

SOFTWARE FOR INVESTIGATION OF STATISTICAL PARAMETERS OF MICROSTRUCTURE OBJECTS

Abstract. Using the languages HTML5, CSS3, JavaScript and Canvas technology, the software for processing of the electron microscopy data has been created. The software allows obtaining the information about statistical parameters of microstructure objects using the scanning data of bitmap obtained by electron microscope.

Keywords: web application, bitmap, scanning, electron microscopy, histogram.

Statement of the problem and purpose of research. The data about microstructure of materials usually get by electron microscope [1]. Electron microscopy data are bitmaps containing the information about statistical parameters of microstructure objects: crystallites, pores and phase inclusions. These parameters are the average sizes of microstructure objects, their standard deviation and the statistical distribution law obtained usually in the form of histogram.

When the scale of bitmap is known the measuring of objects parameters it is possible by means scanning of there coordinates. This requires the appropriate software. Because using the software for bitmaps scanning gives an absolute error of ± 1 pixel, the measurement of the objects parameters can be performed with high accuracy (the relative error is not more than $\pm 1\%$) [2]. Significant opportunities for creating of such software have the means using in the Internet: formatting languages HTML, CSS, object-oriented programming language JavaScript and Canvas technology for using the vector graphics on web pages. The environment for executing programs created by such means is the Internet browsers.

The purpose of this work is to create the software for studying the statistical characteristics of the geometric parameters of microstructure objects based on scanning data of bitmaps obtained by electron microscope.

Major part. With a known scale M_L of a bitmap obtained by electron microscope, it is possible to measure the dimensions of a microstructure objects by scanning of their coordinates [2].

In this work, a statistical sample of N sizes was formed on the basis of scanning the coordinates of each microstructure object of the same type in four points located on its boundary. In this case, for each object, two sizes L_i and L_{i+1} were obtained which were added to the statistical sample N . If the coordinates of the four points are (x_1, y_1) , (x_2, y_2) , (x_3, y_3) , (x_4, y_4) , then the sizes L_i and L_{i+1} were calculated by the formulas:

$$L_i = M_L \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

$$L_{i+1} = M_L \sqrt{(x_3 - x_4)^2 + (y_3 - y_4)^2} \quad (2)$$

At scanning the different quantity of similar objects of microstructure, it is possible to obtain the statistical samples with different quantity N of sizes L_i . This allows to studying the dependence of statistical parameters of objects on the size of statistical sample N . Average size L_{av} of microstructure objects and its root-mean-square deviation σ_L were calculated as:

$$L_{av} = \frac{1}{N} \sum_{i=1}^N L_i, \quad (3)$$

$$\sigma_L = \pm \sqrt{\frac{1}{N} \sum_{i=1}^N (L_i - L_{av})^2}. \quad (4)$$

The histogram allows obtaining the information about statistical law of object's size L_i distribution. For build a histogram it is necessary to determine the maximum L_{max} and the minimum L_{min} values of object size in the random sample N . The number of histogram intervals k was determined by the Sturges formula [3]:

$$k = 1 + \lfloor \log_2 N \rfloor. \quad (5)$$

The length of the histogram interval ΔL calculates by the formula:

$$\Delta L = \frac{L_{max} - L_{min}}{k}. \quad (6)$$

The probability P_j when the size of object L_i is falling into the interval $L_{min} + j\Delta L \leq L_i \leq L_{min} + (j+1)\Delta L$ ($0 \leq j \leq k-1$) was calculated as

$$P_j = n_j/N, \quad (7)$$

where n_j is the number of L_i values hits into interval j of histogram.

In view of the above, the algorithm of program for processing the bitmap of the microstructure obtained with an electron microscope includes the following stages: 1). Selecting file of bitmap in the computer's file system and loading it into a browser window; 2). Embedding bitmap into a canvas in order to visualize the results of scanning by means Canvas technology; 3). The scaling of bitmap; 4). Scanning the

coordinates of microstructure objects; 5). Creation of a selection of N sizes L_i by calculating according to formulas (1), (2) on the base of arrays containing the scanned coordinates; 6). Calculation the values L_{av} and σ_L by formulas (3), (4); 7). The construction a histogram of size distribution for studied microstructure object; 8). Output the results of processing.

