Effect of Nd-rich phase on c-axis orientation of Nd-Fe-B melt-spun magnet and its domain structure

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Abstract

X-ray diffraction and domain observation were performed to evaluate an effect of Nd-rich phase on the c-axis orientation of the Nd-Fe-B melt-spun ribbon. It was found that adequate addition of Nd-rich phase promotes the c-axis orientation of the Nd-Fe-B ribbon. The $(Nd_2Fe_{14}B_1)_{95}$(Nd-rich phase)$_5$ ribbon has c-axis orientation in the entire body from bottom to top when melt-spun at wheel speed of 10.0 m/s.
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1. Introduction

Preferable c-axis orientation of Nd-Fe-B melt-spun magnets has been investigated in the past two decades. It is known that low quench rate causes c-axis orientation of Nd-Fe-B melt-spun ribbons [1],[2]. However, their coercivity is smaller than that of high-quench-rate ribbons because of their coarse grains due to the low quench rate. It is also well established that Nd-rich phase precipitation along grain boundaries is important to increase coercivity in sintered magnets [3],[4]. The purpose of this study is to investigate an effect of Nd-rich phase on the c-axis orientation of the Nd-Fe-B melt-spun ribbon by X-ray diffraction and domain observation.

2. Experiment

Alloys of $(Nd_2Fe_{14}B_1)_{100-x}$(Nd-rich phase)$_x$ at.% with $0 < x < 15$ were melt spun using a Cu wheel in Ar atmosphere at the pressure of 760 Torr, as shown in Fig.1. The composition of $Nd_{4.9}Fe_{6.4}B_1$ at.% is used as Nd-rich phase by the value of Nd-Fe-B sintered magnet in [3]. The melt-spinning parameters were, ejection pressure 0.3 kg/cm^2, orifice of the quartz crucible 0.9 mm, the wheel speed varies from 7.5 to 15.0 m/s.

X-ray diffraction patterns were measured on both surfaces of ribbons. Magnetic domains at the surface and cross section of ribbons were also observed with a Kerr microscope. The c-axis orientation is evaluated as a function of the Nd-rich phase content x and wheel speed v_w.

3. Results and Discussion

X-ray diffraction patterns measured on both surface of the ribbon at $x = 5.0$ and $v_w = 10.0$ m/s is shown in Fig.2. Both surfaces exhibit intense reflections from (004), (006), and (008). The data indicate that the c-axis is oriented normal to the ribbon plane. When the composition is kept at $x = 5.0$ and the v_w increases to 15.0 m/s, the c-axis orientation is not observed at the wheel surface, as shown in Fig. 3. Figure 4 shows X-ray diffraction pattern at $x = 15.0$ and $v_w = 10.0$ m/s. The c-axis orientation is not also obtained at the free surface due to the increase in the value of Nd-rich phase.

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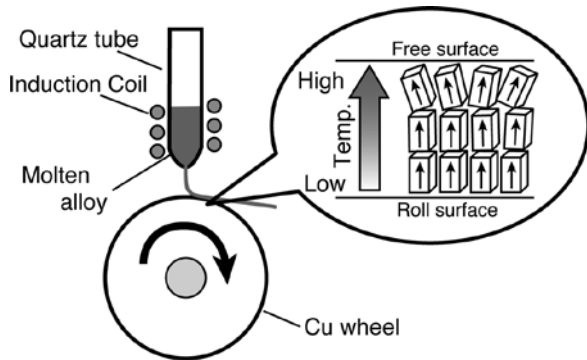*E-mail address*:take@ele.kyutech.ac.jp.

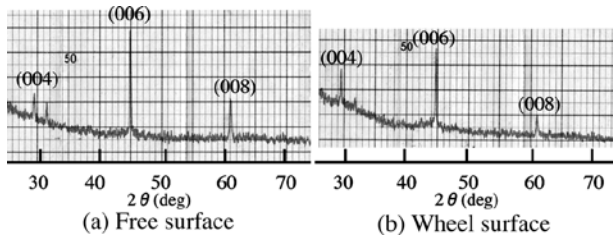Fig. 1 A schematic view of melt-spinning of Nd-Fe-B.

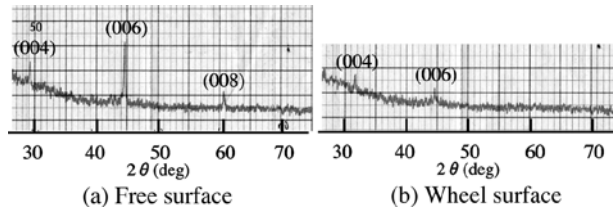Fig. 2 X-ray diffraction pattern at $x = 5.0$ and $v_w = 10.0$ m/s.

