Domain structure of exchange-coupled and exchange-decoupled Nd-Fe-B sintered magnets

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Understanding the magnetization reversal processes in Nd-Fe-B sintered magnets is important in order to obtain a clue to enhance the coercivity of Nd-Fe-B magnets without using heavy rare earth elements. In order to meet the demand of high coercivity without changing the currently established powder metallurgy route, Nakajima and Yamazaki [K. Nakajima and T. Yamazaki, Japan Patent. (2015) 5767788] reported a new series of sintered magnets that achieve the coercivity of more than 1400 kA/m and the remanence of 1.38 T without refining the grain size. The microstructural characterization revealed well-isolated 2:14:1 grains with Ga-doped Nd-rich intergranular phase[1]. Such non-magnetic intergranular phase with the chemical composition $Nd_6(Fe,Ga)_{14}$ was reported to decouple the ferromagnetic grains and reduce the influence of the reverse domain formation between neighboring grains. In this work, we observed the magnetic domain structure of Ga-doped Nd-rich Nd-Fe-B magnet and the commercial Nd-Fe-B magnet by means of magneto-optical Kerr effect in order to understand the mechanisms of magnetization reversal processes in these two types of magnets. The samples were mechanically polished with the c-axis out of the plane and in the plane. Magnets were first fully saturated in magnetizer with the field of 5 T and then brought to the remanent state. In the commercial magnet, much more grains remained saturated compared to the Ga-doped Nd-rich magnet (a1 and b1). The reason for this is better isolation of 2:14:1 grains in Ga-doped Nd-rich magnet. If the grains are better isolated, each grain feels higher stray field which lead to domain formation on the surface of magnet. When the reverse magnetic field was applied to the magnet, we observed different domain formation. In the commercial magnet cascade-like domain propagation occurred (marked region in a2 and a3). At high-enough field the surface domains of a few grains were switched simultaneously. This implies the grains are exchange-coupled due to the low amount of Nd-rich intergranular phase. On the contrary, in Ga-doped Nd-rich magnet the domain formation was initiated from the boundary and at high-enough field the domains propagated through the whole grain (marked region in b2 and b3).

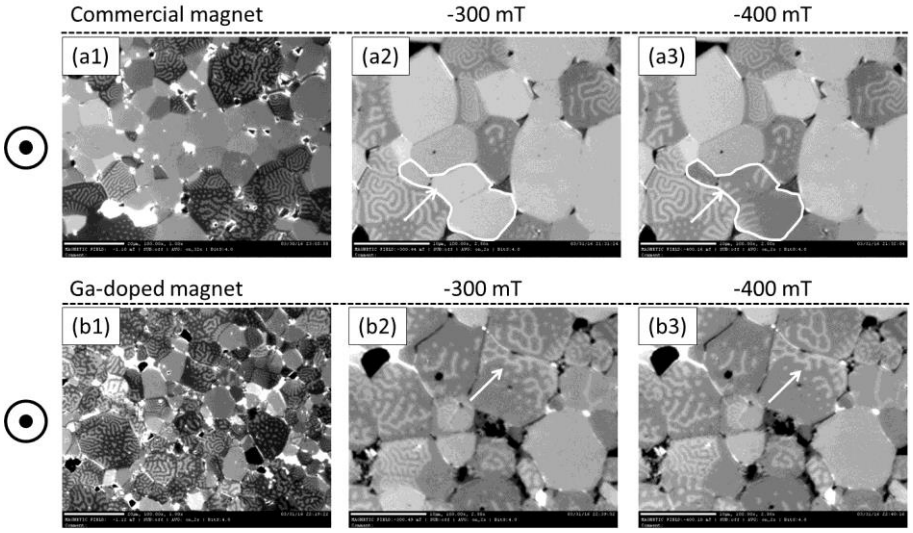

Figure 1: Domain structure in commercial and Ga-doped Nd-rich Nd-Fe-B magnet

[1] T. T. Sasaki, T. Ohkubo, Y. Takada, T. Sato, A. Kato, Y. Kaneko, K. Hono, Formation of non-ferromagnetic grain boundary phase in a Ga-doped Nd-rich Nd-Fe-B sintered magnet, Scripta Materialia 113 (2016) 218–221