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HOT-PRESSED AND DIE-UPSET (MM)12.5Fe77.9Ti1.0B8.6 PERMANENT MAGNET

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<Abstract>

Hot-pressed $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ permanent magnet showed H_c=3.75kOe, B_r=4.64kG, $(BH)_{max}$=2.78MGOe and die-upset magnet H_c=3.29kOe, B_r=5.01kG, $(BH)_{max}$=3.54MGOe. Structural anisotropy in die-upset magnet was envisaged by the increase of relative intensity of (006) peak. The higher magnetic properties of die-upset magnet is attributed to the c-axis alignment along the press direction.

Hot-press 및 Die-upset한 $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ 영구자석의 자기 특성에 관한 연구

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<요 약>

Hot-press로 제조한 $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ 영구자석의 자기특성은 H_c=3.75kOe, B_r=4.64kG, $(BH)_{max}$=2.78MGOe 이었고 die-upset으로 제조한 경우의 자기특성은 H_c=3.29kOe, B_r=5.01kG, $(BH)_{max}$=3.54MGOe이었다. die-upset 자석에서 조직의 이방성은 (006) 회절선의 상대강도의 증가로 확인되었다. die-upset 자석이 더 나은 자기특성을 보이는 것은 압축방향으로 c-축이 배열하는 것과 유관함을 알 수 있었다.

INTRODUCTION

Rare earth magnets, like Nd-Fe-B permanent magnets, are inferior to ferrites and alnico magnets in cost. Some hard magnetic alloys with good cost-performance have been investigated through the replacement of high price Nd element in Nd-Fe-B magnets with low price Misch metal(MM) which is mixture of rare earth elements. A few papers reported magnetic properties of MM-Fe-B permanent magnets[1][2][3] and their economic possibilities in the industry[1][4]. In this research, the magnetic properties and microstructures of hot-pressed and die-upset MM-Fe-B-Ti permanent magnets were investigated using vibrating sample magnetometer, optical microscopy and x-ray diffractometer.

EXPERIMENTS

Commercial grade misch metal(MM), 10wt%B ferroboron and 99.5% Ti were melted into an ingot in a vacuum Ar arc furnace. The composition of the ingot was $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$. Ribbons were melt-spun by ejecting the molten alloy through a small orifice 0.7 mmφ on a copper wheel(200 mmφ) rotating with a surface velocity of ~40 m/sec. The ribbons were crushed into powder with sizes less than ~150㎛. Hot-pressed magnets were formed with ~8 g of powder using a die with a 8 mm bore. MoS_2 was used as lubricant to prevent the magnets from sticking to the punch and die. Holding times of 2~3 min. were given at temperatures from 650 to 750℃, under densifying pressure of 100㎫. Hot pressing was done under initial vacuum and high purity argon gas atmosphere. Die-upset magnet was made in an over-sized die with a 20 mm bore. Temperatures of 720~750℃ and pressures of 300~350㎫ were applied for die-upsetting. Demagnetization curves of the hot-pressed and die-upset magnets were obtained using a VSM hysteresisgraph. X-ray diffraction measurement and optical microscopy were used to investigate crystal structures and microstructures.

RESULTS AND DISCUSSIONS

X-ray diffraction peak intensities of hot-pressed and die-upset $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ alloy are given in Fig. 1. As seen in Fig. 1, (006) peak intensity was greatly increased through die-upsetting. This indicates occurrence of c-axis alignment along the press direction during die-upsetting. The extra peaks belong to a second phase with richer rare earth elements than matrix as suggested in Ref. [3]. Density of the hot-pressed magnet was estimated as 7.17 g/㎤. The reduction ratio of height during die-upset was about 23%. The optical microscopy of the hot-pressed and die-upset magnets showed that ribbons rotated to perpendicular to the pressing direction during die-upsetting as shown in Ref.[5]. The magnetic parameters of the hot-pressed and die-upset magnets are tabulated in table. 1 along with MM-Fe-B permanent magnet's results of Ref. [4] for comparison. When die-upset, the coercivity decreased about 12% and remanence increased by nearly 7%. A small cracks existed in hot-pressed magnets and it might result in lower $(BH)_{max}$ values than those of MM-Fe-B magnets. The magnetic properties of this alloy in general are much lower compared with Nd-Fe-B(C) permanent magnets. This is mainly due to lower magnetocrystalline anisotropy of tetragonal (La,Ce)-Fe-B compounds[6]. Demagnetization curves of the hot-pressed and die-upset magnets are given in Fig. 2. As seen in Fig. 2, it might be suggested that die-upsetting can be a useful tool for fabrication of anisotropic MM-Fe-B permanent magnets as in Nd-Fe-B(C) permanent magnets[7]. The effect of substitution of Ti for Fe element in MM-Fe-B magnets[4] was realized as the increase of coercivity and remanence of both hot-pressed and die-upset magnets.

