Rare earth permanent magnets with ultimate hard magnetic properties

K. Hono
Elements Strategy Initiative Center for Magnetic Materials, National Institute for Materials Science (NIMS), Tsukuba, Japan

There has been much research interest during the past decade to attain high coercivity in Nd-Fe-B magnets without using heavy rare earth (HRE) elements. Now that the supply of rare earth elements has been stabilized, the renewed goal is how to achieve the highest permanent magnetic properties with a balanced use of rare earth elements. In this talk, we will present an overview on our recent progresses on the development of high-coercivity Dy-free Nd-Fe-B magnets that were carried out at NIMS in collaboration with many industrial partners. Thereafter, we will discuss how to achieve ultimate permanent magnet properties by adding trace amounts of HRE to the Nd-Fe-B system. To obtain better understandings of the microstructure-coercivity relationships, we have investigated the microstructures of experimental magnets with wide ranges of coercivities that varied depending on chemical compositions, processing routes and post-manufacturing heat treatments. The microstructure and magnetic domain observations have been carried out using aberration-corrected STEM, atom probe tomography (APT), magneto-optical Kerr microscopy and finite element micromagnetic simulations. We found that the intergranular phase parallel to the c-planes are mostly crystalline with a higher Nd concentration in contrast to the phase lying parallel to the c-axis that contains higher Fe content with an amorphous structure in both sintered and hot-deformed magnets. Micromagnetic simulations suggest that the reduction of magnetization in the latter phase is critical for enhancing the coercivity. Based on these new experimental findings together with our detailed characterization results of the intergranular phases in Nd-Fe-B magnets, we propose a method to increase the coercivity of Nd-Fe-B magnets while maintaining high remanence. Lastly, we will discuss the possibility of industrially viable high-performance magnets other than Due to the concern on the stable supply of heavy rare earth (HRE) elements, the Nd-Fe-B system.

This talk includes results obtained in collaboration with industrial collaborators including TOYOTA, Toyota Central Research Lab. Intermetallics and Daido Steel conducted under JST's Collaborative Research Based on Industrial Demand projects.