Improved coercivity and squareness in bulk hot-deformed magnets by two-step grain boundary diffusion process

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In order to use Nd-Fe-B based permanent magnets for the traction motor of hybrid (electric) vehicles, a coercivity of 0.8 T is required at 160 °C to avoid their thermal demagnetization during operation. To meet this requirement, grain boundary diffusion of RE-based eutectic alloys is employed to improve the coercivity in the hot-deformed magnets. [1)] Recently, Li *et al.* reported a coercivity of ~2.57 T with remanence of 1.38 T in a 2-mm-thick hot-deformed magnet by the grain boundary diffusion of Tb-Nd-Cu alloy. [2)] However, such high performance was demonstrated only using a small piece of samples with a thickness of ~2 mm and a question is whether or not we can apply the process to large bulk samples. Previous reports on conventional Dy-vapor diffusion process in micron-grain sized Nd-Fe-B sintered magnets has shown that the limited diffusion depth results in a poor squareness of demagnetization curves. [3)] In this work, we investigated the method to improve the squareness of demagnetization curves of Nd-HRE-Cu eutectic-diffusion processed 5.6-mm-thick hot-deformed magnets.

The hot-deformed Nd-Fe-B-based magnets with composition of $Fe_{67.1}Pr_{6.7}Nd_{21.2}Co_{3.5}Ga_{0.5}B_1$ (wt.%) were used as starting materials. The samples of × 7 × 5.6 (c-axis) mm^3 in size were covered by the 12 wt.% $Tb_{20}Dy_{10}Nd_{40}Cu_{30}$ ribbons (with respect to mass of hot-deformed magnet) followed by annealing at 750°C for 1.5 h and post-annealing at 650°C for 9h, which is called as “one-step diffusion process”. In comparison, the two-step diffusion process was carried out as follows: the initial samples were covered by the 10 wt.% $Tb_{20}Dy_{10}Nd_{40}Cu_{30}$ ribbons (with respect to the mass of hot-deformed magnet) followed by annealing at 750°C for 1.5 h. Thereafter, the surface of the magnet was polished and the magnet was again covered by 6 wt.% of $Nd_{80}Cu_{20}$ alloy ribbons followed by heat-treatment at 650°C for 9 h. The magnetic properties were studied by pulse BH-tracer.

Fig. 1 shows the demagnetization curves of the one-step and the two-step diffusion processed samples. The coercivity is improved from ~1.14 T in the as-deformed sample to ~2.38 T while remanence degrades from ~1.49 T to ~1.28 T after one-step diffusion procession. In contrast, the coercivity is enhanced to 2.43 T with remanent magnetization reduction to ~1.29 T by the two-step diffusion process. The squareness factor of demagnetization curve is defined as $\mu_0 H_k/\mu_0 H_c$, where $\mu_0 H_k$ is the absolute value of external field when the magnetization equals to 90% of remanent magnetization ($\mu_0 M_r$) and $\mu_0 H_c$ is the coercivity of the sample. The squareness factor was calculated to be ~0.83 for the one-step diffusion processed sample, which is improved to ~0.91 after the two-step diffusion. The origin of the obtained magnetic properties will be discussed based on detailed microstructure characterization.

Reference

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2) J. Li, *et al.*, Acta Mater. 161 (2018) 171-181.
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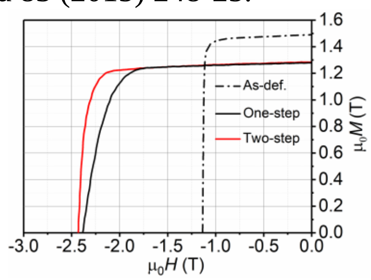

Fig. 1 Demagnetization curves of hot-deformed magnets and diffusion-processed magnets