Large scale micromagnetic simulation and analysis of magnetization reversal within hot-deformed permanent magnet

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Introduction

The hot-deformed permanent magnet is one of the promising material for high coercivity and a remanent magnetization that are necessary for high-efficiency power motors. This permanent magnet consists of many tabular grains that interact with each other through exchange and dipole interaction. The interaction among the grains propagates magnetization reversal across the grain interface during demagnetization process. Thus, it is important for a further high-performance permanent magnet to reveal how the magnetization reversal propagates within the permanent magnet. In this study, we performed large-scale micromagnetic simulation using our simulation code [1] based on Landau–Lifshitz–Gilbert equation and analyzed simulation data to clarify magnetization reversal process inside the hot-deformed magnet.

Model and method

Figure 1(a) shows the simulation model of a nanocrystalline hot-deformed permanent magnet of size 1024 nm $\times$ 1024 nm $\times$ 512 nm. This model is created by stacking the layers that consist of the tabular grain with an average diameter of 160 nm and thickness 32 nm. Directions of the easy axis of the grains tilt from the z axis with the average axial inclination 11.6°. We discretized the simulation model into 2.0 nm $\times$ 2.0 nm $\times$ 2.0 nm. Thus, we use about 0.3 billion calculation cells for our simulation, and the simulation model has the $3,384$ tabular grains. The following $Nd_2Fe_{12}B$ material parameters are assumed in our simulation: saturation magnetization 1281.2 emu/cm^3, uniaxial constant 4.5×10^7 erg/cm^3, exchange stiffness constant 12.5×10^{-7} emu/cm^3, and Gilbert damping constant 1.0. We choose 12.5×10^{-9} emu/cm^3 for inter-grain exchange interaction.

Results

Figure 1(b) shows the calculated hysteresis curve. The coercivity of our simulation model is 29.0 kOe. When an external field exceeds 28.0 kOe, nucleation cores occur in some grains, and the magnetization reversal propagates across the grain interface. Figure 1(c) shows the magnetization structure in the each grain as a function a grain diameter and tilt angle of the easy axis when the nucleation cores appear. The nucleation core tends to be created in the grain whose tilt angle is about 30° (blue circle). The magnetization reversal propagates across the grain interface and, finally, the interaction domain structure appears. However, the distribution of the grain in which the magnetization reverses (green circle) is almost same that of the grains in which magnetization does not reverse (red circle) as shown in Fig. 1(d). In this presentation, we will talk about details of the propagation of the magnetization reversal between the grains.

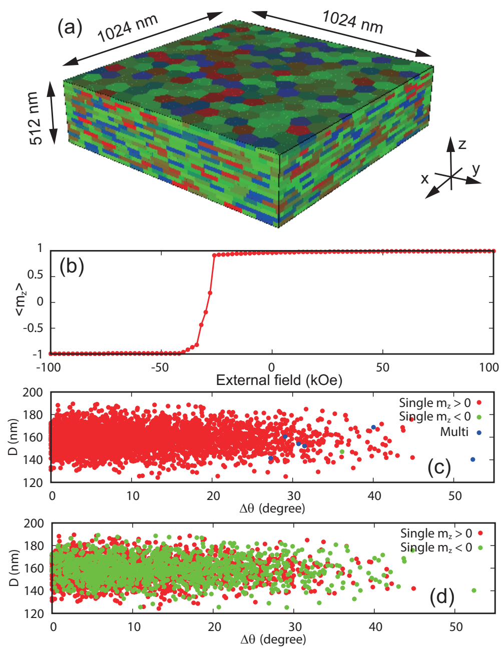

Fig 1: The illustration of the simulation model (a), the calculated hysteresis curve (b), and (c) the magnetization structure of the each grain when the nucleation core occur (c), and the interaction domain is created (d).

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