Forming the Panoramic SPM-Images Scans during Nanoparticles Dispersity

P.V. Gulyaev [1], E.Yu. Shelkovnikov [2], A.V. Tyurikov [3], A.I. Korshunov [4]

[1-3] Laboratory of informational and measuring systems, Institute of Mechanics UB RAS, Izhevsk, Russia
E-mail: [1] lucac@inbox.ru, [2] evshelk@mail.ru, [3] alex.tyurikov@mail.ru
[4] Kalashnikov Izhevsk State Technical University, Izhevsk, Russia
E-mail: [4] kai@istu.ru

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Abstract. The basic principles of particles detectors application, overlapped SPM-images binding programs, positioning devices and sensors for nanoparticles in the scanning probe microscopy research are described.

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INTRODUCTION

In present days searching of an optimal trajectory of sample movement for creation of panoramic images of its surface is an important problem of dispersity control of nanoparticles by methods of the scanning probe microscopy (SPM). The optimum trajectory has to provide:

– the coordinate binding of all images received with scanning probe microscope (SPM-images) to each other;

– minimum duration of control process.

Selection of the nanoparticles sizes has to be the result of sample movement. The less images are required for receiving selection, the quicker dispersion control process is.

FORMULATION

A series of the overlapping SPM-images at scanning probe microscopy can be received in the traditional «snake» sequence used for panoramic pictures developing. During developing of panoramic pictures the value of overlapping Δx and Δy doesn't change. During the dispersity control of nanoparticles Δx and Δy can change depending on different factors [1, 2] (quantity of particles in the pictures for examples, Figure 1). For the automation of Δx and Δy calculation procedure it is necessary to formalize the following procedures.

1. Detecting of special (control) points on the SPM-image i.e. the centers of the particles; calculation of their sizes and coordinates, selection filling; selection filtration for removal of the duplicating sizes of the particles located in a zone of scans overlapping [3, 4].

2. Shifting of the sample or the scanning area in sight of the microscope, implementation of the subsequent scan; definition of mutual orientation of the overlapped scans (shift, turn),

definition of position of special points in single coordinate system. Couples of similar special points are used for a coordinate binding of the overlapped SPM-images. The values of shift and turn of a set of the similar pairs form shift and turn histograms. This procedure formalization is described in [4].

3. Definition of the peripheral area containing enough special points. It is the planned overlapping area. For the SPM-images of high quality 2–3 pairs of special points in an overlapping zone are sufficient.

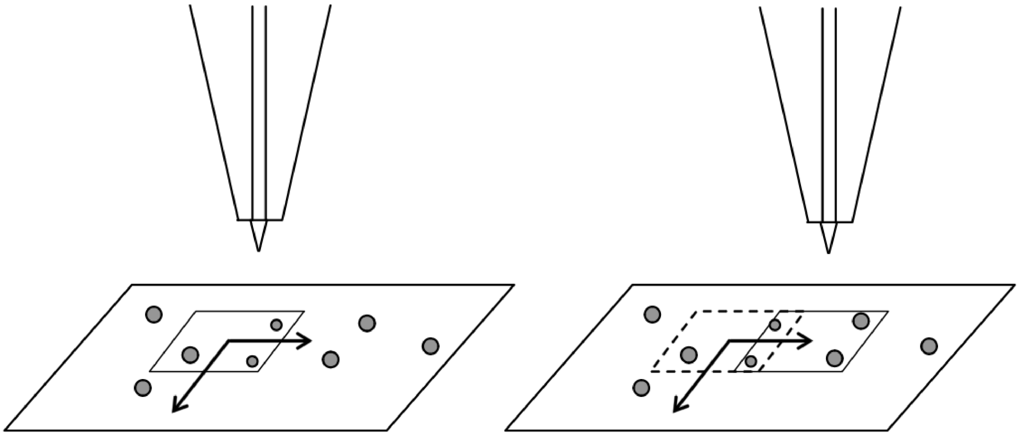

Figure 1. Scanning by the overlapping images and a coordinate binding of a probe and particles to a single coordinate system

OVERLAPPING AREA FORMATION

Consider the definition of optimal overlapping area and the features of a coordinate binding of the overlapped SPM-images.

If the particles concentration on a surface is small or the particles are localized within a certain area the duration of control process can be significant. For reduction of its duration it is necessary to reduce overlapping zones depending on a quantity of the found particles.

The size of overlapping depends on the following factors.

