Layer-number dependence of the magnetic properties of 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 the effect of multilayer deposition on the magnetic properties of MnBi thin films. The multilayered MnBi films were fabricated with alternating deposition of Bi and Mn with N (N = 2−10) layers (L), followed by *in situ* thermal annealing. As N increases, the even-layered and odd-layered films show a similar layer-number-dependence of the magnetic properties, such as an increasing behavior for H_c and a concave-up behavior for M_r and $(BH)_{max}$. According to the results of the electron microscopy analyses, the MnBi films show changes in the microstructure and elemental distribution with an increase in the number of deposition layers. (i) The 2L and 3L films grew with *c*-axis oriented LTP-MnBi having the largest area and the most flat surface, but unreacted Mn remained near the top surface as well as large unreacted Bi islands. (ii) The 4L and 5L films have the relatively smaller fraction of LTP-MnBi, which was obstructed with large amounts of Bi and Mn islands. (iii) The 9L and 10L films grew like nanocrystalline LTP-MnBi with less of the unreacted elements. The higher H_c can be explained by the prevented nucleation of the reversed domain because of the isolated MnBi islands. The higher M_r can be explained by the high volume fraction of LTP-MnBi with less unreacted Bi and Mn. From the results, we found that the changes strongly affect the variation in the magnetic properties and the number of deposition layers is important for obtaining higher magnetic properties. In particular, the element of top layer does affect the magnetic properties and the Bi element at the top layer plays an important role in improving M_r.

Keywords : MnBi, magnetic thin film, multilayer deposition, hard magnetic properties