The interface of program is implemented as a web page (Fig. 1). It contains a toolbox in the top right corner of the browser window, which consists of the blocks "Image upload" and "Processing blocks". To the left of the toolbox block there is the navigator for view the current coordinates of cursor. These coordinates are displayed in pixels in the hidden fields of forms. The "Build histogram" button is intended for launching the program script provides building of histogram. For histogram construction an additional canvas uses in the web page. It locates in the lower right corner of the browser window and has the sizes of 700×450 pixels. The main canvas for embedding the bitmap of microstructure located in the top left corner of the browser window and has the sizes of 1050×780 pixels.

The "Image upload" block contains a form field of the "file" type. The button «Choose File» of this field supplies the user to select a file of bitmap in the computer file system. When he presses the "Download" button, the bitmap is embedded into canvas for providing its further procession.

The "Processing blocks" block contains buttons "Scaling", "Creating a statistic sample", "Correction", "Reset" and an empty space where the hidden blocks "Scale definition" and "The average size" are located. These blocks are opened at the corresponding stages of the program algorithm. Scaling of bitmap performs after pressing the "Scaling" button. When the button "Creating a statistic sample" is pressed, the block "The average size" is opened. This block allows the user to create by scanning the statistical sample N of the sizes L_i for objects in investigated microstructure. The button "Correction" allows correction the scanning results. When this button is pressed, the coordinates of the last scanned point are removed from the coordinate arrays and its image on the bitmap is erased. The "Reset" button is intended for complete clearing of the coordinate's arrays, clearing the forms fields for results, erasing the visual display of scanning points and removing the histogram from the additional canvas. This allows performing the statistical analysis for other object of microstructure.



Figure 1 - Web page after loading the program

The program begins from bitmap loading at pressing the "Choose File" button. The user selects necessary file in standard "Windows" window and presses the "Open" button in this window. Then image builds into canvas at click the "Download" button.

When pressing the "Scaling" button, the program opens the hidden block "Scale definition" (Fig. 2). This block contains a form field for entering the value of calibration length " L_c =" and the button "Calculate". The user must enter the value of calibration length L_c indicated on bitmap of microstructure and scan the ends of segment corresponding to this length. Scanning is performed by pointing the cursor to the selected point of bitmap and then clicking the left mouse key. In this case the "mouseup" event starts a script that reads the coordinates x_i , y_i of point using the "event" object properties "pageX" and "pageY" of the JavaScript language. The coordinates are written to the corresponding arrays of program. After clicking the "Calculate" button, the scale value M_L of bitmap calculates and shows in the hidden field of the "Scale definition" block. Fig. 2 shows the program web page at the final stage of bitmap scaling.

Note that Fig. 2 shows the raster image of microstructure tin dioxide (SnO_2) based varistor ceramics. The main microstructure objects of this ceramics are the crystallites of SnO_2 and pores.



Figure 2 - Web page of program at the final stage of bitmap scaling

For go to the stage of objects coordinates scanning in bitmap the user must click the "Creating a statistic sample" button (Fig. 2). This hides the "Scale definition" block and opens the "The average size" block (Fig. 3). This block contains the hidden fields preceded by the inscriptions "Sample size N =", "Size L_{av} =", "Standard deviation = ". These fields are assigned to output of the sample size N , the average size of microstructure object L_{av} and the standard deviation of the sizes σ_L , respectively.

Scanning performs for each microstructure object in four points of its boundary. The program marks the scanning points with red circles connected by white lines (Fig. 3). When the "Calculate" button is pressed, the program script calculates the average value of the object size L_{av} and its standard deviation σ_L based on the statistical sample N . The values of N , L_{av} , σ_L output to the hidden fields of form in "The average size" block (Fig. 3). At pressing the "Build histogram" button, the histogram of sizes distribution is built. Fig. 3 shows the view of program window at the final stage of procession at study the statistics of SnO_2 grains sizes distribution in SnO_2 based varistor ceramics (the statistic sample of SnO_2 grains sizes $N=52$).

