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Effects of High Magnetic Field on Alignment of Ferrite Grains in Fe-based Alloys

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No structural alignment of ferrite grains are observed for austenite to ferrite transformation in Nb containing alloy in magnetic field. However, alignment of transformed grains in high magnetic field are observed in some conditions for austenite to ferrite transformation in an Fe-0.4C alloy. To clarify these conditions, the specimens were solution treated at 950 ℃ for 15 min, and rapidly cooled to 850 ℃, and slowly cooled to 700 ℃ at various cooling rates of 0.5 ℃/min and rapidly cooled again to room temperature with various magnetic field. In some cases, it was clearly observed that each ferrite grain is elongated and these grains are distributed head to tail along the direction of applied magnetic field. The conditions for the alignment of ferrite grains are (1) austenite grain size is relatively small and (2) cooling rate is relatively small, (3) magnetic field is high enough, (4) chemical composition is Fe-C system for austenite to ferrite transformation.
Key words:ferrite, alignment, magnetic field

1.INTRODUCTION

Magnetic field is expected to affect the alignment of product phase and transformed structure per se during solid/solid phase transformations and then affect the mechanical properties or some functions of materials. Therefore magnetic field is considered to be promising for structural or functional control of materials. Fe-based alloys are very hopeful for such control of materials by magnetic field because they have various kinds of solid/solid phase transformations and therefore various structures. It is expected that the nucleation and growth rates, transformation kinetics, transformed structure and variants are affected by magnetic field in phase transformations since the magnetic moment of parent and product phases are different, and also due to the magnetocrystalline anisotropy, shape magnetic anisotropy, induced magnetic anisotropy and magnetostriction. Among these effects of magnetic field on structural change, the alignment of transformed phases is important because the alignment is expected to affect the mechanical and magnetic properties of materials. However, only a few examples of structural alignment are reported for solid/solid transformations [1,2,3,4] . We have shown that the ferrite grains are aligned along the direction of applied magnetic field in Fe-0.4C alloy [4], but the conditions for the alignment was not clear. Therefore, the purpose of this study is to find the conditions for the structural alignment for austenite to ferrite transformation in magnetic field.

2. EXPERIMENTAL

The alloy used in the present study was an Fe-0.4C (mass%) prepared by vacuum induction melting. After homogenization specimens were machined 5x5x1 mm^3, and heat treated in vacuum by the furnace installed in the He-free type superconducting magnet whose bore size is 100 mm ϕ . Specimens were heat treated in the center of magnetic field and magnetic force applied to the specimen can be neglected. To study the transformation behavior and structure for austenite to ferrite transformation, specimens were solution treated at various temperatures between 900 and 1100 ℃ for 15min, and rapidly cooled to 850 ℃ , and slowly cooled to 700 ℃ at the cooling rates of 0.1 ～ 5 ℃ /min and rapidly cooled again to room temperature with magnetic field of 0 ～ 10T. The surface parallel to the direction of applied magnetic field was observed by optical microscope.

3. RESULTS AND DISCUSSION

No structural alignment of ferrite grains are observed for austenite to ferrite transformation in Nb-containing alloy in magnetic field. However, alignment of transformed grains in high magnetic field are observed for austenite to ferrite transformation in an Fe-0.4C alloy as shown in Fig.1. Specimens were austenitized at 1000 ℃ for 15 min and cooled at (a) 0.5 ℃ /min and (b) 5 ℃ /min in magnetic field of 10T. Well aligned structure is obtained in Fig. 1 (a), but no alignment is observed in (b). It is clearly observed in Fig. 1 (a) that each ferrite grain is elongated and these grains are distributed head to tail along the direction of applied magnetic field. However, ferrite grains are not always aligned in magnetic filed, and some conditions have to be satisfied for the alignment. Fig.2 shows the effects of cooling rate (a), austenite grain size (b) and magnetic field strength (c) on the degree of alignment. Here the alignment degree was measured as the ratio of elongated grain length to the transverse width. Alignment degree increases with decreasing cooling rate, with decreasing austenite grain size and with increasing magnetic field strength. Moreover, no alignment was observed in Nb containing alloy but observed only for Fe-C alloys. Therefore the conditions for the alignment of ferrite grains are (1)

austenite grain size is relatively small, (2) cooling rate is relatively small and (3) magnetic field is high and (4) chemical composition is Fe-C for austenite to ferrite transformation.

References

[1] J. W. Cahn: J. Appl. Phys. **34**, (1963), 3581-3586.
[2] T. Kakeshita, S. Furikado, K. Shimizu, S. Kijima and M. Date: Trans. JIM **27**, (1986), 477-483.
[3] M. Shimotomai and K. Maruta: Scripta Mater. **42** (2000), 499-503.
[4] H. Ohtsuka, Y. Xu, and H. Wada: Mater. Trans., JIM **41**, (2000), 907-910.

