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Hot Isostatic Pressing in Oxygen of Ferrite Magnet

Y. Ogata, H. Iwasaki, Y. Kubota, M. Yamamoto*, T. Imura and T. Shinohara

Magnetic & Electronic Materials Laboratory, Hitachi Metals Ltd., 5200 Mikajiri, Kumagaya City, Saitama Pref., Japan

** Kumagaya Works, Hitachi Metals Ltd., 5200 Mikajiri, Kumagaya City, Saitama Pref., Japan*

Abstract. The effect of hot isostatic pressing in 5%O₂-95%Ar on the magnetic properties of Sr ferrite magnet was studied. It was found that the size of voids at grain boundaries are decreased by hot isostatic pressing without substantial grain growth and the density of isostatically hot-pressed body is about $5.03 \times 10^3 \text{ kg/m}^3$. Magnetic measurement revealed that the hot isostatic pressing does not significantly decrease coercive force and keeps the good squareness of B-H curve of pre-sintered body unchanged. The typical value of residual flux density Br of the isostatically hot-pressed magnet is 0.438T at $\mu_0 H_c = 318 \text{ kA/m}$.

1. Introduction

Recently, it is intensively demanded to improve the magnetic properties of Sr ferrite magnet in order to decrease the weight of motors used in automobiles and to increase the efficiency of motors used in electric appliance such as air conditioner. There are four ways as listed below to increase residual flux density and the coercive force of anisotropic ferrite magnet.

- 1) To increase the degree of crystallographic alignment[1].
- 2) To increase the density of sintered body
- 3) To control the size distribution of ferrite particles and to make the average grain size as equal as to the critical size for single domain possible[1].
- 4) To increase the intrinsic magnetization or anisotropic constant of ferrite material[2].

This report is concerned with 2) shown above. The density of commercial ferrite magnet is around $4.9 \times 10^3 \text{ kg/m}^3$ which is 96% of X-ray density. It is thought that there is a possibility to improve magnetic properties of ferrite magnet by increasing the density of sintered body. The purpose of this investigation is to show how the increase of the density influences the magnetic properties of ferrite magnet using hot isostatic pressing (HIP) technique.

2. Experimental Procedure

Fe₂O₃ and SrCO₃ were mixed in water, then dried and calcined in air. The calcined ferrite powder was wet-milled with additives(CaCO₃, SiO₂, SrCO₃, Cr₂O₃) using a ball-mill. The finely milled slurry was pressed into disk shaped compacts in a magnetic field of 800kA/m which was parallel to the pressing direction. The compacts were pre-sintered in air at 1453 ~ 1493K. Each pre-sintered specimen was cut into two pieces. One was used for the reference and the other was successively hot-pressed isostatically in 5%O₂-95%Ar and 100%Ar atmosphere. The pressure and the temperature were 101.3MPa and 1353 ~ 1373K respectively. The change of density, magnetic properties and microstructure were investigated.

3. Results and Discussion

Fig.1 shows the dependence of the density of isostatically hot-pressed body on the density of pre-sintered body in the case of 5%O₂-95%Ar, 101.3MPa and 1353K condition. It is found that the density of sintered body can be increased by $0.05 \sim 0.1 \times 10^3 \text{ kg/m}^3$ in hot isostatic pressing process if the density of pre-sintered body is higher than $4.7 \times 10^3 \text{ kg/m}^3$. Typical value of the density of isostatically hot-pressed body in this experiment is around $5.03 \times 10^3 \text{ kg/m}^3$ which is 96.8% of theoretical density assuming that the theoretical density of Sr ferrite is $5.1 \times 10^3 \text{ kg/m}^3$. Almost the same result was obtained in the case of 100%Ar atmosphere. Fig.2 shows the change of magnetic properties of Sr ferrite magnet by hot isostatic pressing in the case of 5%O₂-95%Ar, 101.3MPa, 1353K. It is found that the isostatic pressing process increases the residual flux density by $0.005 \sim 0.007 \text{ T}$. Little change of coercive force was observed, which indicates that there was no significant grain growth in the

Fig. 1 Relation between the the density of isostatically hot-pressed and pre-sintered body

Fig. 2 Change of magnetic properties of Sr ferrite magnet by hot isostatic pressing (5%O₂-95%Ar, 101.3MPa, 1353K)

hot isostatic pressing because coercive force is a good reference of the average grain size. The good squareness of B-H curve of the pre-sintered body was kept unchanged in the hot isostatic pressing. The comparison of the microstructure between pre-sintered body and hot isostatically pressed body is shown in Fig. 3. It is found out that the size and the number of voids at grain boundaries of the pre-sintered body was decreased without substantial grain growth by hot isostatic pressing. Therefore, it is inferred that this improvement of magnetic properties was caused not by the increase of the degree of crystallographical orientation occurring together with grain growth but by the increase of density. The typical value of residual flux density obtained in this experiment was $Br=0.438T$ at $\mu H_c=318kA/m$. On the other hand, no substantial increase of magnetic properties was observed in the case of 100%Ar atmosphere although the same degree of density increase occurred. It is speculated that the decrease of intrinsic magnetization due to valency change of Fe ion ($Fe^{3+} \rightarrow Fe^{2+}$) cancelled the effect of the density increase.

(a) Before HIP

(b) After HIP

1 μm

Fig. 3 Change of the microstructure of Sr ferrite magnet by hot isostatic pressing (5%O₂-95%Ar, 101.3MPa, 1353K)

4. Conclusion

The density increase without substantial grain growth by hot isostatic pressing was found to improve the magnetic properties of Sr ferrite magnet. The typical value of Br obtained in this investigation is $0.438T$ at $\mu H_c=318 kA/m$, which is $0.005 \sim 0.007T$ higher compared with that of pre-sintered body.

References

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