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Magneto-transport properties of single-crystalline Bi nanowires

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Semimetallic bismuth (Bi) has been extensively investigated over the last decade, since it exhibits very intriguing transport properties due to its highly anisotropic Fermi surface, low carrier concentrations, long carrier mean free path l and small effective carrier mass m^* . The magnetoresistance (MR) behavior and long carrier mean free path l in Bi thin films are of particular importance, since they can be exploited for spintronic device applications such as magnetic field sensors and spin-injection devices. With respect to "spintronics", it is expected that Bi can be used as a spin channel in a spin-injection device due to the very long spin diffusion length l_{sd} of a few ten μm, following the relation $l_{sd} = (\upsilon_F \tau_{\uparrow\downarrow})^{1/2}$, where, υ_F is the Fermi velocity and $\tau_{\uparrow\downarrow}$ is the spin relaxation time. In recent years, comprehensive studies have focused on Bi nanowires because of quantum confinement effect. Transport properties in Bi nanowires has been known to depend on the purity and the concentration of crystal defects since a distorted structure compromises the unusual electronic properties of Bi nanowires. Therefore, high crystal quality of Bi nanowires is crucial to investigate unique transport properties of Bi nanowires. In the present work, we report a novel method to grow high crystal quality single crystalline Bi nanowires ranging from 1.0 μm to 100 nm in diameter and lengths up to several hundred micrometers. Bi thin films ranging from 400 nm to 10 μm in thickness have been grown by an RF magnetron sputtering system and followed by heat treatment at 270 °C for 10 hours. The observed grain size of as-grown films was found to be proportional to a thickness of the films and directly related to the dimension of nanowires, indicating the diameter of nanowire is controllable by the grain size of thin films. The MR of a single Bi nanowire has been measured using ac lock-in amplification technique with a magnetic field H applied perpendicular to the plane of the structure, showing as high as 1200 % at 80 K, supporting a long carrier mean free path of the Bi nanowire due to the high crystalline quality. The growth mechanism and magnetotransport properties in Bi nanowires with various diameters are discussed.

Key-words —Bi nanowires , single-crystalline, magnetoresistance, heat treatment