Improving Exchange-Spring Nanomagnets via Interface Modification

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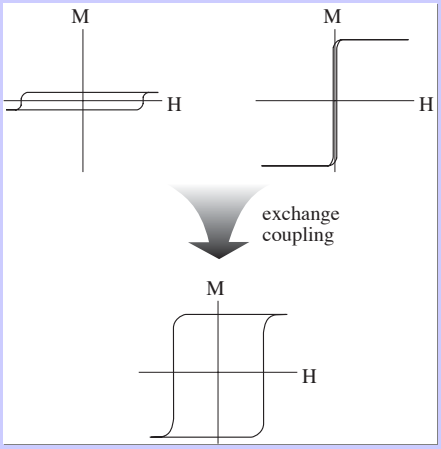
We have demonstrated a nanotechnology strategy to realize the full potential of exchange-spring nanocomposite permanent magnets. By thermally processing sputtered epitaxial SmCo/Fe exchange-spring bilayer structures to promote interdiffusion at the interface, we improved their resistance against magnetization reversal, thereby improving their energy product.

Motivation

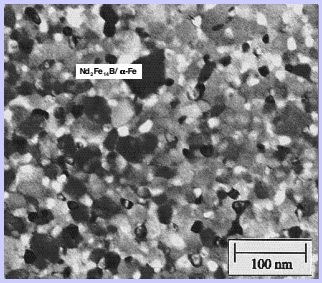
•High-performance permanent magnets improve the energy efficiency of motors and generators by making them lighter;

•The *exchange-spring* magnets can potentially achieve twice the energy product of Nd-Fe-B magnets, whose performance is incrementally approaching the theoretical limit;

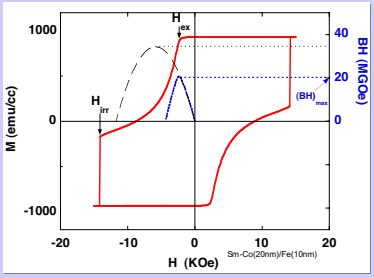
•Exchange-spring magnets fabricated using conventional processing techniques have soft phases too large to achieve effective coupling or high performance.



Exchange-spring nanocomposite magnets exploit the high magnetization of the soft phase and the high anisotropy of the hard phase combine to give rise to high energy product.

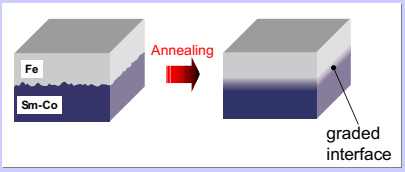


Microstructure of a melt-spun $Nd_2Fe_{14}B/\alpha$-Fe exchange-spring magnet.

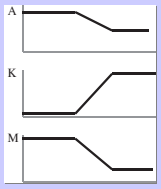


Early magnetization reversal of the large soft phase limits the energy product (BH) of exchange-spring magnets.

Interface Modification



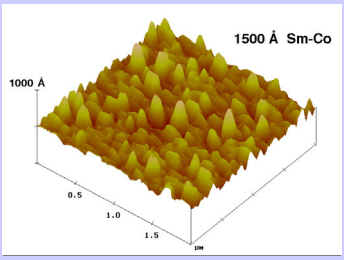
We annealed model exchange-spring structures (sputtered epitaxial Sm-Co/Fe bilayers) to promote interdiffusion and create a *graded* interface.



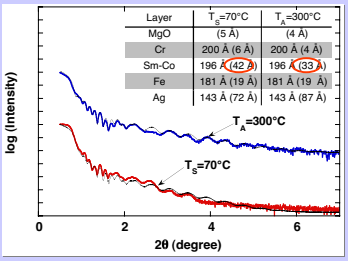
Schematic illustration of the variation of the material parameters across a graded interface.

Results

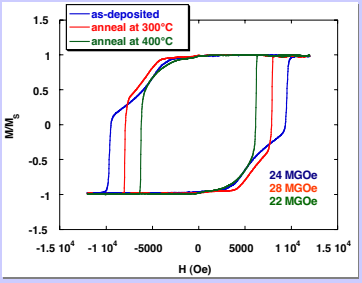
- Improved resistance against reversal
- Full recoverable magnetization
- Increased energy product
- Reduced interfacial roughness indicates interdiffusion
- Qualitative agreement with numerical modeling



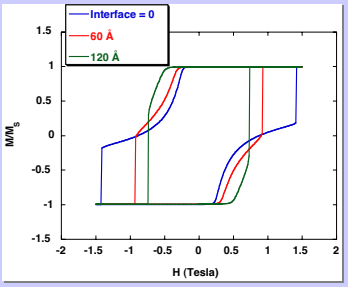
Atomic Force Microscopy image showing a rough as-deposited Sm-Co surface



X-ray reflectivity showing reduced Sm-Co/Fe interfacial roughness due to annealing



Magnetization hysteresis loops of a Sm-Co(20nm)/Fe(10nm) bilayer before and after annealing at various temperatures.



Simulated magnetization hysteresis loops of a Sm-Co(200A)/Fe(100 Å) bilayer assuming various extent of graded interface.

J. S. Jiang, J. E. Pearson, J. P. Liu and S. D. Bader, Proc. 17th International Workshop on Rare Earth Magnets and Their Applications, G. C. Hadjipanayis and M. J. Bonder Eds., p. 727-737 (Rinton Press, Princeton, 2002).

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