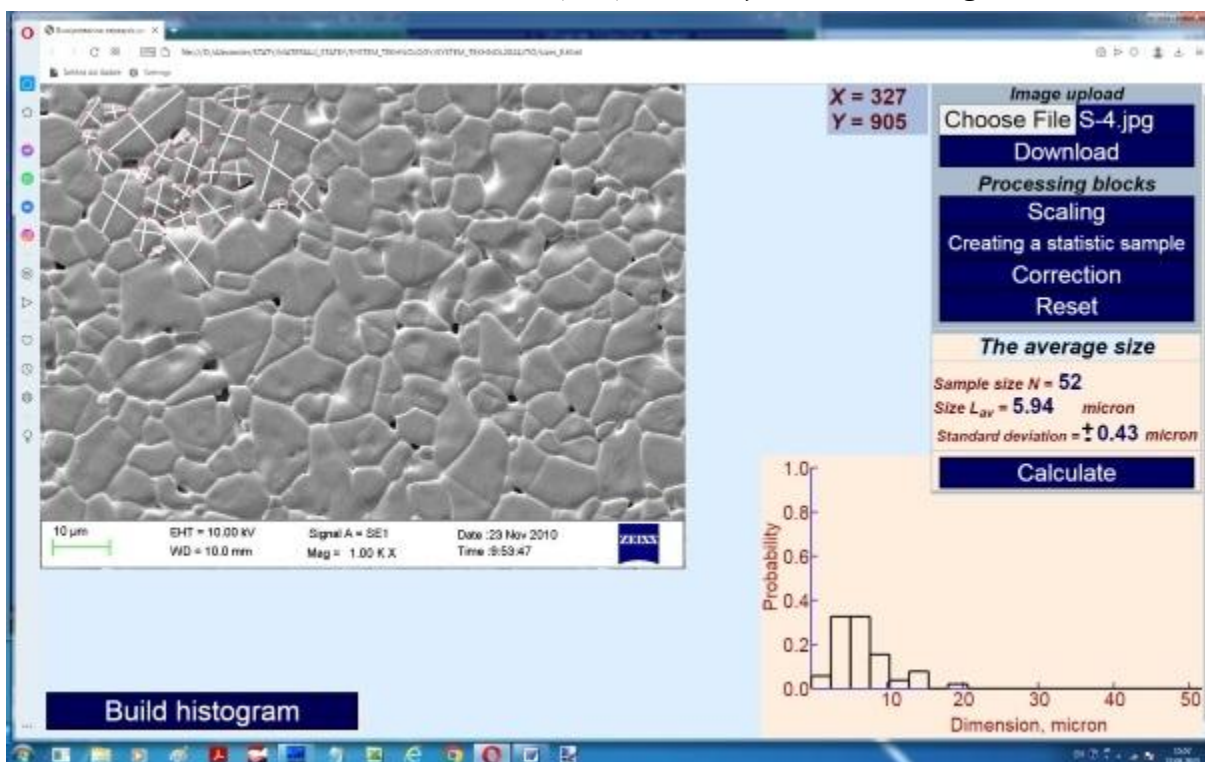


Figure 3 - Web page of program at the final stage of investigation the size distribution of SnO₂ grains in SnO₂ based varistor ceramics (N = 52)

Described program has possibility to scan the coordinates of different objects in bitmap of electron microscope and to obtain the statistic samples with different N . This gives possibility to investigate the dependence of static parameters on the sample size N . Fig. 4 shows the program window at the studying the distribution of grains size in SnO₂ based ceramics for varistors when the statistic sample is $N = 520$.

At pressing the "Reset" button, the arrays for storage of scanned coordinates and the form fields for results output are cleared. This enables the user to perform statistical studies of other objects of microstructure. Fig. 5 shows a program window after study the statistics of pore size distribution in SnO₂ based varistor ceramic.

