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MAGNETOTRANSPORT OF SEMIMETALLIC Bi THIN FILMS GROWN BY ELECTROPLATING AND SPUTTERING

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In recent years, semi-metallic Bismuth (Bi) has attracted significant attention due to very large magnetoresistance (MR) at room temperature originating from long carrier mean free path l and small effective carrier mass m^* [1, 2]. In particular, the MR behavior and long carrier mean free path l in Bi thin films can be exploited for spintronic devices, e.g. magnetic field sensors and spin-valve transistors. In present work, we present the magnetotransport properties of the electroplated and sputtered Bi thin films in the temperature range 4 – 300 K.

The Bi thin films in the thickness range 1 – 20 μm were electroplated on 100 Å thick Pt/Si(100) from aqueous solutions of $Bi(NO_3)_3 \cdot 5H_2O$. The Bi thin films were also deposited on a thermally oxidized Si(100) substrate in an RF magnetron sputtering system with a base pressure of 4×10^{-8} Torr. The as-electroplated and sputtered Bi thin films were heat-treated in a vacuum tube with Sm powders as an oxygen getter at 268 °C for 8 hrs.

A marked increase from 5,200 % to 80,000 % in the positive MR was observed after anneal for the 20 μm Bi thin film grown by electroplating at 4 K under a magnetic field of 9 T applied perpendicular to the film plane [see Fig. 1(a)]. This result is attributable to structural transformation from an as-grown polycrystalline film of trigonal structure during heat-treatment. The values of the MR ratio for the as-grown and annealed Bi thin films were found to exhibit 560 % and 590 %, respectively, at room temperature, indicative of little difference in the MR between the polycrystalline and single crystalline Bi films [see Fig. 1(b)]. The thickness dependence of MR was also found for both the films in the range 1 – 20 μm, implying long mean free path l of the order of a few ten microns, comparable to spin diffusion length l_{sd} in the Bi films. On the other hand, the positive MR for the annealed sample was found to reach 600 % at 300 K [see Fig. 1(d)] Our result demonstrate that the Bi films can be used as a spin channel in a spin-injection device due to a few ten micrometers-long spin diffusion length l_{sd}, which follows the relation

$$l_{sd} = \sqrt{l v_F \tau_{\uparrow\downarrow}} \qquad (1)$$

where, υ_F is the Fermi velocity and $\tau_{\uparrow\downarrow}$ is the spin relaxation time. We discuss "spin-valve" effect in the spin-injection device, consisting of Bi film and two ferromagnetic contacs: an injection part (w = 100 nm) and a detection part (w = 500 nm).

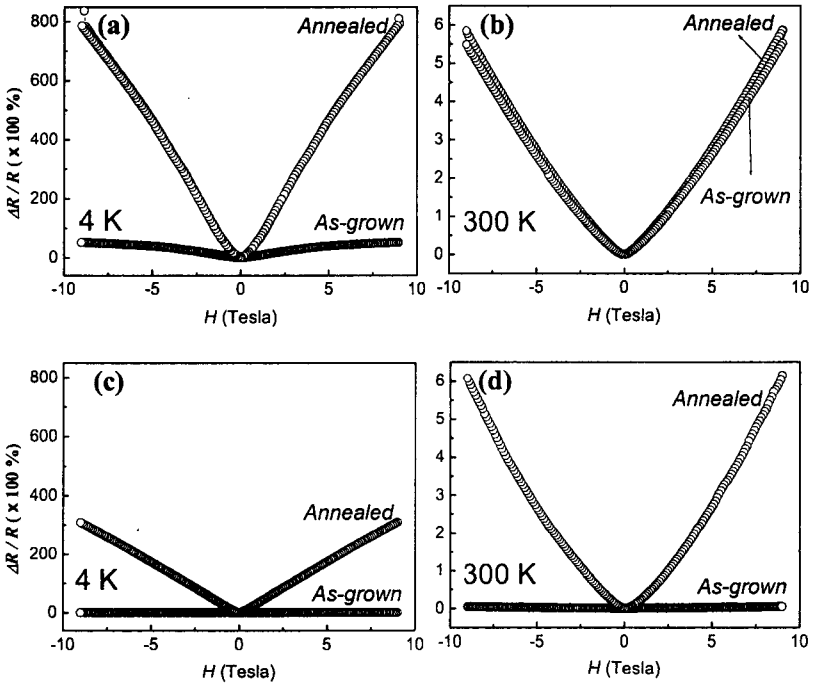

Fig. 1. The variation of magnetoresistance ($\Delta R/R$) against magnetic fields for (a), (b) the electroplated and (c), (d) sputtered Bi thin films.

References

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