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급속 응고된 비정질 Sm-Fe-B 합금의 저온 자기 거동

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Effects of B on the Low Temperature Magnetic Properties of Amorphous SmFeB Alloy Ribbons

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1. Introduction

Magnetic properties of amorphous alloys are known to be sensitive to local atomic environment. Since local atomic arrangement varies with fabrication process, it is common to observe, even for a given alloy, a large change of magnetic properties depending on fabrication method or condition. This is particularly true for amorphous rare earth-transition metal based alloys [1, 2]. Unfortunately, however, this large change in magnetic properties is not fully supported by detailed microstructural results, mainly due to the difficulty of characterizing the microstructure (atomic correlation length, for example) of an amorphous phase with the precision of explaining magnetic properties. In an effort to understand the change of magnetic properties as a function of microstructure, low temperature magnetic properties of amorphous Sm-Fe alloys with differing B contents are investigated in this work. These alloys have attracted much interest because of the rich varieties of magnetic order and hysteresis behavior they show in particular at low temperatures and also for their technological importance [3]. Several theories and models have been presented either to interpret the magnetic hysteresis in these materials at T =0 K, as extrapolated from the experimental data at low temperatures, or to study the coercivity dependence on temperature.

2. Experimental

The alloys investigated in this work are $(Sm_{0.33}Fe_{0.67})_{1-x}B_x$ with x =0, 0.01, 0.02, and 0.03. The alloys were induction melted, thay carried out in Ar atmosphere to minimize the oxidation Sm. Amorphous ribbons were fabricated by melt-spinning also in an Ar atmosphere at a high wheel velocity of 50 –55 m/s. The composition of both melted ingots and melt-spun ribbons was determined with an inductively coupled plasma emission spectrophotometer. The composition given in this paper is that of melted ingots. The loss of Sm which has a high vapor pressure at the melt-spinning temperature, was observed to be 0.01~0.02 during melt-spinning. The microstructure was examined by x-ray diffraction with Cu K_α radiation. The temperature dependence of magnetization was measured with a SQUID magnetometer and VSM during heating from 5 to 700 K, with applied field of 50 kOe. Hystersis loops were measured with a SQUID magnetometer at several temperatures ranging from 5 to 250 K, and also with a VSM at room temperature.

3. Results and Discussion

The coercivity increases rapidly with decreasing temperature at a given B content (Fig.1). In the temperature range of room temperature to 70 K, the plot of log (Hc) vs. temperature is nearly linear, indicating that the coercivity increases exponentially with decreasing temperature indicting much greater temperature dependence of the coercivity. This indicates different interaction energies in theses two temperature ranges. At temperatures above 70 K, the dependence of the coercivity can be explained by a strong domain wall pinning model. This model gives the following temperature dependence of Hc:

$$Hc^{1/2} = H_0^{1/2}\left(1 - \left(\frac{21.4k_BT}{Ei}\right)^{2/3}\right),$$

where Ei is the energy of interaction between the magnetic domains and pinning sites in the materials. At temperatures below 70 K, however, an upward deviation from the linearity occurs indicating much greater temperature dependence of the coercivity. This temperature dependence may partly be explained by the random anisotropy model, in addition to the domain wall pinning model. In the model magnetocrystalline anisotropy can be effectively reduced by the averaging effect when the structural correlation length is smaller than the ferromagnetic exchange length. In our system, the ferromagnetic exchange length varies from 390Å (at 300 K) to 80Å (at 5 K) for the alloy $(Sm_{0.33}Fe_{0.67})_{0.99}B_{0.01}$. Since the structural correlation length will certainly remain constant in this temperature range, the change of the ferromagnetic exchange length with the temperature results in a change in the relative magnitude of the ferromagnetic exchange length and the structural correlation length, which in turn affect the effective anisotropy, and hence coercivity.

4. References

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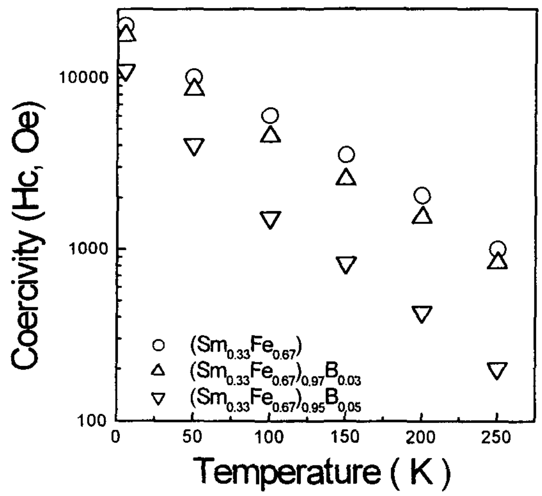

Fig. 1. The plots of log Hc vs T at various B contents.

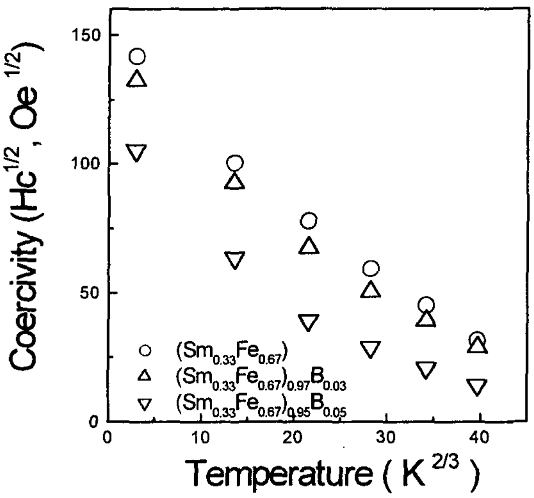

Fig. 2. The plots of $Hc^{1/2}$ vs $T^{2/3}$ at various B contents.