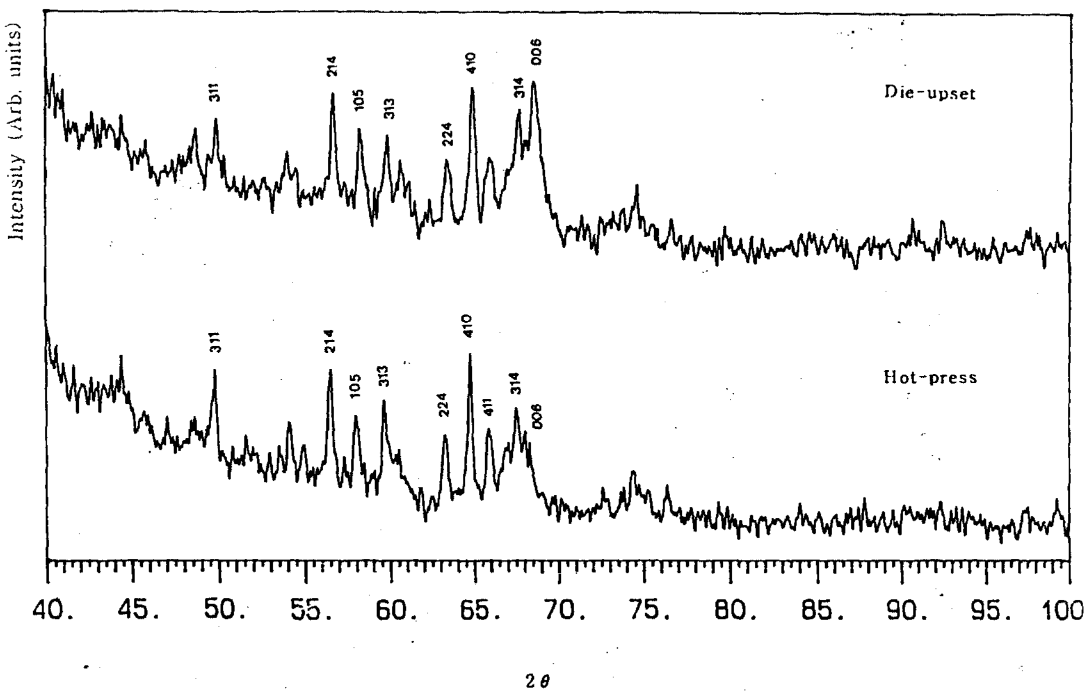
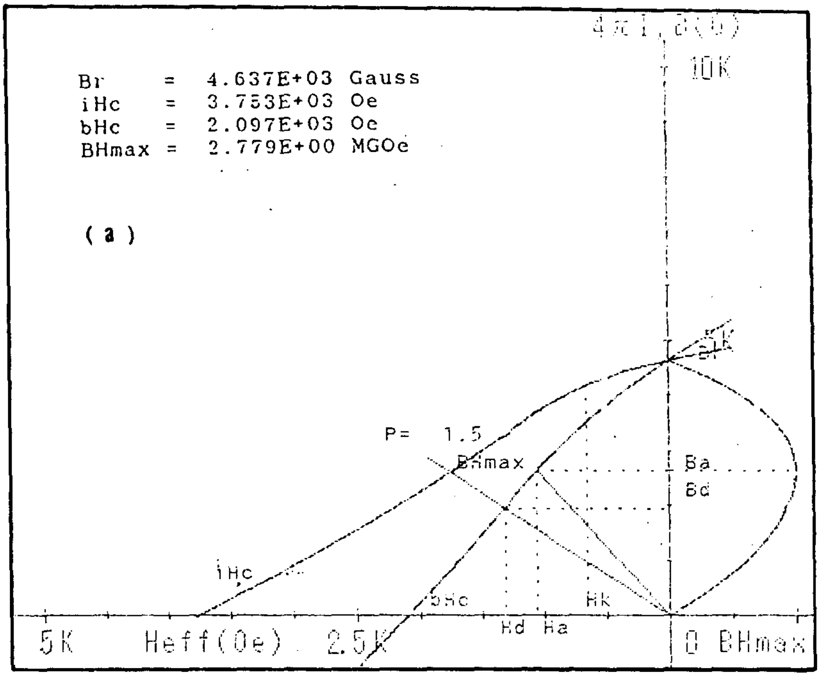


Figure 1. X-ray diffraction patterns of hot-pressed (a) and die-upset (b) $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ alloy.



