Manganese-Based Permanent Magnet with 40 MGOe at 200°C

Jun Cui, Pacific Northwest National Laboratory (PNNL)

Partners: Ames Laboratory, University of Maryland, United Technologies Research Center, University of Texas at Arlington, University of Kansas, University of Alabama, University of California San Diego, Mississippi State University, University of Delaware

Critical Need

MnBi is an attractive alternative to the permanent magnets containing rare earth elements, especially the ones for medium temperature applications (423~473 K) such as NdFeB-Dy and SmCo. MnBi has unique temperature properties: its coercivity increases with increasing temperature, reaching a maximum of 2.6 T at 523 K. The large coercivity is attributed to MnBi’s large magnetocrystalline anisotropy ($1.6 \times 10^6$ J/m$^3$). MnBi has relatively low magnetization. Its room temperature saturation magnetization is about 75 emu/g or 8.4 kG with 5 T field. The corresponding maximum theoretical energy product (BH)max is about 17.6 MGOe. In practice, a single-phase MnBi should exceed 12 MGOe, which is competitive compared to magnets such as ferrite and AlNiCo, but is only half of what NdFeB and SmCo magnets can offer at 473 K. To best utilize MnBi’s unique high temperature properties, MnBi should be used a hard phase to be exchange-coupled with a soft phase, so that the remanent magnetization can be improved to >10 kG while coercivity is maintained at >10 kOe. The corresponding (BH)max entitlement is 25 MGOe.
Challenge

In the past three years, ARPA-e REACT program, a team of scientists involving eleven organizations has made significant progress:

1) how to prepare high purity MnBi compound in large quantity
2) how to encourage exchange coupling between MnBi and soft phases such as Fe and Co
3) how to fabricate bulk nanocomposite magnet with fine grain size, uniform phase distribution, and high degree of texture.

Supported by ARPA-e REACT program, a team of scientist involving eleven organizations worked on these challenges in the past three years and made significant progresses.

Project Innovation

» Large quantities of high purity MnBi single-phase particles can be routinely prepared. Each batch weighs about 8 lbs; the average particle size ranges from 0.5 to 2 μm; and the magnetization of the powder at 2.3 T field is about 70 emu/g. This achievement is significant because the method is not based on the melt-spinning method which has limited productivity and higher cost. Rather, it is based on conventional thermal-mechanical treatment that is compatible with the current industrial practices.

» Under the guidance of theoretical calculation, the exchange coupling of MnBi and Co was successfully demonstrated using the thin film method. The fabricated double-layer film can exhibit an energy product about 25 MGOe. In parallel to the thin film effort, MnBi-Co core-shell particles were synthesized using a colloidal synthesis method. The Co layer can be controlled to ~20 nm and the overall magnetization exceeded 80 emu/g. 3) After alignment, the energy product of the powder reached 12.1 MGOe, and that of the sintered bulk magnet reached 8.6 MGOe at room temperature.

For additional information contact:
Dr. Jun Cui
Jun.Cui@pnnl.gov