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THE STUDY OF GEOMETRIC DISTORTION OF DIGITAL SEM IMAGES OBTAINED AT SEM-106 I (SUMY, UKRAINE)

O. Ivanchuk
Lviv Polytechnic National University

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Statement of the problem

Digital images obtained in scanning electron microscope (SEM) significant inherent geometric distortions. They do not take into account significantly reduces the accuracy of quantitative spatial characteristics of micro-surfaces of the objects that can be obtained by methods of digital SEM-stereophotogrammetry. Therefore, the quantitative parameters of different surfaces to be obtained with the highest possible accuracy to ensure high quality and efficiency of various products in many industries: engineering, micro-electronics, aircraft, with the creation of space and military equipment and so on.

Analysis of recent research and publications devoted to the solution of this problem

Scientists involved in this issue since the creation of the first SEM both in our country and abroad. The most important publications on the subject we presented the list of references [1-16]. In a previous publication [8] led by the results of studies of linear (large-scale) component of the geometric distortion of digital SEM images obtained on the local SEM-106I. In this article the results of research quantities of nonlinear integral geometric distortion of digital images (distortion).

Remaining part of the general problem

Digital SEM images obtained at SEM-106I created in Sumy plant «SELMI», studied for the first time. It was important to examine not only the size and nature dystorsiynyh image distortion, but the possibility of their effective incorporation.

Problem

To investigate the magnitude and nature of nonlinear geometric distortion of digital SEM images based on measurements of a reference image of a special test facility with a resolution of r = 1425 lines / mm, obtained for SEM-106I magnifications ranging from 1000h to 30000h.

Set accuracy incorporation of geometric distortion of digital SEM images by polynomial approximation of the general form of the third degree.

The main material and research results

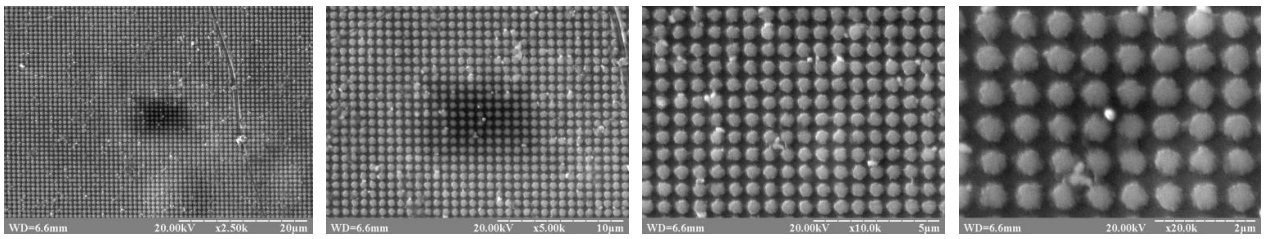
1. The SEM-removal.

During SEM-removal was obtained 9 pictures benchmark test object (mesh) with a resolution of r = 1425 lines / mm with fixed values increase: 1000h, 2500h, 5000h, 8000h, 10000h, 15000h, 20000h, 25000h, 30000h. Images recorded in digital format BMP (Fig. 1). Scan digital SEM images on the screen REM is 1280x960 pixels. A feature of these images is that their real scale (increase) only roughly corresponds to the scale set to REM when they are on screen size 120x90 mm. The physical pixel size in this case is 0.09375 mm. However, the photogrammetric processing of digital SEM images using a special software package «Dimicros», their real (conventional) size on the screen is much larger and is 338,56x253,92 mm and 0.2645 mm pixel size . Thus, the conversion factor to determine the actual scale of digital images for each of its fixed value is approximately k = 2,8213.

