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LARGE MAGNETORESISTANCE OF SPUTTERED BI THIN FILMS AND APPLICATION OF SPIN DEVICE

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Bismuth (Bi) has been an attractive materials for studying spin dependent transport properties because it shows very large magnetoresistance (MR) resulting from its highly anisotropic Fermi surface, low carrier concentrations, long carrier mean free path l and small effective carrier mass m*[1-3]. With all the intriguing properties, difficulty in fabrication of high quality Bi thin films may have prevented extensive application of Bi in magnetic field sensing and spin-injection devices. Previous works found that the surface roughness and small grain size in 100~200 nm of Bi thin film made by evaporation and sputtering are major causes of low MR. Although relatively higher MR in electrodeposited Bi followed by annealing was reported, it still suffers from rough surface roughness which is so severs that it is hardly able to make a field sensing and spin-injection device using conventional photolithography process.

On the other hand, we have found that the surface smoothness of the sputtered Bi thin film is good enough for photolithograph process as well as that higher MR of 300~500 % at RT can be achieved with post-annealing process owing to dramatic decrease in grain boundary sputtering effect. In addition, since sputtering is fast and highly compatible process with conventional device fabrication process, it is worth studying transport properties and furthermore exploring application of spin devices with sputtered Bi thin films.

In this study, we investigated MR behavior of Bi thin film as-sputtered and annealed with various heat treatment conditions at 4 K and room temperature. Based on the MR results, we tried to make spin-valve type spin-injection device in order to search the possibility of Bi thin film for field sensing and spin-injection device.

Bi films are grown onto thermally oxidized Si(100) substrates in a dc magnetron sputtering system from a Bi (99.99%) target. The system base

pressure is 4 × 10-8 Torr, the argon operating pressure is 2 × 10-3 Torr and deposition rate is 0.4 ㎛s-1. The as-sputtered Bi thin films were heat treated in a vacuum tube with Sm powders as an oxygen getter at 255 ℃~ 265 ℃ for 3hrs. We measured the transport properties of the Bi films with a conventional four-probe method.

A marked increase in the positive MR from 8 % to 30,000 % for the sputtered Bi thin film was observed after anneal at 260 ℃ for 3hrs measured at 4 K under a magnetic field of 9 T applied perpendicular to the film plane. Also, the MR ratio of annealed Bi thin films was also found to exhibit 600 % at 300 K (Fig. 1). This is attributable to dramatic increase in the grain size of Bi thin films during annealing. Fig. 2 presents scanning electron microscopy (SEM) images of (a) as-sputtered and (b) annealed Bi films. This figure clearly shows large change in grain size of as-sputtered Bi and annealed Bi thin films. The as-sputtered sample shows sub-micron sized grains, which is much smaller than that in the annealed sample.

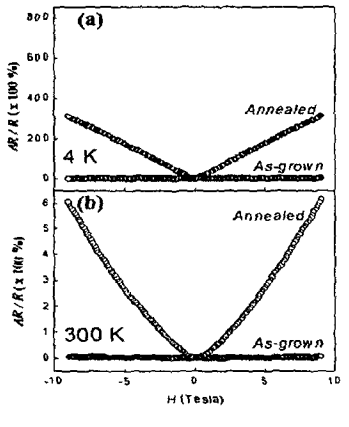

Fig. 1. The MR curves of Bi thin films: (a) 4K, (b) 300 K.

Fig. 2. SEM images of (a) as-sputtered and (b) annealed Bi

References

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