Magnetization and High Temperature $(BH)_{max}$ of Ferromagnetic MnAl and Low Temperature Phase (LTP) MnBi

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The figure of merit for permanent magnet is the maximum energy product $(BH)_{max}$ in the units of MGOe. Sintered $Nd_2Fe_{14}B$ and Sm_2Co_{17} magnets show 64 MGOe and 39 MGOe of theoretical $(BH)_{max}$, at 0 K, respectively. Operation temperature is 473 K for Nd-Fe-B and 623 K for Sm_2Co_{17}. However, low operation temperature of Nd-Fe-B and availability of rare-earth and transition elements are potential barriers for the use of these rare-earth metal based permanent magnets for the electric vehicle's (EV) motor and wind system's generator. Rare-earth element Dy was partially substituted for Nd in $Nd_2Fe_{14}B$ to increase the operation temperature and the $(BH)_{max}$, but the substitution effect was not significant and Dy is more expensive than Nd. Addition of Al and Cu to Nd-Fe-B also shows insignificant effect on the operation temperature [1]. Thus, aiming at developing high operation temperature MnBi and MnAl magnets, we have theoretically calculated the $(BH)_{max}$ for MnBi and τ-phase MnAl alloys using density functional theory and for core (hard magnet) - shell (soft magnet) nanomagnets using modified Skomski's model [2]. Our preliminary calculation shows 20 MGOe (3.71 μ_B/f.u.; H_k = 53 kOe) and 25 MGOe of $(BH)_{max}$ at 0 K for MnBi and MnAl magnets, respectively. Accordingly, it is envisioned that core - shell nanomagnets with MnBi and MnAl core will exhibit large remanent magnetization, thereby increasing the $(BH)_{max}$. We have estimated $(BH)_{max}$ of 53 MGOe for a given core-shell nanomagnet. Finally, the role of exchange coupling between hard magnetic core and soft magnetic shell for further enhancement in $(BH)_{max}$ of considered core-shell magnets is discussed.

[1] T. Akiya, H. Kato, M. Sagawa and K. Koyama, *Mater. Sci. and Eng.*, Vol. 1, 012034 (2009)
[2] R. Skomski and J. M. D. Coey, *Physical Review B*, Vol. 48, No. 1, 15812 (1993)