

# Exchange coupled hard (LTP MnBi)/soft ( $\text{Fe}_{65}\text{Co}_{35}$ ) composites

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## 1. Introduction

Ferromagnetic low temperature phase (LTP) MnBi possesses a moderate magnetization of 8 kG [1] and the Curie temperature ( $T_c$ ) of 613 K [2], and positive magnetic anisotropy coefficient [3]. However, its maximum energy product,  $(BH)_{\max}$ , is about 17 MGOe at 290 K [1]. This maximum energy product is not enough for high-energy magnetic device applications. Therefore, we have proposed core (LTP MnBi hard magnet)/shell (soft magnet) structure to enhance the  $(BH)_{\max}$ .

## 2. Experiment

We have synthesized LTP MnBi micron-powder by arc-melting technique and manual grinding, and  $\text{Fe}_{65}\text{Co}_{35}$  nano-powder by chemical reaction. The synthesized LTP MnBi and  $\text{Fe}_{65}\text{Co}_{35}$  powder were mixed using low energy ball milling. The volume fraction of hard magnetic phase ( $f_h$ ) dependences of magnetizations and intrinsic coercivities were measured by vibrating sample magnetometer (VSM) and compared with theoretical values. The theoretical  $f_h$  dependences of magnetizations [4] and intrinsic coercivities [5] were calculated as shown in Fig. 1.

## 3. Discussion

The magnetizations and coercivities of synthesized powder were 7 kG and 2.8 kOe for LTP MnBi powder and 16.7 kG and 0.1 kOe for  $\text{Fe}_{65}\text{Co}_{35}$ , respectively. It was found that magnetizations and coercivities of low energy ball milled core(LTP MnBi hard magnet)/shell(soft magnet) composites follow theoretically calculated values as a function of  $f_h$  as shown in Fig. 1. This indicates that well controlled exchange coupled hard and soft composite magnets can be a breakthrough of enhancement of  $(BH)_{\max}$ , as shown in Fig. 2, for permanent magnets without rare-earth-elements.

## 4. Conclusion

The MnBi/FeCo composites were fabricated by mixing separately synthesized MnBi and  $\text{Fe}_{65}\text{Co}_{35}$  powder. The volume fraction of hard magnetic phase ( $f_h$ ) dependences of magnetizations and intrinsic coercivities of the composites well follow the theoretical values, which indicates potential enhancement of  $(BH)_{\max}$ , if one can successfully synthesize perfectly exchange coupled composite.

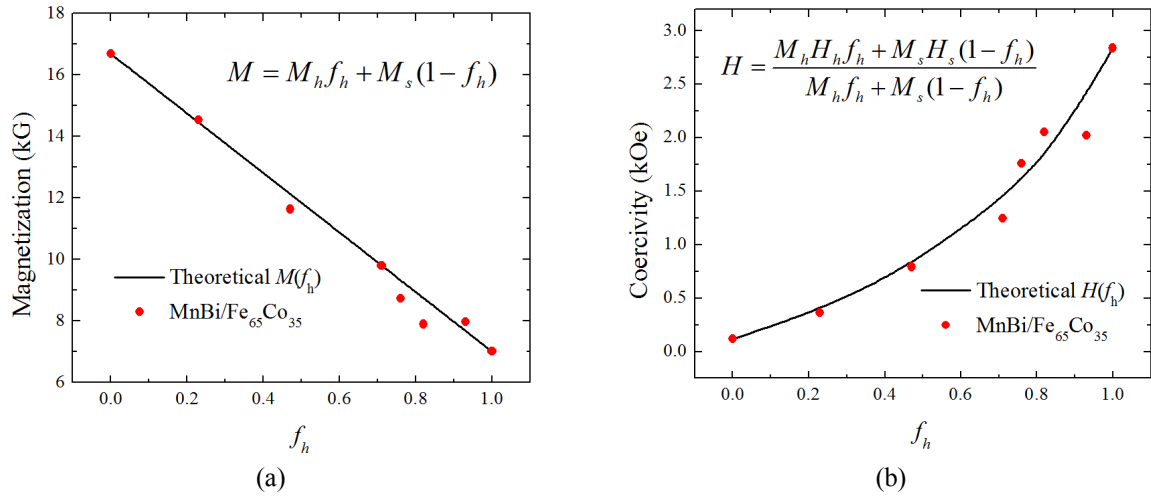


Fig. 1. Experimental and theoretical volume fraction of hard magnetic phase ( $f_h$ ) dependence of (a) magnetizations and (b) coercivities.

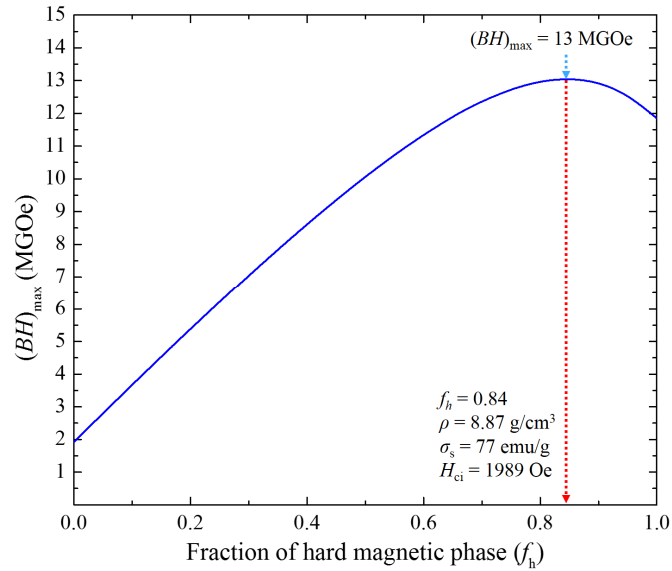


Fig. 2. Calculated maximum energy product,  $(BH)_{\max}$ , as a function of fraction of hard magnetic phase ( $f_h$ ) based on the experimental magnetizations and intrinsic coercivities in Fig. 1.

## 5. References

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