1. The more particles or other special points are on the periphery of the image, the less the overlapping area is:

1.1. the detectors of the special points based on the analysis of surface curvature are sensitive to noise therefore the size of overlapping is increased at their application;

1.2. detectors of special points based on the correlation analysis of the image and reference images of special points do not demand the overlapping zone increasing since they can carry out a coordinate binding of the SPM-images without presence of the particles.

2. Use of movements sensors or other means of the images overlapping estimation complication gives the possibility to reduce the overlapping size.

The overlapping area at the periphery of the image has to contain enough pairs of points for the subsequent coordinate binding of the overlapped images. The minimum quantity of pairs is two. Special points coordinates define the position of the overlapping zone and the planned shift of the subsequent scan. This shift will be used for results specification of the coordinate binding algorithm.

If the scanner control voltages are used for overlapping of the SPM-images, difference between real and planned overlappings will be approximately 5–10 % owing to temperature drift of the structure.

If for obtaining the overlapping images the stepper drive is used, the real and planned overlappings can differ for tens percent. In this case it is necessary:

1. to increase the minimum value of the overlapping coefficient;

2. to use movement sensors indications of which are used for filtration of coordinate binding results.

At shift histograms there is a set of false local maxima. At small quantity of the special points in the overlapping area, the amplitudes of true and false peaks are equal. In this case the estimation of the overlapping size or sensors indication allows to filter false extrema of the shift histogram.

Other types of the coordinate binding inaccuracies are:

1. at significant density of the particles there are histogram maxima with shift close to zero;

2. noises distort shape of the particles and their centers coordinates therefore there can be some small local maxima instead of one big in the shift histogram.

The shift estimation eliminates the first type of errors and limits an error of coordinate binding by means of a true histogram maximum positioning area localization.

The Sample Nanoscale Movements Formation

Originally scanning is carried out with constant Δ*x* and Δ*y* overlapping coefficients until the quantity of the nanoparticles is insignificant. Thus the coordinate binding is carried out by method of statistical differentiation with use of reference images (Figure 2) [4]. Processing of the SPM-image with using a detector gives the average radius of roughnesses which is used for scaling of the SPM-image of the special point.

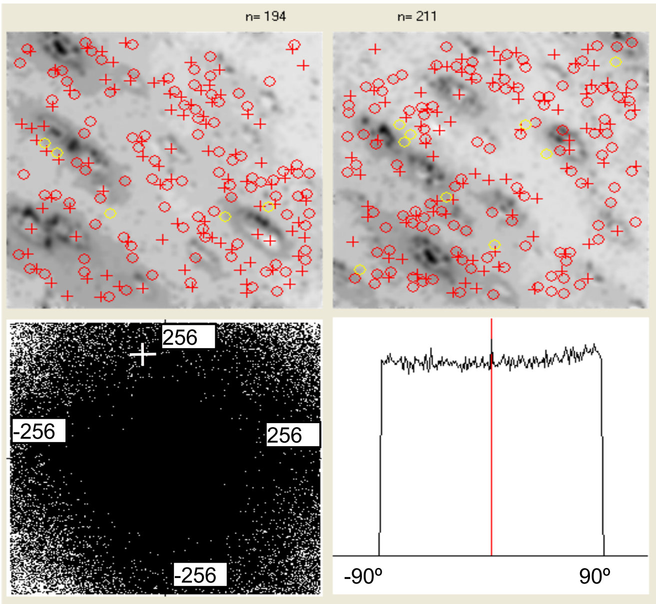

Figure 2. SPM-images **c**oordinate binding results with the reference image (two overlapping images of 256×256 pixels are above, the special points are marked by crosses and circles; two-dimensional shift histogram of 512×512 pixels with the maximum marked by a cross and the turn histogram are below)

If the detector shows enough quantity of nanoparticles in the SPM-image, the "tracing" trajectory of the sample shift can be established (Figure 3). The coordinates and the size of particles are established by means of the detectors of particles depending on the curvature of a surface. Thus coordinates are sorted by increase. The minimum values of overlapping Δ*x*, Δ*y* is established at the level of 2 rcp, where rcp is the average radius of the particles determined by the detector. Then values Δ*x*, Δ*y* serially increase until enough quantity of nanoparticles are at the area of overlapping.

