Compound may magnetically outperform neodymium magnets

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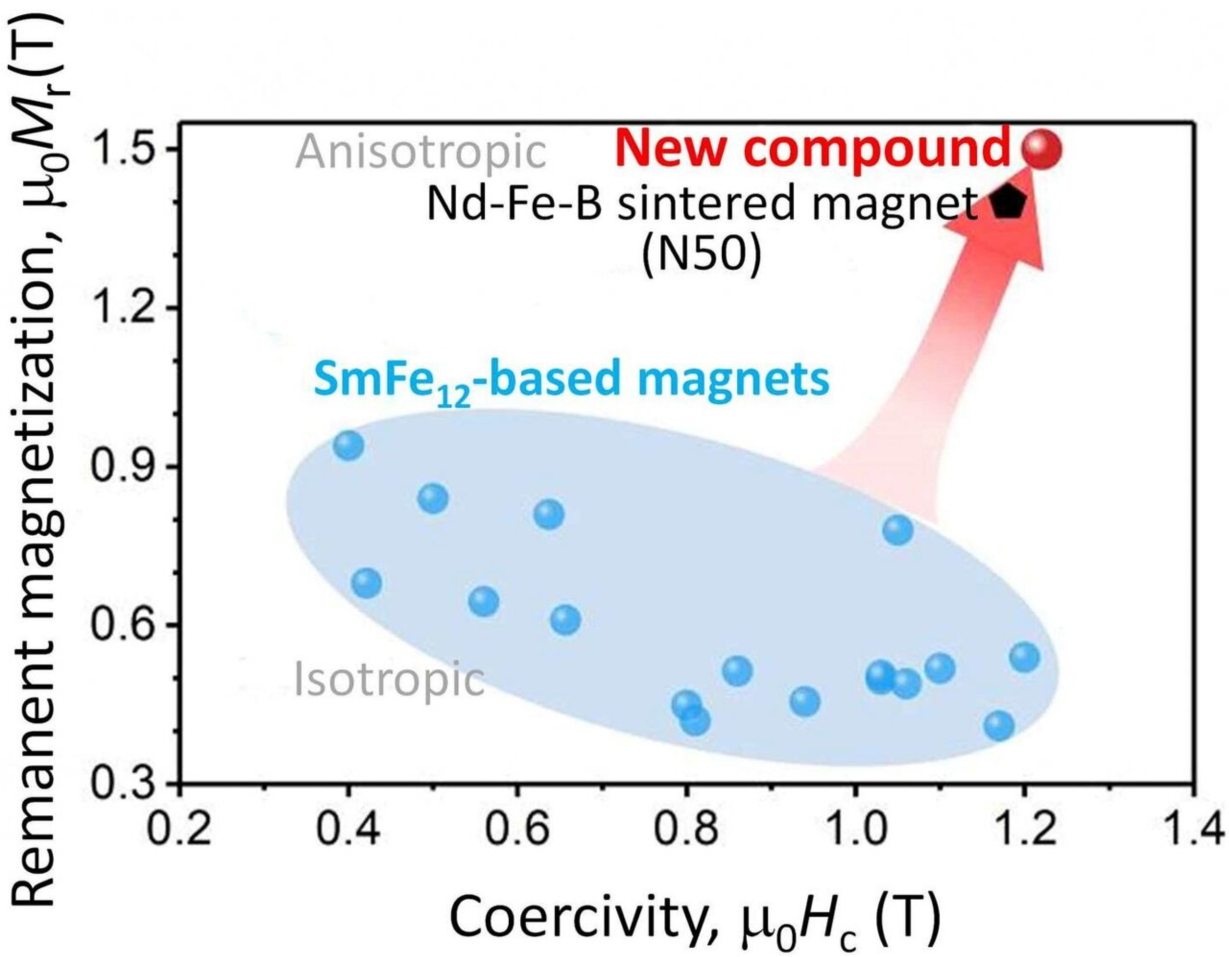

The new compound developed in this research exhibited magnetic properties significantly superior to those exhibited by other SmFe12-based magnets previously developed. Credit: NIMS

NIMS and Tohoku Gakuin University have developed a boron-doped anisotropic $Sm(Fe_{0.8}Co_{0.2})_{12}$ thin film containing only small amount of rare earth elements. The compound exhibited 1.2 tesla coercivity, sufficient for use in automotive electric motors. This was achieved by creating a unique granular nanostructure in which $Sm(Fe_{0.8}Co_{0.2})_{12}$ grains are uniformly enveloped by an amorphous grain boundary phase approximately 3 nm in thickness. This compound exhibited superior magnetic properties to that of Nd-Fe-B based magnets even when processed into a thin film.

Demand for green technologies that can help to reduce CO_2 emissions (e.g., electric motors for environmentally friendly vehicles and wind power generation) has been growing, leading to rapidly increasing demand for the high-performance permanent magnets needed for these technologies. The Nd-Fe-B based sintered magnets currently in use are composed not only of the rare earth element neodymium but also a heavy rare earth element: dysprosium. Because of the geopolitical risks associated with the acquisition of these materials, development of new magnets that do not rely on the scarce elements is desirable. Anisotropic $SmFe_{12}$-based compounds containing relatively small quantities of rare earth elements have been studied for their potential to serve as an effective alternative candidate for the next generation permanent magnets. In 2017, NIMS confirmed that samarium-iron-cobalt compounds ($Sm(Fe_{0.8}Co_{0.2})_{12}$) are superior to neodymium magnets in terms of several important magnetic parameters: magnetization, magnetocrystalline anisotropy and Curie temperature. However, previous studies had found these compounds' coercivity—another important parameter for practical magnets—to be inadequate.

This research group focused on the fact that high-performance neodymium magnets with high coercivity have a multiphase microstructure in which $Nd_2Fe_{14}B$ microcrystals are arranged in one direction and individually enveloped by an amorphous phase approximately 3 nm in thickness. The group then attempted to develop a similar microstructure in which individual $Sm(Fe_{0.8}Co_{0.2})_{12}$ grains are uniformly enclosed by a thin layer of an amorphous phase. In this research project, the group doped $Sm(Fe_{0.8}Co_{0.2})_{12}$ with boron, thereby fabricating a nano-granular microstructure in which $Sm(Fe_{0.8}Co_{0.2})_{12}$ nanoparticles are evenly surrounded by an amorphous phase approximately 3 nm in thickness. Moreover, this compound has an anisotropic granular microstructure, enabling it to exhibit a remnant magnetization greater than that exhibited by other $SmFe_{12}$-based compounds with isotropic granular microstructures. As result, this compound exhibited a large coercivity of 1.2 T combined with a large remanent magnetization of 1.5 T, much larger than the previously developed $SmFe_{12}$-based magnetic compounds.

This $Sm(Fe_{0.8}Co_{0.2})_{12}$ compound with an anisotropic, multiphase microstructure was proven to have very high coercivity, even when processed into a thin film. It may serve as a novel magnet capable of outperforming neodymium magnets. Previously studied anisotropic $Sm(Fe_{0.8}Co_{0.2})_{12}$ compounds exhibited significantly lower coercivity than the compound developed in this research. The underlying mechanisms which lead to realizing a high coercivity discovered in this research may be applicable to bulk magnets with the aim of developing practical anisotropic $Sm(Fe_{0.8}Co_{0.2})_{12}$ magnets with high coercivity.

More information: H. Sepehri-Amin et al, Achievement of high coercivity in Sm(Fe0.8Co0.2)12 anisotropic magnetic thin film by boron doping, *Acta Materialia* (2020). DOI: 10.1016/j.actamat.2020.05.026

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