Magnetic and Microstructural Properties of Multilayered MnBi Films

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Ferromagnetic low-temperature-phase (LTP) of MnBi has attracted much attention because it has a higher coercivity than that of Nd-Fe-B at high temperature (~ 200°C) and it has been a desirable material as rare-earth-free permanent magnets that can be used in such high temperature. We present a change of magnetic properties of MnBi films by controlling the numbers of Bi/Mn bilayer. The thin films of LTP-MnBi were fabricated onto glass substrates by UHV sputtering, followed by in-situ annealing process at an optimized condition of 350°C and 1.5 hours. The composition ratio of Bi/Mn in the films was adjusted with a variation of the thickness of Bi and Mn layers. The highest value of maximum energy product $(BH)_{max}$ was about 8.5 MGOe at room temperature, which was obtained in one Bi/Mn bilayer with the thickness ratio of 34 nm/16 nm. To investigate the effect of Bi/Mn multilayers on the magnetic properties, we increased the numbers of Bi/Mn bilayer ($[Bi/Mn]_N$) up to five (N = 5). Here, the total film thicknesses were fixed with 100 nm and the ratio of Bi/Mn was sustained with 34 nm /16 nm. (e.g. Bi/Mn/Bi/Mn = 34nm/16nm/34nm/16nm for $[Bi/Mn]_2$) The increase of coercivity was observed from 5.8 kOe (N=1) to 9.8 kOe (N=5) with increasing number of bilayer. However, the remnant magnetization exhibited an unusual behavior. It was decreased at N=2 and increased up to N=5. We found that these are closely related to a microstructural change of LTP-MnBi, which were confirmed with XRD, TEM, and EDX analyses. We will discuss how the multilayered structure of MnBi films affects their magnetic properties in details.

Keywords: Permanent magnet, MnBi, Coercivity, Multilayer film