

Microstructure and Coercivity of Tb₄O₇ Grain Boundary Diffusion Processed Sintered (Nd,Dy)-Fe-B Magnets

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In the grain boundary diffusion (GBD) process of Nd-Fe-B magnets, heavy rare earth elements (HREs) such as Dy and Tb are incorporated preferentially along the grain boundaries, instead of alloying them into the bulk. This results in a dramatic improvement in coercivity without losing remanence, leading to substantial savings in HREs.¹⁻³ However, it is well known that the alloying of Dy to the matrix is required to attain the coercivity higher than 2 T. In this study, a detailed microstructural characterization was carried out on terbium fluoride GBD processed (Nd,Dy)-Fe-B sintered magnets with four different Dy contents in order to understand the combined effect of Dy alloying and Tb GBD process. The nominal Dy compositions of the four base-alloys (prepared by two-alloy method) were 0, 2, 5, and 11 wt.%. Coercivity values of the four magnets before and after GBD process are, 1.2 and 1.9 T, 1.5 and 2.4 T, 2.1 and 3.2 T, and 3.6 and 4.3 T respectively. Microstructure of the four samples was characterized using scanning electron microscopy (SEM), electron probe micro analysis (EPMA), transmission electron microscopy (TEM) and atom probe tomography (APT). Figure 1 shows STEM/EDS mapping of Nd, Dy, Tb and Fe; average concentration (wt.%) of each element in the shells is shown next to it. Figure 2 shows high resolution STEM/EDS mapping of a grain boundary region containing shell. In addition to the Tb and Dy rich shell, a thin Nd-rich grain boundary phase is observed. The concentrations of Tb and Dy in the shell next to the grain boundary phase were estimated from the EDS analysis and correlated with coercivity. The coercivity after the GBD process is in accordance with the increase in the anisotropy field estimated from the concentration of Tb and Dy.

References

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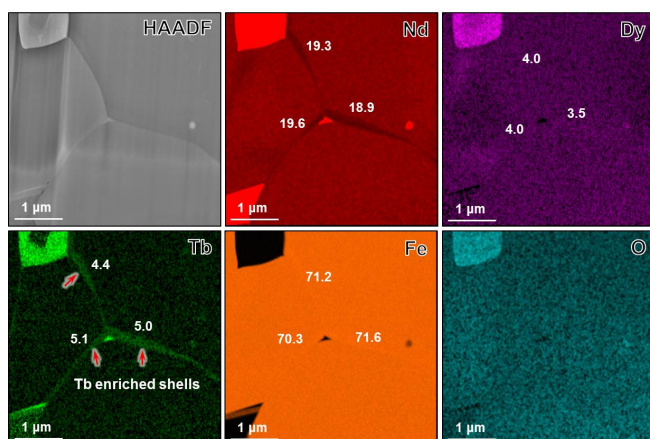


Figure 1. STEM/EDS mapping of Nd-5Dy-Fe-B sintered magnet showing Tb enriched shells

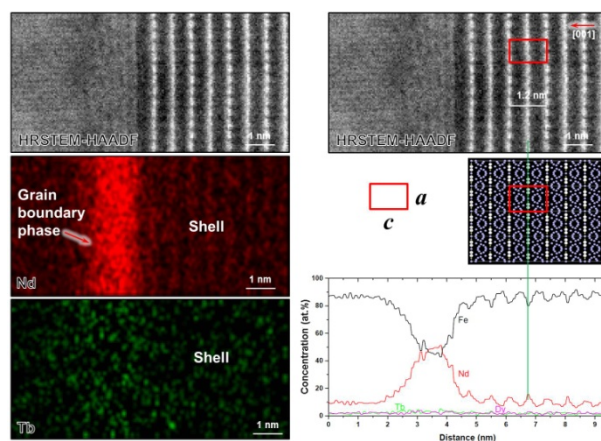


Figure 2. High resolution STEM/EDS mapping of the magnet showing Nd-rich grain boundary phase. Concentrations of Nd, Tb and Dy in a shell very close to the grain boundary were obtained