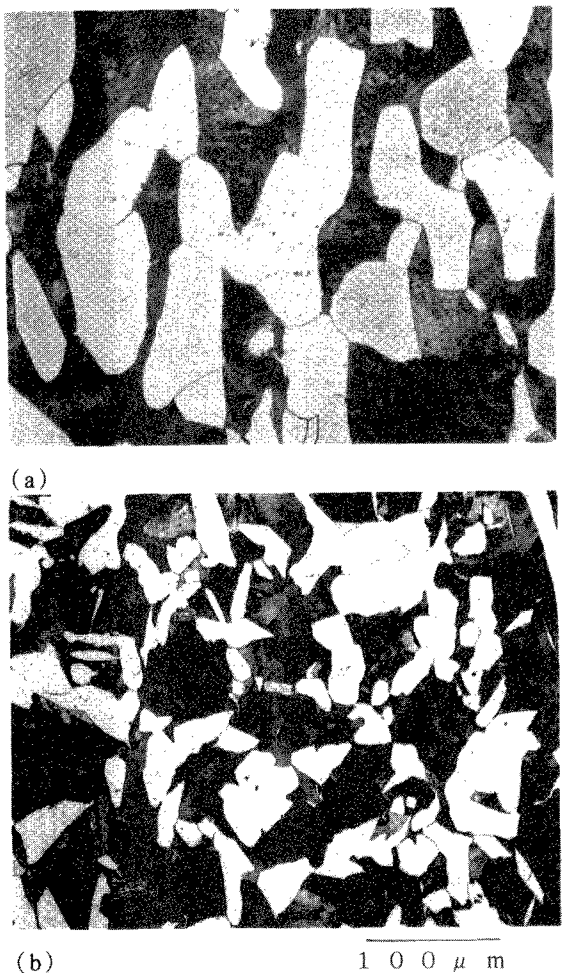

Fig.1 Optical micrograph showing the effects of cooling rate on the transformed structure of Fe-0.4C alloy. Specimens were austenitized at 1000 ℃ for 15 min and cooled at (a) 0.5 ℃ /min and (b) 5 ℃ /min in magnetic field of 10T.

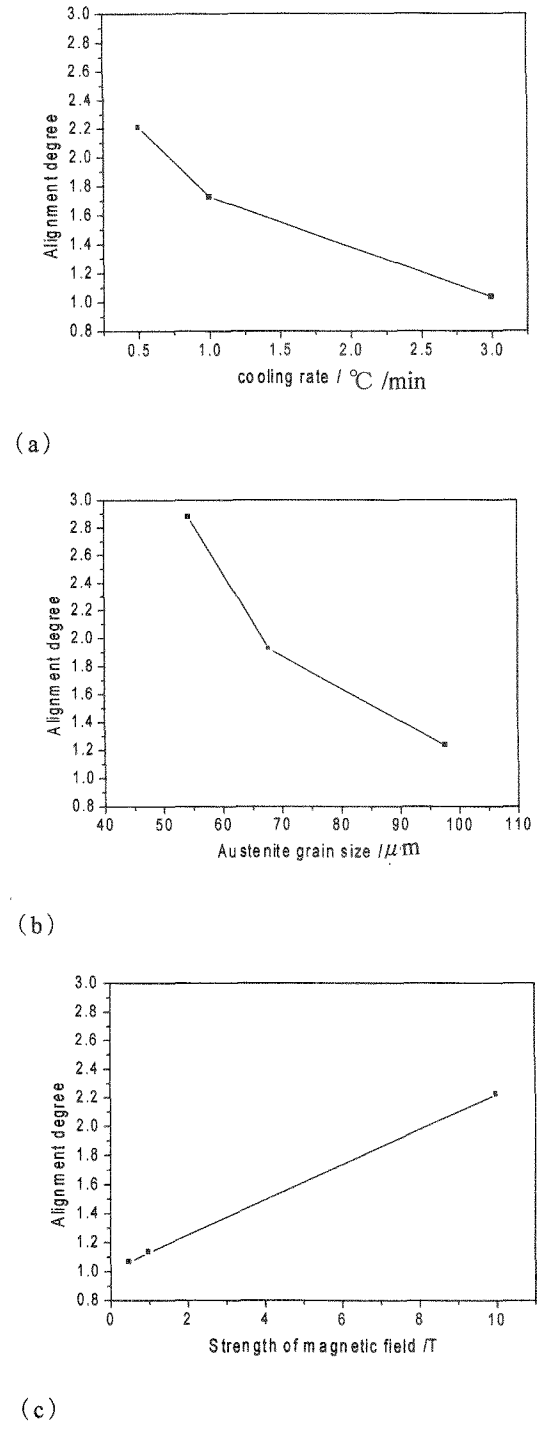

Fig. 2 Effects of cooling rate, austenite grain size and magnetic field strength on the degree of alignment of ferrite grains in Fe-0.4C alloy.

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