AFM Based Diagnostic And Lithography Of Semiconductor Nanostructures

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Permanent nanoscaling for the geometrical size of device element does not only increase the bit density, but demonstrates a principle new physics based on quantum mechanics. Nanophysics progress is generally depended on nanostructure fabrication and structural diagnostic with an atomic resolution. There is restricted number of methods, which allow to create low-dimensional structures. Promised way for nanostructure fabrication can be considered methods of lithography, overpassing the physical limitation of optical phenomena, and atom rearrangements based on so called self-organized and self-assembled methods during epitaxial technologies. Essential progress is achieved for molecular-beam and chemical vapor epitaxial methods, which allow to manufacture principle new man-made materials with required mechanic, electronic, optical and magnetic properties, including two-, one- and zero-dimensional structures. However, nanostructure fabrication methods based on lithography and selective plasma etching are among intensity development purposing on minimization of the operated element.

So far, electron or ion lithography introduces non-control modifications of electro-physical properties of radiated area up to the crucial damaging of structures at these scales. The existence of the fundamental limitation for resolution of the corpuscular lithography demands the search of principle new nanolithographical methods. One of the potential candidates for perspective nanolithography is a scanning probe microscopy (SPM) lithography, which has demonstrated the theoretical limitation of lithography through single atom manipulation. It was the aim of this paper to cover some advantages of atomic force microscopy in the areas of nanostructure lithography based on probe induced surface modifications for diagnostic and fabrication of electronic nanodevices [1].

The AFM experiments are carried out with Solver P-47H and P7-LS (NT-MDT) microscopes having lithography software. Standard silicon cantilevers and ones with conductive covering were used for imaging and lithography by AFM. For stability reasons, stiff cantilevers were preferable minimizing the effects of tip-substrate forces. To reduce noise contribution of external electromagnetic fields on the image formation during scanning, the AFM apparatus used for these studies have been positioned inside of a metal box having a good electric connection to ground. Additional rubber bearers for this box have been installed reducing mechanical vibration noise. The both temperature and humidity of the atmosphere inside of the box were controlled during AFM scanning. The coherent pulse voltage feed system (±50V) was developed and integrated to the microscope for the nanolithography based on AFM-tip-induced nanooxidation. All experiments were carried out at the room temperatures.

The novel approaches of AFM-tip-induced modification with nanometer-scale resolution are demonstrated for nanostructures fabrication on silicon, titanium and gallium arsenide substrates. These materials were chosen as a model material with well-studied surface structure and morphology. Peculiarities of local anodic oxidation kinetics and mechanic scratching are under consideration. In spite of large number of publications, there is not universal explanation of oxidation process doing complicated development of tip-induced nanolithography. We carried out precision experiments on oxidation intensity depended significantly on anodic potential, initiation pulse duration, air humidity and type of oxidized material (Si, GaAs and Ti). The new scale of nanostructures was obtained by this method (10-100 nm) [2].

KEYNOTES

The advanced TINE&MEMO [3,4] technology is developed to realize the principle new scale of modification depth, up to 100 nm, for manufacturing electronic and mechanic nanodevices. The quantum interferometer with an effective radius 90 nm was fabricated by nanoscaled AFM lithography. The small size of obtained structure allowed to increase the interferometer work temperature about one order (to 15 K). The fabrication processes are analyzed in details to minimize the spatial resolution and to increase the depth of modified films.

Small-radius (110 nm) ring interferometers were fabricated by the local anodic oxidation of AlGaAs/GaAs heterostructures containing 2D electron gas. Measurements and modeling show that a small ring asymmetry, which is detected by an atomic force microscope, leads to a small amplitude of Aharonov–Bohm oscillations, while a stronger asymmetry completely suppresses these oscillations [5].

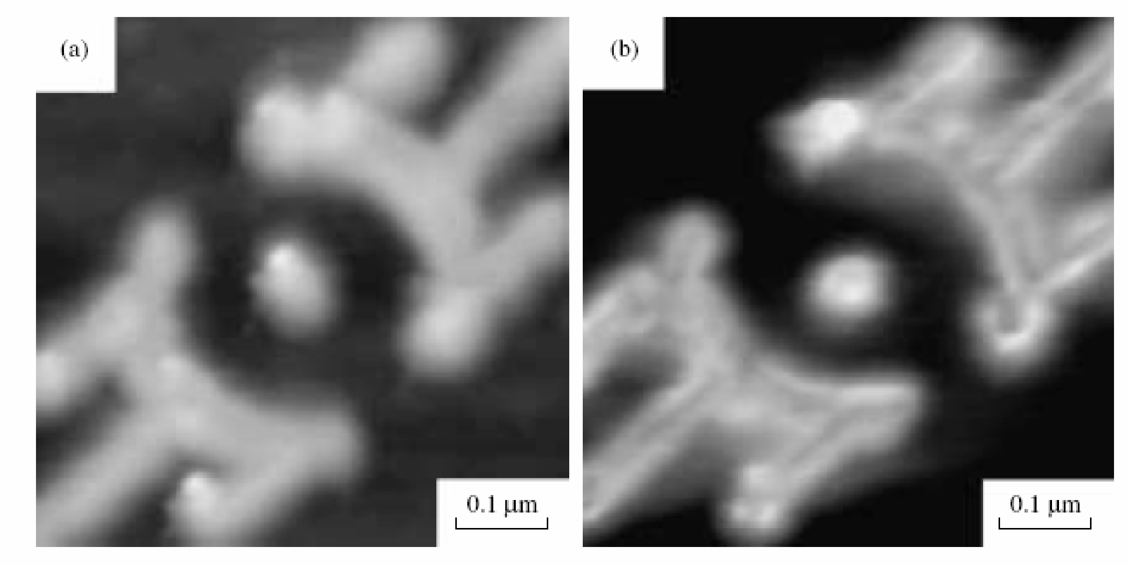

Fig.1 AFM images of open rings fabricated by the local anodic oxidation nanolithography: (a) symmetric and (b) asymmetric rings.

The number of applications of ultimate possibilities of AFM diagnostic and tip-induced lithography in nanosclale is demonstrated to fabricate electronic devices.

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