM images using the ImageJ software. Since only the data on the main pores are of practical importance, and the presence of the initial pores interferes with the analysis, some of the pores with a small diameter were not taken into account when approximating. To this end, only one smaller value was left to the maximum on the pore size distribution curve.

The maximum on the Gaussian curve corresponded to d_{pore}. To obtain correct results, the SEM images were processed at least ten times and a new time was selected each time for comparison.

To visualize the analysis process, histograms of the pore diameter distribution on the sizes using the Origin package were plotted. The algorithm used in the ImageJ program was tested using SEM images of various samples with different magnification, resolution, and pore sizes of the anodic alumina. Digital image processing of the nanoporous structure in the ImageJ program provided a good estimate of the pore size distributions for all the samples investigated.

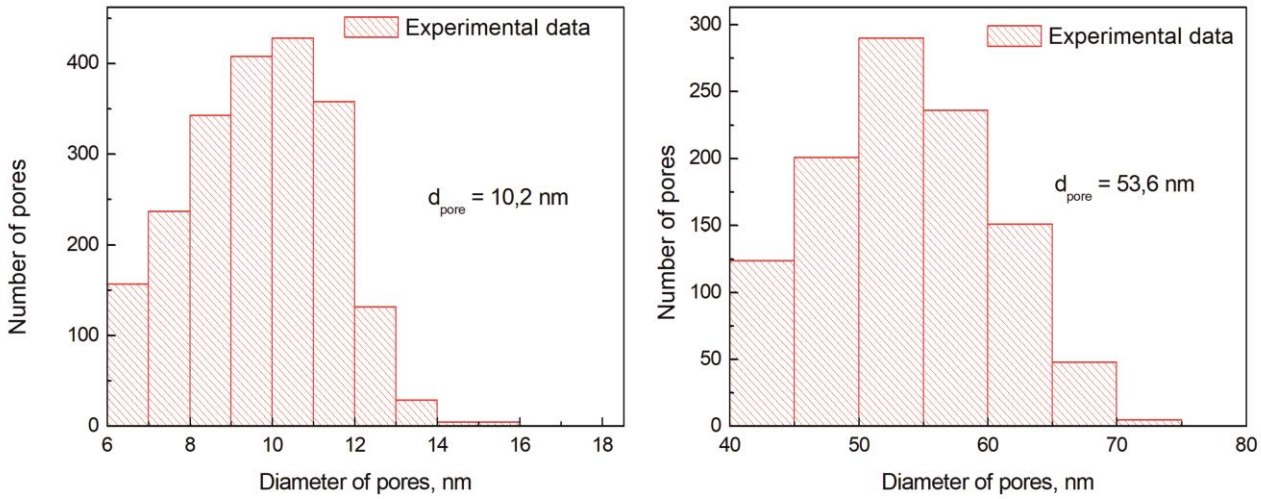

Figure 2. Histograms of the pore size distribution by the image processing results in the ImageJ program for porous anodic alumina films with small a) and large b) pore diameters

Our results shows that d_{pore} = 10.2 nm (fig.2a) for porous alumina films obtained in sulfuric acid and d_{pore} = 53.6 nm (fig.2b) for the anodic alumina films obtained in oxalic acid. The parameters of the structure of porous alumina films obtained in our work coincide with the data reported in [4]

The results of the studies led to the conclusion that the ImageJ image analysis program is a suitable tool for quantitative analysis of the morphology of anodic aluminum oxide films with nanoscale pores. Data processing in the ImageJ program allowed to calculate the mean pore diameter of anodic alumina films obtained under different conditions.

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