Magnetic domain structure observation of Dy free hot-deformed Nd-Fe-B magnets

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Nd-Fe-B magnets have a fine microstructure due to their unique fabrication procedure, which gives them 1/10 finer crystal grain size (100~500nm) compared to sintered magnets and produces both better coercivity and reduced Dy content[(1)]. However, the coercivity is not as high as expected from the grain size. To further improve the magnetic properties of this type of magnet, it is important to clarify the reason for the higher coercivity of this magnet. As the first step, we investigated the magnetic domain pattern structure of this magnet in detail.

A hot-deformed Dy-free Nd-Fe-B magnet with the composition of $Nd_{13.5}$-$Co_{3.82}$-$B_{5.64}$-$Ga_{0.57}$-$Fe_{bal.}$ (at.%) was prepared. Its remanence and coercivity were 1.35 T and 1353 kA/m (17.0 kOe), respectively. Observations for this sample were performed from two directions, perpendicular to the c-axis and almost parallel to the c-axis. In this study, the observations of the magnetic domains in the thermally magnetized state and in the magnetization process were performed. These observations were performed using not only Magnetic Force Microscope (MFM) and Atomic Force Microscope (AFM) but also Low Voltage Scanning Electron Microscope (LV-SEM) at the same areas, in order to investigate the relationship between the microstructure and magnetic domain pattern.

Figure 1(a) shows MFM images for the c-plane and (b) shows the illustration of magnetic domain pattern in the same area. Contours of grains observed using LV-SEM are overlaid in the figure. These figures reveal the following: 1. the sample consists of single domain and multi-domain grains, 2. a group of grains form a maze pattern, 3. multi-domain grains exist uniformly throughout the powder, and 4. relatively large grains at the edges of the maze pattern are multi-domain grains. In Fig. 1(c), magnetic domains looking at the plane parallel to the c-axis exhibited the stripe patterns parallel to the c-axis with various widths, some of which are interrupted by the equiaxial grains at powder boundaries. From these observations, the 3D magnetic domain structure of hot-deformed magnet is as portrayed in this figure.

Based on these observations, the magnetic domain structure of hot-deformed Nd-Fe-B magnets will be discussed.

Reference

1) K. Hioki, A. Hattori, and, T. Iriyama, *J. Magn. Soc. Jpn.*, **38**, 79-82(2014)

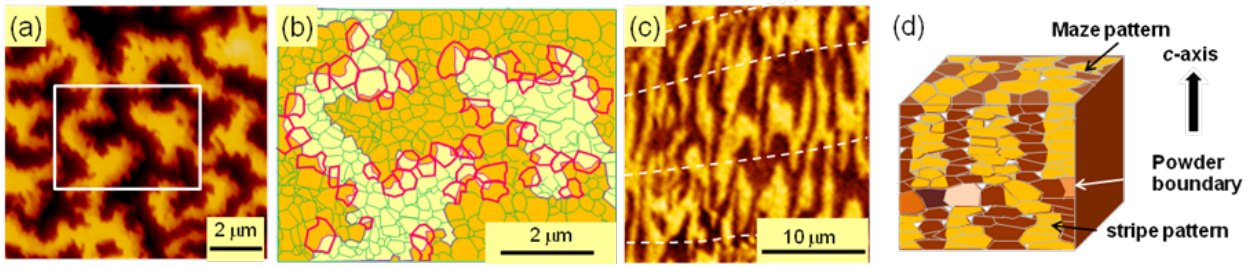

Fig. 1. (a)(c) MFM images in the thermally demagnetized state. Looking at the planes (a) perpendicular and (c) parallel to the c-axis, respectively. Dotted lines indicate powder boundaries. (b) Illustration of magnetic domain pattern shown in Fig. 1(a) in the white square. Contours of grains observed using LV-SEM are overlaid. Multi-domain grains are shown in bold lines. (d) Illustrations of three dimensional magnetic domain structure of hot-deformed magnet in the thermally demagnetized state.