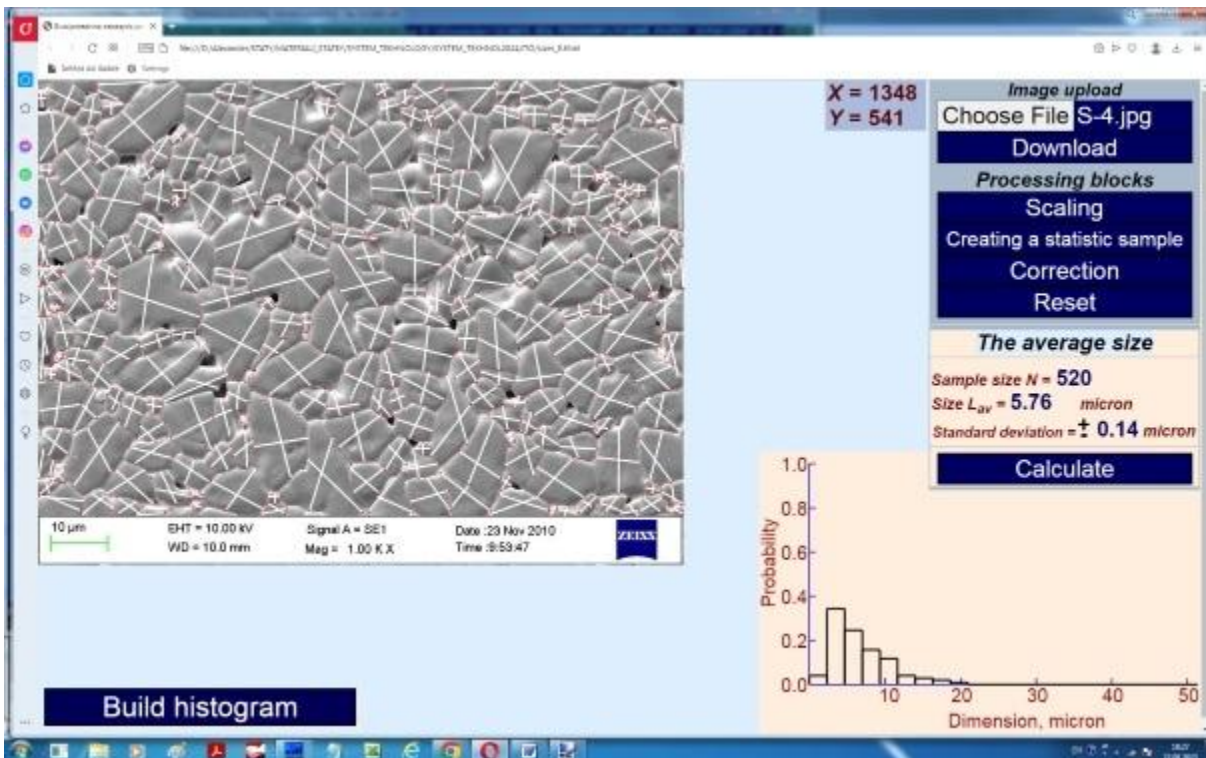


Figure 4 - The program web page with results of study the distribution of grains sizes in SnO₂ based varistor ceramics ($N = 520$)