2. Measuring SEM images of test object.

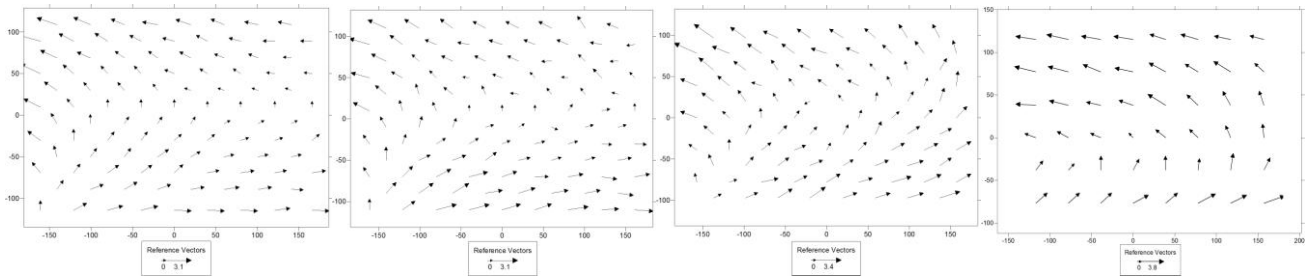
For photogrammetric processing of digital SEM images of Geoionformatic Master I.V. Khrupin algorithm was created by a group of programs under the title «Dimicros» [4]. The program «Test-Measuring» allows to measure digital SEM images of a special test object, resulting in the establishment of their real value increases along the axes *x* and *y* image and geometric distortion values evenly throughout the field image. The following program «Polycalc» the results of calculations performed by the program «Test-Measuring» and using the general form of the polynomial 3rd degree, calculates corrections to the measured coordinates of the points (intersections) test object (test-grid) and mean square error values residual distortion, that establishes the accuracy of the approximation of geometric distortion polynomial (Table 1).

On each image was measured (uniformly throughout the field photo) different number of points: 35 points (at M = 30000h) to 200 points (with M from 1000h to 10000h fold). In Fig. 2. and Fig. 3 given vector diagrams of geometric distortion REM - pictures before and after their approximation.



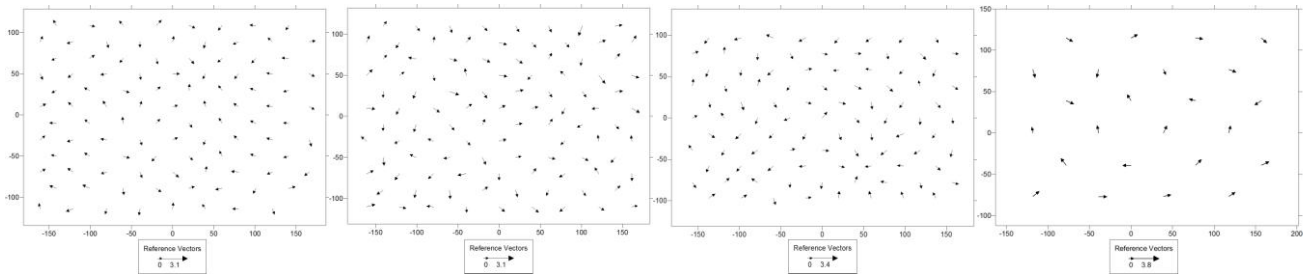
a) M = 2500h b) M = 5000h c) M = 10000h d) M = 20000h

Fig. 1. Digital-SEM images of test object at a resolution r = 1425 lines/mm at different magnifications M



a) M = 2500h b) M = 5000h c) M = 10000h d) M = 20000h

Fig. 2. Diagram Vector geometric distortion of digital images SEM-test object at different magnifications M to approximation.



a) M = 2500h b) M = 5000h c) M = 10000h d) M = 20000h

Fig. 3. Diagram Vector geometric distortion of digital images SEM-test object at different magnifications M after approximation.

Table 1

The results of the approximation of geometric distortion SEM images of test object with r = 1425 lines/mm

№ p/p	M_{SEM}	Valid values M		ΔM_x,%	ΔM_y,%	By approximating		After approximation	
		M_x	M_y			$m_{\Delta x}$, mm	$m_{\Delta x}$, mm	$m_{\delta x}$, mm	$m_{\delta y}$, mm
1	1000h	1014,50	1005,58	+1,45	+0,56	1,254	0,525	0,134	0122
2	2500h	2544,65	2517,18	+1,79	+0,69	1,085	0,534	0,155	0,127
3	5000h	5079,73	5024,04	+1,60	+0,48	1,186	0,586	0,257	0,239
4	8000h	7927,84	7875,68	-0,90	-1,55	1,274	0,222	0,173	0,159
5	10000h	9932,99	9832,54	-0,67	-1,67	1,289	0,906	0,211	0,219
6	15000h	14862,42	14650,90	-0,92	-2,33	1,306	0,482	0,309	0,219
7	20000h	19871,75	19491,75	-0,64	-2,54	2,179	1,260	0,347	0,307
8	25000h	24943,48	24318,29	-0,23	-2,73	1,424	1,069	0,301	0,261

Table 2

Accuracy of spatial coordinates of points micro surfaces for different magnifications M

	1000h	2500h	5000h	8000h	10000h	15000h	20000h	25000h
$3m^o_x = 3m^o_y$, mm	0,280	0,280	0,280	0,280	0,280	0,280	0,280	0,280
$M_X = M_Y$, mkm	0,280	0,112	0,056	0,035	0,028	0,019	0,014	0,011

Analyzing the results of research quantities from the measurements of geometric distortion of digital images of special test objects (Fig. 1), which are shown in Table. 1 as their mean-square values $m_{\Delta x}$ (mm), $m_{\Delta y}$ (mm) , we note the following: the absolute values of the geometric distortion of digital images in the conventional scale of measurement program «Test-Measuring» rather large , reaching a maximum value of ± 4 mm relative to the central point of the image in its size 338,56x253,92 mm. The nature of these distortions clearly show vector diagrams (Fig. 2), which have a spiral shape, which is essentially unchanged regardless of changes in value increase (scale) image in the range of 1000h to 25000h .

