The fabrication of monocrystall nanowires from Bi films grain by the probe lithography

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Semimetal Bi films less than 50 nm thin are the most suitable material for the creation of quantum-well structures, quantum wires included, because electrons in Bi have a Fermi wavelength up to 100 nm. Quantum wires are supposed to be used, in particular, in facilities for management and reading in solid-state qubits. To date, Bi nanowires in the form of whiskers have been mainly studied, whereas a more preferable, from the viewpoint of applications, planar technology of Bi nanowire fabrication based on thin films has not been created yet. For its realization, initial films should be continuous and smooth with the surface roughness not more than approximately 1 nm. It is known that Bi films like other fusible metal films are subject to the growth of hillocks of height which can noticeably exceed film thickness. However, the surface morphology of the thin, less than 50 nm, Bi films and their roughness at a level of about 1 nm have never been checked. We have developed a technology of producing 15 - 50 nm thin continuous Bi films with the surface roughness of about 1 nm by molecular beam deposition (MBD) methods. The dependence of film surface morphology on key parameters of the deposition process was investigated, and optimum growth conditions were determined. Bismuth films were deposited onto Si wafers covered by the 0.5 micron thermal oxide with a surface roughness of 0.2 nm. The film surface morphology was investigated in a contact mode using a P4-SPM-MDT atomic force microscope and the following parameters: root-mean-square height (roughness), and height drop within the scanned area were specified. The surface morphology and continuity of Bi the films were controlled as a function of different parameters: (1) the deposition temperature (40-120°C) of a substrate and (2) the annealing treatment temperature (up to 275°C). The microstructure of the film surface morphology was found to strongly depend on these parameters. A decrease of the growth temperature down to 40°C substantially suppressed the growth of surface hillocks and the roughness of a film surface was reduced down to 1 nm. Crystallites as large as 200 - 300 nm with facets characteristic for bismuth prevailed in the film surface structure, which, at the film thickness 20 nm, signify attainment of equilibrium conditions for the growth of a film with a high-quality crystal structure. The annealing of Bi films near the melting point leads to the appearance of large single crystals 500 - 1000 nm in size in the film plane. This suggests the possibility of fabricating monocrystal nano objects on the basis of these films on the plane of the substrate. The reported results can promote creating a nanotechnology for quantum-well structure fabrication from thin semimetalic films.

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