Analyses on magnetization reversal process of Nd-Fe-B hot-deformed magnets

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The magnetization reversal process of a Nd-Fe-B magnet has been long a controversial issue since its discovery. Recently, the importance of this subject becomes more significant because of the growing demands of high performance permanent magnets for electric/hybrid vehicle and generator applications. Since a Nd-Fe-B magnet has a microstructure of the $Nd_2Fe_{14}B$ main phase grain and the intergrain phase, it has been widely accepted that the grain boundary plays a crucial role for the magnetization reversal process. In Nd-Fe-B sintered magnets, however, the grain boundary direction is randomly distributed with respect to the *c*-axis of $Nd_2Fe_{14}B$ phase. On the other hand, a Nd-Fe-B hot-deformed magnet has a microstructure of well aligned platelet $Nd_2Fe_{14}B$ gran, and the grain boundary mostly exists along the directions of parallel and perpendicular to the *c*-axis of $Nd_2Fe_{14}B$ phase. Thus, a Nd-Fe-B hot-deformed magnet is expected to be a model magnet for the analysis of the magnetization reversal process. In this talk, we discuss the magnetization reversal process of the Nd-Fe-B hot-deformed magnets through the magnetic viscosity [1] and the first-order reversal curve (FORC) analyses [2].

The samples used in this study are the Nd-Fe-B hot-deformed magnets with and without the Nd-Cu eutectic alloy grain boundary diffusion process [3]. The former and latter are referred as GBD and HD, respectively. The coercivity H_c of these two samples are quite different, i.e. 2.2 T for GBD and 1.1 T for HD at ambient temperature. Under finite temperature, the magnetization reversal takes place through the thermal activation process against the energy barrier $E_b(H)$. $E_b(H)$ is usually expressed as $E_b(H) = E_0(1 - H/H_0)^n$, where H is the magnetic field, E_0 the energy barrier height at $H = 0$, n the constant depending on the magnetization reversal mode; $n = 1$ for domain wall pinning and $n = 1.5 \sim 2$ for nucleation or coherent rotation. Recently we proposed the method to determine these energy barrier parameters from the magnetic viscosity measurement [1]. Fig. 1 shows the value of n for HD and GBD magnets as a function of temperature. Surprisingly, the value of n almost keeps to be 1 irrespective of temperature and samples whereas H_c varies significantly with temperature and samples. This fact indicates that the domain wall pinning is the major magnetization reversal process at $H \approx H_c$. Fig. 2 shows the FORC diagrams of HD and GBD samples. For this experiment, the samples are shaped into long rods of 3*0.5*0.5 mm^3 in order to reduce the demangetiation factor N_z. Both the FORC diagrams of HD and GBD exhibit simple Gaussian patterns with narrow distributions. From these results, we may conclude that the effect of local demagnetization field which has been frequently discussed is negligibly small, and the coercivity distributions are also very small. This work was partially supported by ESICMM

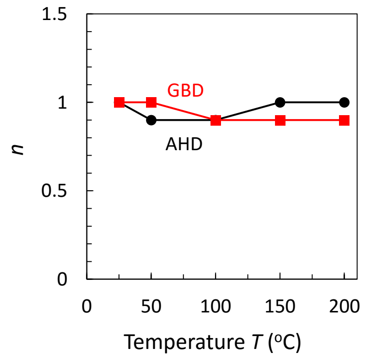

Fig. 1 Power index n of energy barrier function as a function of temperature.

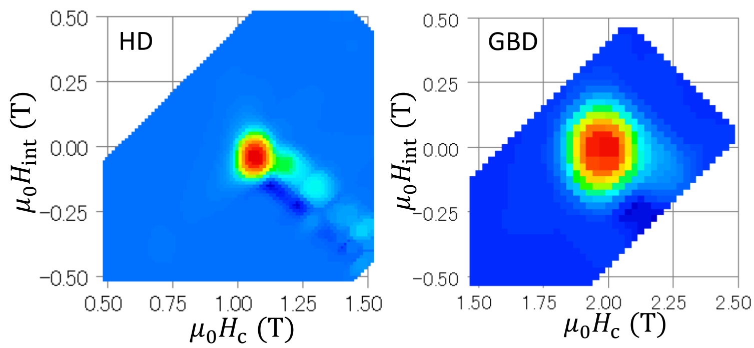

Fig. 2 FORC diagrams of HD and GBD samples at ambient temperature.

References

[1] S. Okamoto et al., J. Appl. Phys. **118**, 223903 (2015), [2] T. Yomoita et al., submitted to proceedings of PEPM2016, [3] T. Akiya et al., Scr. Mater. **81**, 48 (2014).