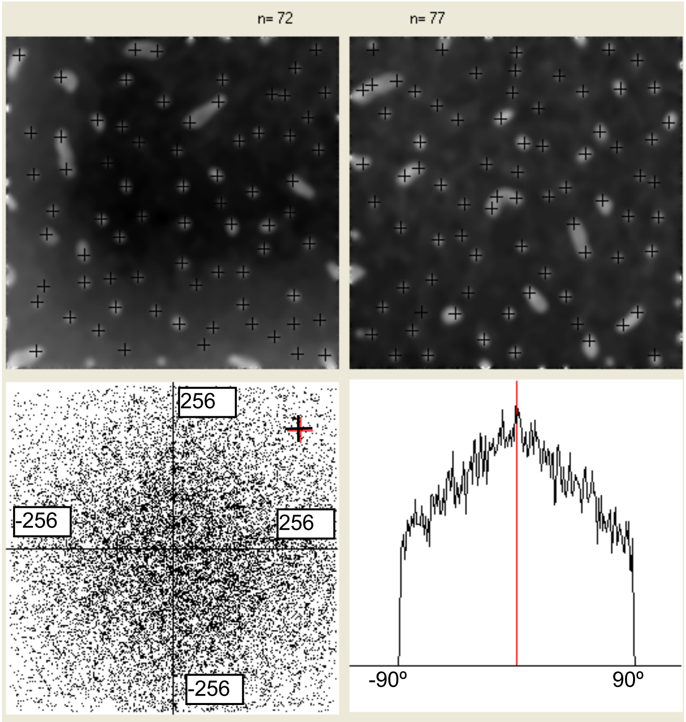

Figure 3. Results of a coordinate binding of SPM-images with the analysis of a surface curvature

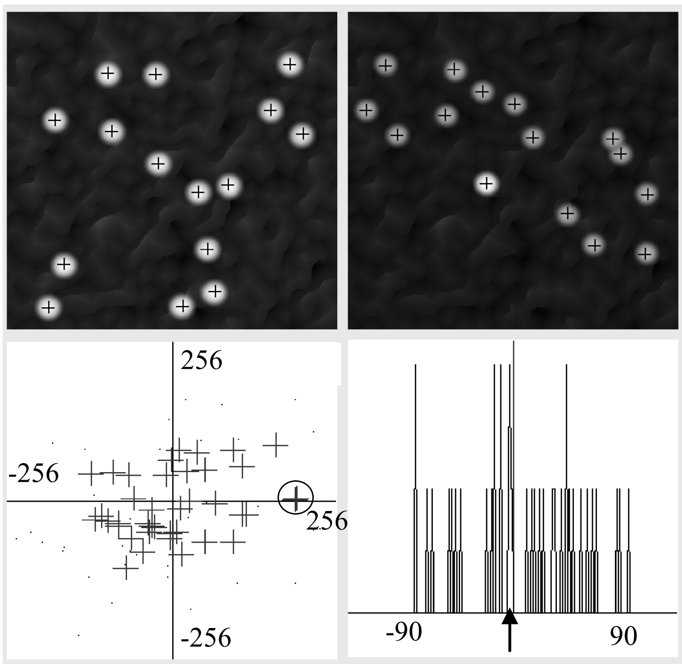

Figure 4. Use Δ*x* and Δ*y* values for the choice of a true SPM-images shift

In the subsequent calculation of orientation parameters of these SPM-images, using the values Δ*x* and Δ*y* as shift estimation is obligatory owing to the presence of the set of "false" extrema at the shift histogram.

The case when values Δ*x* and Δ*y* allow to choose the true estimate from a set of estimations of the shift of the SPM-images is presented in Figure 4.

Using the Drives of the Coordinate Nanoscale Movements of the Sample

For coordinate nanoscale moving of the sample at *XY* plane the step drives of positioning can be used. Thus the established overlapping values of Δx and Δy are used for determination of the operating signals amplitude. As it was mentioned, the size of a positioning error can be significant [5]. In this case the estimations of Δx and Δy can be inexact and their application will lead to an error of a coordinate binding of the SPM-images. This problem is solved by use of drives with the integrated movement sensors [6] considering functioning features of the drive of nanoscale coordinate movements.

Conclusions and Results

Thus, optimum scans sequence formation demands complex use of nanoparticles detectors, programs of mutual shift calculation of the overlapped SPM-images and the sample positioning drive control. Detectors are used to define the planned overlapping area the estimation of which is used for the nanoscale movements drive control and calculation of the mutual shift of the overlapped SPM-images. The sensors of movements integrated into the drive can be used for specification of an estimation of the real overlapping area if an error of drives positioning is significant.

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