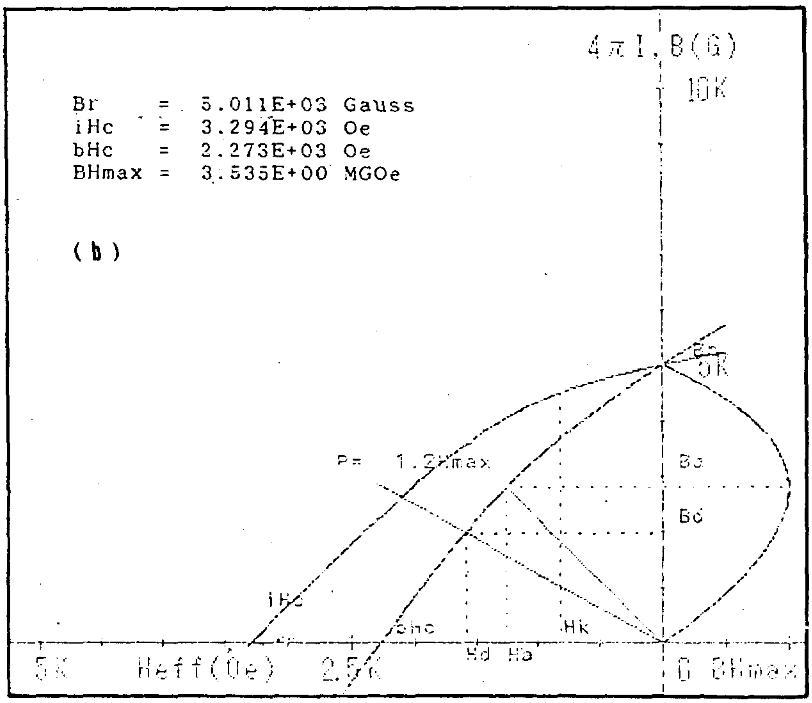


Figure 2. Demagnetization curves of hot-pressed (a) and die-upset (b) $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ alloy.

Table 1. Magnetic parameters of hot-pressed and die-upset $(MM)_{12.5}Fe_{77.9}Ti_{1.0}B_{8.6}$ alloy.

samples \ variables	ρ(g/cm³)	B_r(kG)	$_iH_c$(kOe)	$_bH_c$(kOe)	$BH)_{max}$(MGOe)
MM-FeB:Hot-pressed[4]	7.23	4.64	3.04	2.05	2.89
MM-FeB:Die-upset[4]	7.23	5.45	1.75	1.75	4.12
MM-FeB-Ti:Hot-pressed	7.17	4.64	3.75	2.10	2.78
MM-FeB-Ti:Die-upset	7.17	5.01	3.29	2.27	3.54

CONCLUSIONS

Die-upset MM-FeB-Ti magnets showed 3.54 MGOe of $(BH)_{max}$ which is much higher than that of the hot-pressed magnets. This seems mainly due to the occurrence of the c-axis alignment along pressing direction during die-upsetting. The substitution of Ti in part for Fe in MM-Fe-B permanent magnets increased the coercivity and remanence of both the hot-pressed and die-upset magnets. Results for die-upset magnets proved the possibility of die-upsetting as a method of fabrication of anisotropic MM-Fe-B-Ti permanent magnets.

REFERENCES

[1] J. Yamasaki, H. Soeda, M. Yanagida, K. Mohri, N. Teshima, O. Komoto, T. Yoneyama and N. Yamaguchi, IEEE Trans. on Magn. **22**, 763(1986)

[2] K.Y. Ko and J.G. Booth, Proc. on 3rd international symposium on Phys. on Magn. Mat. **2**, 771(1995)

[3] K.Y. Ko, J.G. Booth, H.J.Al-Kanani and H.Y. Lee, J. Kor. Magn. Soc. : J. of Magn. **1**, 82(1996)

[4] K.Y. Ko, S. Yoon and J.G. Booth, Magnetic properties and microstructures of hot-press and die-upset MM-FeB-(Al) permanent magnets, J. of Magn. and Magn. Mat, 1997 (Inpress)

[5] K.Y. Ko, J.G. Booth and S. Yoon, Die-upset MM-Fe-Co-Al-B permanent magnets, submitted J. of Magnetics, 1997

[6] K.H.J. Buschow, Rep. Prog. Phys. **54**, 1123(1991)

[7] C.D. Fuerst and E.G. Brewer, J. Appl. Phys. **70**, 6444(1991)