Magnetic Properties of MnBi Bulk Magnets with High-Portion Low-Temperature-Phase

Sumin Kim*, Hongjae Moon, Hwaebong Jung, Hyun-Sook Lee, and Wooyoung Lee†
Department of Materials Science and Engineering, Yonsei University,
262 Seongsanno, Seodaemun-gu, Seoul 120-749, Korea
†E-mail: wooyoung@yonsei.ac.kr

LTP-MnBi [1] is well-known to exhibit a larger anisotropy field with increasing temperature, resulting in a higher coercivity (H_c) at elevated temperature, as compared with the $Nd_2Fe_{14}B$ magnet. Hence, it is a potential candidate for high-temperature applications for use in the electric motors of EVs and renewable power generators. In order to achieve MnBi bulk magnets with high magnetic performance, synthesis process of anisotropic precursor powders is a key. For the synthesis, ingots of MnBi with various Mn and Bi contents were prepared by arc-melting and melt spun at a wheel speed of 55 m/s. And then an annealing process was carried out at 300°C for 40 h to make LTP-MnBi. XRD results indicate that the ingot prepared with 5wt.% excess Mn produces high fraction of LTP-MnBi (95.1wt.%). Low-energy planetary ball milling was employed with various mill times to produce highly anisotropic MnBi powders and magnetic separation method was added to increase the amount of pure LTP-MnBi. The LTP-MnBi bulk magnets were fabricated by utilizing magnetic pressing and hot compaction[2,3]. The bulk magnets show different magnetic properties with depending on the mill time. As the milling time increases, $_iH_c$ increases while remanence (B_r) and maximum energy product ($(BH)_{max}$) decrease: (i) $_iH_c$ = 5.60 kOe, Br = 6.00 kG, and $(BH)_{max}$ = 7.27 MGOe for 1 h, (ii) $_iH_c$ = 6.70 kOe, Br = 5.63 kG, and $(BH)_{max}$ = 6.92 MGOe for 2 h, (iii) $_iH_c$ = 7.30 kOe, Br = 5.51 kG, and $(BH)_{max}$ = 6.49 MGOe for 2.5 h. Increase of coercivity can be due to the decrease of grain size reaching toward a critical single domain diameter. The reduction of remanence leading to the lowered $(BH)_{max}$ arises from the loss of main pure LTP-MnBi(defects and microstructural changes) during the low-energy milling. However, it is noteworthy that our synthesis process for 1 h milling gives rise to the higher $(BH)_{max}$ = 7.27 MGOe.

[1] T. Chen and W. E. Stutis, IEEE Trans. Magn, 10, 581-586 (1974).
[2] N V Rama Rao, A M Gabay and G C Hadjipanayis, J. Phys. D: Appl. Phys. 46 (2013) 062001
[3] J. Cui, et. al., J. Phys.: Condens. Matter 26 (2014) 064212