Rare-Earth-Free Permanent Magnets : MnBi Bulks and Thin Films

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Low-temperature phase (LTP) of MnBi has attracted much attention due to its larger coercivity than that of Nd-Fe-B at high temperature. Moreover, according to the theory of exchange-coupled core-shell magnet, when the LTP-MnBi is used as a hard magnetic core and combined with soft magnetic shell, the maximum energy product $(BH)_{max}$ is estimated to overcome that of Nd-Fe-B. In this regards, there have been many efforts to obtain the LTP-MnBi bulks and thin films for the exchange-coupled magnets. We report on the magnetic properties of low-temperature-phased (LTP) MnBi bulks synthesized by arc-melting and melt-spinning, and LTP-MnBi thin films grown by a UHV sputtering system. First of all, we found that MnBi bulks shows ${}_iH_c$ = 5.60 kOe, B_r = 6.00 kG, and $(BH)_{max}$ = 7.27 MGOe for 1 h milling (low-energy planetary ball milling) in the synthesis process, indicating that anisotropic precursor powders are crucial in achieving high-performance MnBi bulk magnets. On the other hand, we found that the ratio of Bi/Mn strongly has an effect on the magnetic properties of LTP-MnBi films. The highest value of $(BH)_{max}$ of LTP film was obtained to be ~ 8.6 MGOe at room temperature when the thicknesses of Bi and Mn were adjusted in 36nm and 14nm, respectively. The magnetic properties of exchange-coupled MnBi with various soft layers such as FeCo and Fe will be discussed in detail.