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Application Notes

SPM methodology

LITHOGRAPHY WITH SPM

Voltage Lithography

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Term Probe Nanotechnology has been assigned to a local change of any properties of the surface by SPM tip, and the process itself has been called Nanolithography. The Probe Nanotechnology is the complex of techniques of controlled producing of nanometer functional elements on the surface of solid substances including individual molecules and atoms with the possibility of their visualization and control. There are two main methods of effecting the surface of the solid substance by SPM Probe: mechanical - controllable pressing by the tip and electrical - application of voltage to the conductive cantilever in pre-selected points. Both lithography methods are available with every NT-MDT AFM.

With the help of the Voltage Lithography not only geometrical properties of the surface can be changed but also its electrophysical properties, for example, by application of voltage to conductive cantilever the electrochemical processes on the surface can be stimulated under the Probe and, thus, material will be transformed from conductor into dielectric. On Fig.1 abilities of tip-induced oxidation of the surface of hyperfine titanium film on silicon under normal conditions are demonstrated. It should be noted that the indicated surface area is 200 nm^2, diameter of nanoparticles is 8-10 nm by the semi-height of island. It corresponds to information recording density of 0,6 Tbit/inch2.

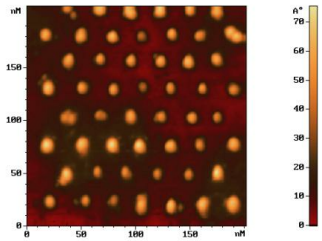

Fig.1.

Nanomodification of the surface is not limited only by formation of points. Using software we can make the Probe traveling along preset vectors and, therefore, to form lines and complex objects. Fig.2 gives example of the Vector Lithography on titanium film through its local oxidation, which is induced by conductive tip.

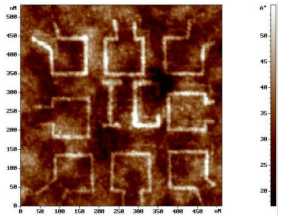

Fig.2.

The width of oxide stripe of 8-10 nanometers enables formation of tunnel-transparent barriers for electrons as well as one-electron instruments, which will operate by quantum laws even at normal indoor temperature. Lots of papers devoted to produce MIM diodes and one-electron transistors have been published [1-3]. The process of local oxidation is based on anodization.

For complex pictures Raster Lithography can be execute by using PCX-file. Difference between minimum and maximum tone voltage will be applied proportionally to brightness and, correspondingly, anode oxide will grow to a different height forming different contrast of topographical image. Examples of the Raster Voltage Lithography are shown on Fig.3 and Fig.4. Two Nobel Laureates A. Szent-Gyorgyi (Fig.3) and Zh. Alferov (Fig.4) are imaged on these figures.

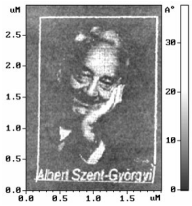

Fig.3.

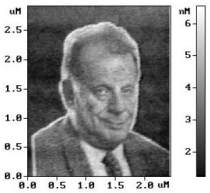

Fig.4.

Selection of cantilevers: To perform the Voltage Lithography on titanium film semi-contact one-beam silicon cantilever with conductive coating of high-melting alloys based on titanium and tungsten (W_2C, TiO, TiN) are recommended. Type of coating does not change significantly the Voltage Lithography mode.

Selection and preparation of a sample for the Electric Lithography: To test microscope and to control program in the Probe Lithography mode we recommend to use thin titanium films on thermally oxidized silicon substrate with thickness from 1 to 10 nm. Selection of titanium as test sample is specified by electrochemical potential of anodization of up to 98% as well as its use for the Voltage Lithography described in many scientific articles [4-8]. Of course, any material, which can be electrochemically oxidized in water can be suitable for this process. We also have performed experiments to study the process of tip-induced oxidation on semi-conductors surfaces - for example on doped silicon, gallium arsenide, heterostructures and W, Nb, Al metals. Important factor in forming of the nanopattern is initial roughness of the film, which was, in our case, 0.5-2Å. Since the height of oxide lines is only 1-6 nm, therefore, for good contrast image the film should have small irregularities. To get continuous thin and smooth films of metals and semi-conductive materials we have used methods of molecular-beam epitaxy and impulse plasma deposition.

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