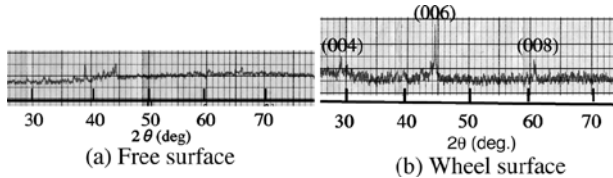Fig. 3 X-ray diffraction pattern at $x = 5.0$ and $v_w = 15.0$ m/s.

Fig. 4 X-ray diffraction pattern at $x = 15.0$ and $v_w = 10.0$ m/s.

Figure 5 shows domain patterns of the free surface and cross section of the ribbon showing the c-axis orientation by the X-ray diffraction pattern at $x = 5.0$ and $v_w = 10.0$ m/s. The Kerr contrast in Figs. 5(a) and 5(b) indicate normal component of magnetizations to the ribbon plane due to polar Kerr effect and longitudinal Kerr effect, respectively. Small sized grains show stripe domain configurations with deteriorated c-axis orientation at the free surface, as shown in Fig.5(a). However, most of grains exhibits maze domain configurations indicating preferable c-axis orientation normal to the ribbon plane. Fig.5(b) also indicates preferable c-axis orientation normal to the ribbon plane because of the stripe domain structure.

Cross-sectional domain pattern at $x = 5.0$ and $v_w = 15.0$ m/s is shown in Fig. 6(a). In the case of fast wheel speed, the c-axis orientation normal to the ribbon plane is deteriorated because some grains exhibit tilted stripe domain configurations. When the Nd-rich phase increases to 15.0%, the c-axis orientation normal to the ribbon plane is not also

obtained, as shown in Fig.6(b).

The coercivity of the ribbon with the c-axis orientation at $x = 5.0$ and $v_w = 10.0$ m/s is about a few kOe. The coercivity increases with increasing Nd-rich phase because the Nd-rich phase reduces the grain size. However, the c-axis orientation induced a large magnetic anisotropy.

Consequently, the data by X-ray diffraction and domain observation indicate that the ribbon has c-axis orientation in the entire body from bottom to top surfaces at $x = 5.0$ and $v_w = 10.0$ m/s. It was revealed that adequate addition of Nd-rich phase promotes the c-axis orientation of the Nd-Fe-B melt-spun ribbon.
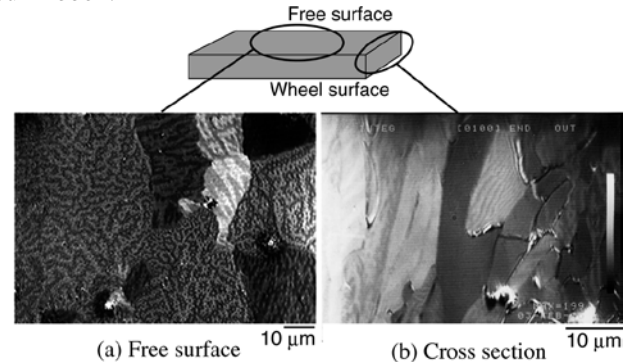

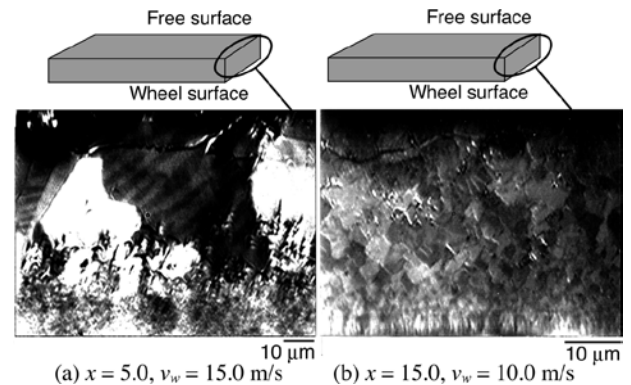Fig. 5 Domain patterns of Nd-Fe-B ribbon at $x = 5.0$ and $v_w = 10.0$ m/s.

Fig. 6 Cross-sectional domain patterns of Nd-Fe-B ribbons.

4. Conclusion

In the present work, X-ray diffraction and domain observation are performed to evaluate an effect of Nd-rich phase on the c-axis orientation of the Nd-Fe-B melt-spun ribbon. It was found that adequate addition of Nd-rich phase promotes the c-axis orientation of the Nd-Fe-B magnet.

References

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