Effects of microstructure on magnetization reversal inside hot-deformed permanent magnet

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Introduction

For the development of high-performance permanent magnet, it is indispensable to know magnetization dynamics inside the permanent magnet. In demagnetization process, magnetization reversals are initialed and domain walls move across inside grains and grain boundaries. Magnetizations are interacted with each other through exchange and dipole fields, and these interactions play important roles in the domain wall displacement. However, the mechanism of magnetization process is not yet fully understood. 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 × 1024 nm × 512 nm. The simulation model consists of 3,391 tabular grains whose averaged diameter and thickness are 158.4 nm and 32 nm, respectively. Easy axes of the grains are randomly orientated from the z-direction, and the averaged tilt angle of the easy axis is 11.7°. 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 a snap shot of magnetization reversal process inside the permanent magnet. The magnetization reversals are initiated in some regions where the dipole field of over 1.0T is applied. These dipole fields promote the magnetization reversal. After initiating the magnetization reversal, the domain walls move inside the grains and across the grain boundaries. The domain wall displacement creates pillar-shape magnetization reversal regions owing to the dipole filed. The distribution of the dipole field has relationship with the microstructure of the permanent magnet. Figure 1(c) shows the magnetization reversal and the easy-axis orientations of the grain ($\Delta\theta$) and contacted grain ($\Delta\theta_j^{\max}$). The magnetization is preferentially reversed inside the grains having large $\Delta\theta + \Delta\theta_j^{\max}$.

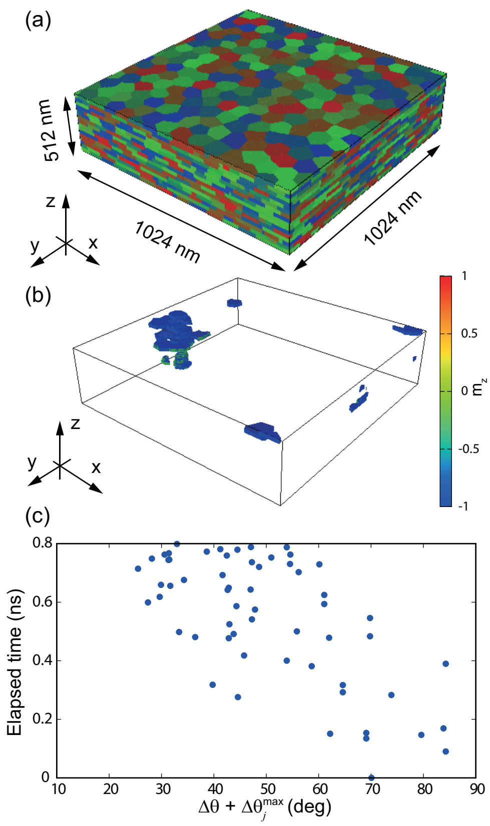

Fig 1: (a) Simulation model of this study, (b) the snap shot of the magnetization reversal process, and (c) the relationship between magnetization reversal and the orientation of the easy-axis of grains.

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