Texture development in die-upset Nd-lean Nd-Fe-B alloy

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1. Introduction

The likelihood of $Nd_2Fe_{14}B$ hard magnetic grain texture in a die-upset Nd-Fe-B alloy depends heavily upon the Nd-content. While a Nd-rich Nd-Fe-B alloy with Nd-content well over 11.8 at% shows good texture by the die-upset, a Nd-lean Nd-Fe-B alloy with Nd-content near or well under the $Nd_2Fe_{14}B$ stoichiometric composition shows poor texture. The poor texture in the die-upset Nd-lean Nd-Fe-B alloy may be attributed primarily to the lack of grain boundary phase. However, it has been reported recently that an appreciable texture was achieved in the die-upset Nd-lean alloy modified with certain additives [1-2]. In the modified alloy, there is still no grain boundary phase. It is thought, therefore, that a distinct texture formation mechanism, which is different from that operating in the Nd-rich alloys, would operate in Nd-lean alloys. In the present study, the texture formation mechanism operating in Nd-lean Nd-Fe-B alloys was discussed.

2. Experimental work

The $Nd_xFe_{93.5-x}Cu_2Ga_{0.5}B_6$ (x = 9 – 13.5) starting alloys were melt-spun (Cu wheel surface velocity of 40 m/s), and the obtained ribbon was briefly milled. The milled powder was hot-pressed at 775 ℃ to prepare a compact, and the compact was subsequently die-upset at various temperatures to achieve height reduction of approximately 75 %. Texture in the die-upset magnets was evaluated by magnetic measurement. Demagnetization curve (corrected using demagnetising factor of 0.33) of the cubic sample was measured along the directions parallel and perpendicular to the pressing direction using a VSM at room temperature after pre-magnetizing with a 50 kOe DC pulsing field. Texture in the die upset sample was evaluated by the ratio, $M_{7(//)}/M_{7(\perp)}$, where, $M_{7(//)}$and $M_{7(\perp)}$ are the magnetization at 7 kOe in the first quadrant of the demagnetisation curve along the directions parallel and perpendicular to the pressing direction, respectively. Microstructure of the material at various conditions was examined using TEM and SEM.

3. Results and discussion

Fig. 1(a) shows the texture variation as a function of die-upset temperature for the die-upset $Nd_xFe_{93.5-x}Cu_2Ga_{0.5}B_6$ (x = 9 – 12) alloys. The texture variation for the Nd-rich $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$ alloy was also included in Fig. 1 for comparison. The Nd-lean $Nd_xFe_{93.5-x}Cu_2Ga_{0.5}B_6$ (x = 10.5, and 9) alloys showed negligible texture.

However, the Cu-added $Nd_xFe_{93.5-x}Cu_2Ga_{0.5}B_6$ (x = 12) alloy showed an appreciable texture, and it is noted that the texture increased with increasing the die-upset temperature. This trend goes into reverse compared to that in the Nd-rich $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$ alloy, for which the texture decreased with increasing the die-upset temperature. In the $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy, a lack of Nd-rich grain boundary phase is inevitable, therefore it is less likely that the texture formation mechanism of stress-induced preferential grain growth, which operates in the die-upset Nd-rich Nd-Fe-B alloy like $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$, may not operate in the $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy. The reverse trend of the texture variation with die-upset temperature for the $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy with respect to the $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$

alloy also suggests that a different texture formation mechanism may operate in the $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy. Microstructural observation on the fractured surface of the $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy die-upset at 900 ℃ showed that crystal layer blocks with thickness around 10 nm ~ 20 nm slid over each other (Fig. 1(b)). This observation suggested that the $Nd_2Fe_{14}B$ grains were deformed plastically by a slip of certain crystallographic plane. It can be concluded, therefore, that unlike the Nd-rich alloy in which the texture was formed by a stress-induced preferential grain growth, the Cu-containing Nd-lean $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy developed texture by basal plane slip deformation of the $Nd_2Fe_{14}B$ grains.

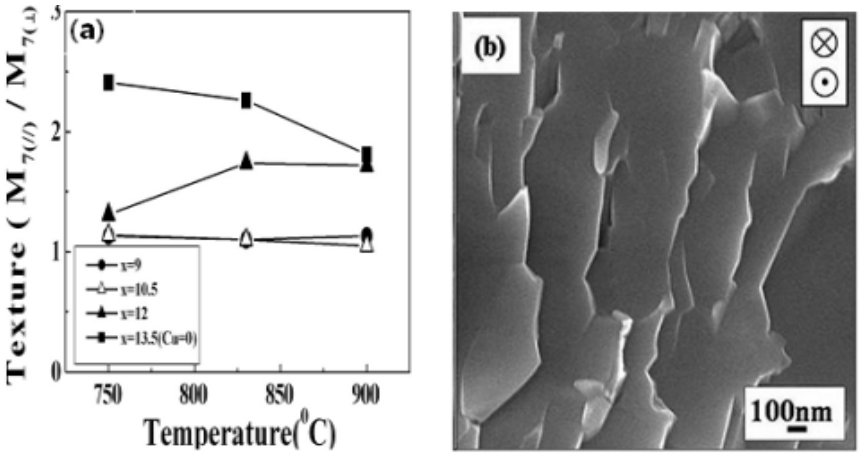

Fig. 1. (a) Variation of texture as a function of die-upset temperature for the $Nd_xFe_{93.5-x}Cu_2Ga_{0.5}B_6$ alloys, (b) microstructure of the fractured surface perpendicular to the pressing direction for the $Nd_{12}Fe_{79.5}Cu_2Ga_{0.5}B_6$ alloy die-upset at 900 ℃.

4. References

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