RAPID PUBLICATION

High Coercivity in Melt-Spun SmFe_{10}(TiV)_2 Ribbons

By M. Okada*, K. Yamagishi* and M. Homma*

SmFe_{10}(TiV)_2 melt-spun ribbons based on the ThMn_{12} structure exhibit the high coercive force of nearly 728 kA/m after annealing at 1073 K. This is the highest value among the reported melt-spun ThMn_{12}-type structure ribbons. Microstructural studies indicate that the ribbons consist of fine ThMn_{12} grains of 50-150 nm in diameter with α-Fe precipitates.

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I. Introduction

The discovery of the Nd_{2}Fe_{14}B permanent magnets\(^{(1)}\) has stimulated the researchers to find other new useful compounds by exploring the ternary systems. Several attempts have been reported in ternary phases that consist of iron and rare earths with some third components\(^{(2)-(4)}\). A promising candidate for permanent magnets seems to be RE(FeM)_{12}-type compounds with ThMn_{12} crystal structure, since the compounds have relatively high Curie temperatures and some of them have a sufficiently high magnetization and magnetocrystalline anisotropy\(^{(5)-(6)}\).

The intrinsic magnetic properties of RE(FeM)_{12} compounds, where RE is Sm, Nd, Dy, and Ga, and M is Ti, Si, V, Cr, Mo, and Al, were studied\(^{(7)-(10)}\). But the highest observed coercivity among the reported works is 240 kA/m for the SmFe_{10}Ti_{12} compound by melt-spinning\(^{(7)-(9)}\), and is 304 kA/m for the Sm-Fe-Mo alloys prepared by mechanical alloying method\(^{(10)}\). There still remains the possibility for achieving the higher coercivity in these systems on the base of the reported high anisotropy field.

The purpose of the present investigation is to explore the possibilities for obtaining the high coercivity in ThMn_{12} type compounds by melt-spinning. The studied alloys are based on Sm(FeM)_{12}, where M is Ti, Si, V, Cr, Mo and Al. As the result, melt-spun SmFe_{10}Ti_{2} compound has the highest coercivity of around 256 kA/m among the Sm(FeM)_{12} systems. The further additions of the elements to SmFe_{10}(TiM')_{2} alloys, where M' is V, Cr, Mo, and Al, improved the coercivities. Especially, SmFe_{10}(TiV)_{2} compounds reveal the coercivity of 728 kA/m after annealing. This is the highest value among the reported coercivities on melt-spin ThMn_{12} type ribbons, so far. Then this paper focuses to describe the magnetic properties of melt-spun SmFe_{10}(TiV)_{2} ribbons.

II. Experimental Procedures

The quenched ribbons were prepared by a single wheel technique under Argon atmosphere. The substrate surface velocity (\(v_s\)) of Cu wheel varies from 20 m/s to 40 m/s. Over-quenched ribbons were annealed at 873–1173 K for 3.6 ks. The size of the fabricated ribbon in flake form is (10-70) \(\mu\)m \(\times\) (1-1.4) mm \(\times\) (15-100) mm. The magnetic properties were measured by vibrating sample magnetometer with the maximum applying field of 1.2 MA/m (15 kOe). The crystal structures of the ribbons were measured by X-ray
diffractions with CuKα radiation.

III. Results and Discussion

Figure 1 shows X-ray diffraction patterns of SmFe_{10}(TiV)_{2} melt-spun ribbons quenched at the wheel velocity of (a) 40 m/s, and (b) 20 m/s, which give the coercivity of (a) 32 kA/m, and 440 kA/m, respectively. Then it can be said that the wheel speed of 20 m/s is optimum for giving the high coercivity as spun state. The diffraction pattern of the optimally quenched ribbons shown in Fig. 1(b) are indexed with the ThMn_{12}-type crystal structure. Over-quenched ribbons consist of finer crystallized grains of ThMn_{12}-type structure and amorphous phase, as shown in Fig. 1(a).

The over-quenched ribbons are followed by the annealing. Figure 2 shows the variation of the coercive force for SmFe_{10}TiV ribbons annealed at 873–1173 K for 3.6 ks. The coercive force of the ribbons has the maximum value of 728 kA/m (9.1 kOe) after annealing at 1073 K. This is the highest coercivity among the reported values on melt-spun ThMn_{12}-type compounds so far. The reported maximum value was 240 kA/m (3.8 kOe)\,(7)-(9). Figure 3 shows the variation of the coercive force of

![Fig. 1 X-ray diffraction patterns of SmFe_{10}(TiV)_{2} melt-spun ribbons quenched at the wheel velocity of (a) 40 m/s, and (b) 20 m/s.](image1)

![Fig. 2 The coercive force of SmFe_{10}(TiV)_{2} ribbons annealed at 873–1173 K for 3.6 ks.](image2)

![Fig. 3 The coercive force of SmFe_{10}(Ti_{1-x}V_x)_{2} ribbons before and after annealing at 1073 K for 3.6 ks vs. V content.](image3)
SmFe$_{10}$Ti$_{1-x}$V$_x$$_2$ ribbons annealed at 1073 K for 3.6 ks. The coercive force of the ribbons quenched at 40 m/s before annealing, is around 30 kA/m independent of V content. But annealing enhances the coercive force of the ribbons in the range of 290–720 kA/m. The highest coercivity of 728 kA/m was achieved with the composition of SmFe$_{10}$TiV$_2$ (x=0.5). The corresponding magnetic hysteresis loops of SmFe$_{10}$TiV$_2$ ribbons before and after annealing are shown in Fig. 4. The magnetization intensity of the ribbon measured at 1.2 MA/m, is around 50 emu/g, and the demagnetization curve of the annealed ribbon has the knee in its shape. This may be attributed to the presence of some magnetically soft phase in the annealed sample.

Figure 5 shows the X-ray diffraction pattern

![X-ray diffraction pattern](image)

Fig. 5 X-ray diffraction patterns of SmFe$_{10}$TiV$_2$ ribbons (a) after and (b) before annealing at 1073 K for 3.6 ks.

(a)

![Electron micrograph](image)

Fig. 6 (a) Electron micrograph and (b), (c) corresponding EDX spectrum of the SmFe$_{10}$TiV$_2$ ribbons annealed at 1073 K for 3.6 ks.
of the annealed SmFe₁₀(TiV)₂ ribbon in comparing with that of ribbon prior to annealing. The annealed ribbons consist of mainly ThMn₁₂-type crystallized grains, an α-Fe phase, and unknown phase. The corresponding electron micrograph shown in Fig. 6(a) reveals that the crystallized fine grains have the average diameter of nearly 50–150 nm. EDX analysis suggests that the sample contains two kinds of grains in its composition. One is the grain with the bright contrast, which has the composition of nearly SmFe₁₀TiV; the other is one with dark contrast, which has Sm and V poor phase in comparison with that of the bright grain. But it is still uncertain how these grains correlate with the coercivity mechanism.

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REFERENCES