In bringing these images to the size of 120x90 mm, which corresponds to the scale of the images set to increase the scale of the SEM, the maximum value of distortion still reach values up to ± 1,5 mm (15 pixels). Obviously, it is necessary to take into account these distortions. Our studies using «Polycalc» reaffirmed the effectiveness of distortion polynomial approximation of the general form of the third degree. The research results are presented in Table 1 in the columns mean square error values $m_{\delta x}$ (*mm*), $m_{\delta y}$ (*mm*) after approximating polynomial. We see that these values are about an order of magnitude smaller than the initial values of distortion. Visually, the residual value of the geometric distortion as we are shown as vector diagrams (see Fig. 3). For photos size 120x90 mm maximum their value does not exceed ± 0,3 mm, ie 3 pixels. Thus polynomial approximation distortion enables approximately an order of magnitude increase the accuracy of the spatial coordinates of points explored various mikropoverhon solids. In Table. 2 shows the absolute values of the maximum possible error in the coordinates $M_X = M_Y = 3m^o_x/M_x^x = 3m^o_y/M_y^x$ (mkm) depending on the magnification (zoom) the picture they have a value between 0,28 mkm at M = 1000h to 0.01 mkm at M = 25000h. This makes it possible to obtain quantitative parameters of micro-surfaces of solids on the micron and submicron levels with high accuracy, which is so important in today's nano-technology in production.

Based on the studies, the following conclusions.

Conclusions

1. 1. Geometric distortion of digital images generated by SEM 106I domestic production (JSC «SELMI» Sumy) increases in the range of 1000h to 30000h quite large and reach maximum values of 1 to 1.5 mm (about 10 to 15 pixels). Visually, these distortions are spiral in nature almost regardless of size and increase their value increases with the distance from the center of the image to its edges.

2. Confirmed the effectiveness of the approximation of geometric distortion SEM images, the general form of a polynomial of the third degree, which allows them to reduce by 5-10 times.

3. SEM-106I can be considered high-tech scanning electron microscope, which allows you to receive high-quality digital images of micro-surfaces of solids with relatively minor distortions: linear (large-scale) within ± 1-3% and nonlinear (dystorsial) - maximum of ± 1,5 mm for image size 120x90 mm.

4. Through honiometrycal table in the SEM can obtain stereo images of experimental micro surfaces of solids, processing them into digital stereofohrammetryc Station (DPS) allows to obtain their spatial quantitative parameters with high accuracy:

from $m_x = m_y$ = **0,1-0,2** ***mkm,*** $m_{h(Z)}$ = **1-1,5** ***mkm*** at **M=1000h**;

to $m_x=m_y$=**0,005-0,01** ***mkm,*** $m_{h(Z)}$=**0,1-0,2** ***mkm*** at **M=25000h**.

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The study of geometric distortion of digital SEM images obtained by SEM-106 I (Sumy, Ukraine)

O. Ivanchuk

The results of these studies, geometric distortion of digital SEM images obtained are in SEM-106I increases ranging from M=1000h to M =25000h. After taking into account the relatively small linear (large-scale) distortions (ΔM = ± 3%), the residual nonlinear distortion geometry are still substantial - up to ± 1,5 mm (± 15 pixels) for images of size 120x90 mm. The method of polynomial approximation of geometric distortion into account , then their residual values do not exceed ± 0,3 mm (± 3 pixels). It enables spatial parameters mikrosurface quantitative research objects with high accuracy, in particular by increasing the (scale) image of M=1000h : $\boldsymbol{m_x = m_y}$ **= 0,1-0,2** ***mkm*****,** $\boldsymbol{m_{h(Z)}}$ **= 1-1,5** ***mkm***, and when M=25000h - $\boldsymbol{m_x=m_y}$**=0,005-0,01** ***mkm*****,** $\boldsymbol{m_{h(Z)}}$**=0,1-0,2** ***mkm***.