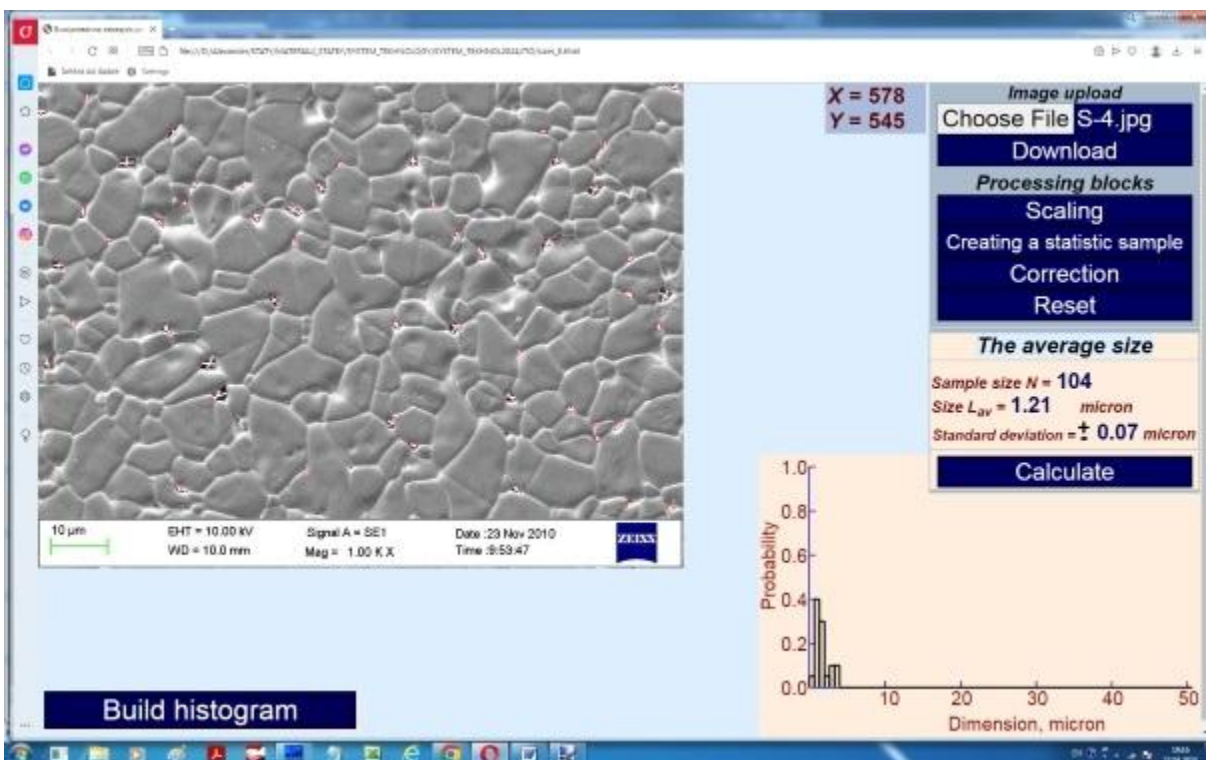


Figure 5 - The program web page with results of study the distribution of pore sizes in SnO₂ based varistor ceramics ($N = 104$)

Conclusions. On a basis of means for presenting information in the Internet (the languages HTML5, CSS3, JavaScript and Canvas technology) an applied web application has created to study the statistical parameters of the materials microstructure objects. The web application gives possibility for users to measure the average size and its standard deviation for objects of electron microscope raster images and to build the histogram of sizes distribution. For measuring uses the coordinates of objects, which user obtains by click in select points of the microstructure bitmap obtained by an electron microscope. The environment for using of software is the Internet browsers.

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Програмне забезпечення для дослідження статистичних параметрів об'єктів мікроструктури

Інформацію про мікроструктуру матеріалів отримують за даними електронної мікроскопії як растрові зображення. Такі зображення, при відомому масштабі, надають можливість виміряти розміри об'єктів мікроструктури (кристалітів, пор, укруплень фаз, тощо). Статистичне вибирання розмірів дозволяє дослідити статистичні характеристики цього параметру. Вимірювання розмірів можна здійснити на підставі даних сканування координат об'єктів мікроструктури. Таке сканування потребує розробки відповідного програмного забезпечення (ПЗ).

Метою роботи є створення засобами HTML5, CSS3, JavaScript і технології Canvas ПЗ для дослідження статистичних параметрів об'єктів мікроструктури: середнього розміру, середньоквадратичного відхилення розміру та гістограми розподілу розмірів. Для вимірювання розмірів об'єкту мікроструктури виконується сканування координат в чотирьох точках його границі. За цими координатами для окремого об'єкту мікроструктури розраховуються два розміри. При скануванні різних однотипних об'єктів мікроструктури створюється статистичне вибирання розмірів об'ємом N. Програма надає можливість створювати статистику

стичне вибирання будь якого об'єму N . Це дозволяє дослідити залежність статистичних параметрів від N .

Інтерфейс програми реалізовано у вигляді веб-сторінки. Програмним середовищем для її виконання є браузері мережі Інтернет.

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