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Effect of grain size and hot-deformation temperature on texture in die-upset Nd-Fe-B magnet

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I. Introduction

Magnetic performance of a permanent magnet is determined by a combination of high coercivity and high remanence, together with a good squareness of the demagnetisation curve. For the high remanence and good squareness a good alignment of magnetic grain (good texture) is essential. One of the most common techniques being used to align the $Nd_2Fe_{14}B$ grains in the Nd-Fe-B material is a die-upset or hot deformation technique. The die-upset technique is usually applied to the melt-spun Nd-Fe-B material. The melt-spun material is hot-pressed first in to a high density compact, and then the compact is subjected to the die-upset to cause a severe deformation. The die-upsetting leads to a good texture of thenanocrystalline $Nd_2Fe_{14}B$ grains with their easy magentisation c-axis is parallel to the compression direction. The formation of texture is known to take place via the stress-induced preferential grain growth. Considering the texture formation mechanism, the grain size before the die-upsetting is believed to play an important role. In the present study, the hot-pressed compactswith various grain sizes ranging from several tens of nm to several hundreds nm were prepared, and then they were subjected to a die-upsetting. The effect of grain size in the hot-pressed compact on the texture in die-upset magnet was investigated.

II. Experimentals

Starting alloy of $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$was prepared by an arc-melting using high purity elements. The prepared alloywas melt-spun with surface velocity of 40 m/s. The obtained ribbon was briefly milled for 5 min using a mortar and pestle, and the powder was compacted by a hot pressing. The hot pressing was carried out under vacuum at various temperatures in a closed die for 2 minwith pressure of 1 T/cm^2. The hot-pressed compact wassubsequently die-upset with strain rate of 5.8 x 10^{-3}/sec in an open die at various temperatures to achieve height reduction around 75 %. Texture in the die-upset magnets was evaluated by a magnetic means. A cube (2 x 2 x 2 mm^3) was cut from the die-upset sample. Demagnetization curve was measured along the direction parallel and perpendicular to the pressing direction using a VSM at room temperature after pre-magnetizing with pulsing field of 50 kOe. The obtained demagnetization curve was corrected to compensate the demagnetizing field of the specimen using a proper correction factor. Texture in the die upset sample was evaluated using the ratio of $M_{7(//)}/M_{7(\perp}$, where, $M_{7(//)}$and $M_{7(\perp}$ are the magnetization at 7 kOe along the directions parallel and perpendicular to the pressing direction, respectively. Microstructure of the material at various conditions was examined using HRSEM and TEM.

Ⅲ. Results and discussion

In order to prepare the hot-pressed compacts with different grain size, the powder material was hot-pressed at different temperatures. The compacts hot-pressed at 750 ℃ 770 ℃and 800 ℃ad grain size of around 50 nm, 100 nm and 200 nm, respectively. These compacts with different grain size were die-upset at 750 ℃and the texture in the die-upset sampleswas examined. Fig. 1(a) shows the effect of grain size in the hot-pressed compact on the texture in the die-upset sample. It appears that the die-upset sample from the hot-pressed compact with fine grain size (50 nm) exhibited much higher texture with respect to the samples from the hot-pressed compacts with coarser grain size (100 nm and 200 nm). Meanwhile, the effect of die-upset temperature on the texture in the die-upset sample was investigated using the compact hot-pressed at 770 ℃ and the results were shown in Fig. 1(b). It appears that the sample die-upset at lower temperature of 700 ℃had lower texture, so did the sample die-upset at higher temperature of 900 ℃ The samples die-upset at modest temperature range from 750 ℃to 850 ℃ howed much higher texture. The dependence of texture in the die-upset samples on the initial grain size and hot-deformation temperature is to be explained based upon the dissolution and precipitation mechanism.

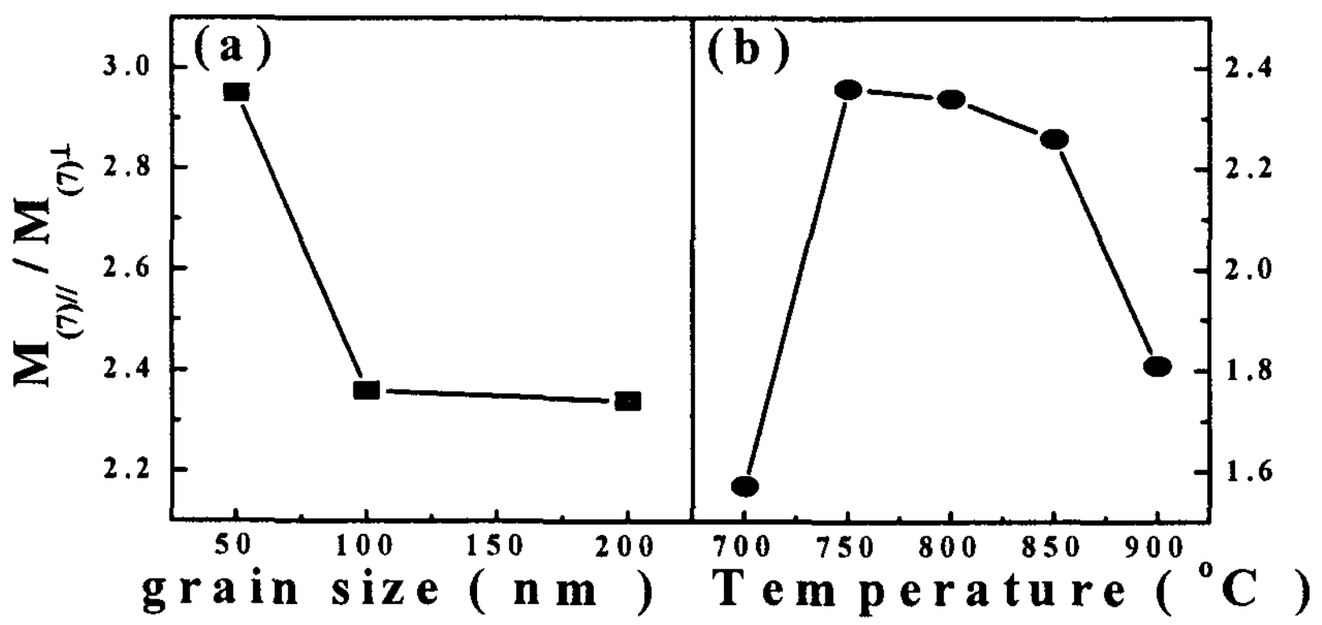

Fig. 1. Effects of (a) grain size and (b) die-upsetting temperature on the texture in the die-upset $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$ sample.