Narrow stripe domains and low iron loss in nanocrystalline alloys by controlled annealing

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We have achieved extremely low iron loss at high frequencies by using amorphous alloys through the formation of a narrow magnetic stripe domain structure. Low iron loss is achieved by controlled annealing for amorphous alloys in the early crystallization region, but it is sensitive to temperature and time. The magnetic domain structure was confirmed by the magneto-optical Kerr effect microscopy, and narrow stripe magnetic domains were formed when the iron loss became very low. The stripe domain width decreased with increasing the annealing time, and the *B-H* curve slanted. These results indicate that the perpendicular magnetic anisotropy plays an important role in the formation of narrow stripe magnetic domain structure, and it increases with the annealing time, and there exists an optimum value of PMA for low iron loss.

Keywords: Iron loss; Amorphous alloy; Nanocrystalline alloy; High-frequency; Magneto-optical Kerr effect microscopy

1. Introduction

Effective use of limited electric power resources is necessary to achieve a sustainable society. The importance of soft magnetic materials in power electronics technology is increasing day by day, and it is necessary to present performance beyond the limits. Using an amorphous alloy capable of nanocrystallization as a precursor, we have found that iron loss is significantly reduced under certain annealing conditions [1]. In this report, we will discuss the mechanism of iron loss reduction induced by annealing.

2. Results and discussion

The amorphous ribbon was fabricated using the melt-spun method. The composition was $Fe_{84.8}Si_{0.4}B_{9.4}P_{3.4}Cu_{0.8}C_{1.2}$ (at. %), and the ribbon width was 60 mm, and the thickness was 25 μm. The annealing was carried out using an infrared lamp furnace. The heating rate was set at 20 K/min, and the experiments were conducted comprehensively at various set temperatures and holding times. The iron loss at high frequencies was measured using a *B-H* analyzer (IWATSU SY-8219), and the magnetic domain structure was observed using the time-resolved vector magneto-optical Kerr effect (MOKE) microscopy [2].

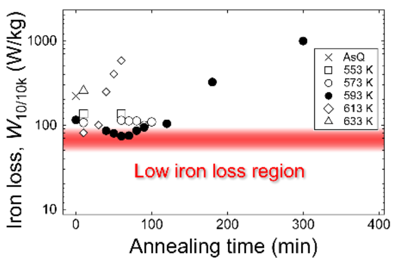

Figure 1. Relationship between the iron loss and the annealing time at various annealing temperatures T_a.

Figure 1 shows the relationship between the annealing time and the iron loss at 10 kHz, 1 T. Iron loss is significantly reduced at a specific T_a and annealing time.

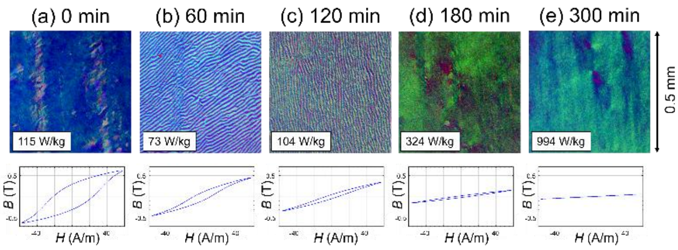

Figure 2. Magnetic domain images measured by the MOKE microscopy and *B-H* curve at various annealing times at $T_a = 593$ K. The measurement frequency is 10 kHz and current is 500 mA-peak. Iron loss values at 10 kHz, 1 T are inserted in the figure.

Figure 2 shows the magnetic domain images measured by the MOKE microscopy and *B-H* curves at various annealing times at $T_a = 593$ K. (a) At 0 min, large magnetic domains due to structural relaxation is observed. At (b) 60min, when the iron loss reaches the minimum, a narrow stripe domain of about 3 μm is observed. From (c) to (e), domain subdivision progresses and finally a dot-like magnetic domain structure is observed. The stripe domain width decreased with increasing the annealing time, and the *B-H* curve slanted, and the magnetic permeability decreased. The low iron loss region with a narrow stripe domain, as shown in (b), is thought to be introduced by the perpendicular magnetic anisotropy (PMA) as explained by classical magnetic domain theory [3,4] and the slanting *B-H* curve shape. The PMA increased with the annealing time, and there exists an optimum value of PMA for low iron loss.

References

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