FORCED MAGNETOVOLUME EFFECTS IN Sc1-xTixFe2 AT THE FERROMAGNETIC TO FERROMAGNETIC TRANSITION

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FORCED MAGNETOVOLUME EFFECTS IN $Sc_{1-x}Ti_xFe_2$ AT THE FERROMAGNETIC TO FERROMAGNETIC TRANSITION

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Abstract. – Magnetostriction was measured up to 300 kOe in a hexagonal Laves phase compound $Sc_{1-x}Ti_xFe_2$ which exhibits a transition between the different ferromagnetic states. A capacitance method was employed to measure the striction in pulsed magnetic fields. A forced volume increase of a few percent was found at the transition.

1. Introduction

Hexagonal Laves phase intermetallic compounds $Sc_{1-x}Ti_xFe_2$ change from ferromagnetic to antiferromagnetic states with increasing x. Recently, various magnetic states were revealed in the intermediate Ti concentration compounds [1-3]. An existence of two ferromagnetic states with different ferromagnetic moments was found in $0.3 < x < 0.7$ by the analysis of Mössbauer spectra and magnetization measurements. A ferromagnetic state with large moment of 1.3 μ_B/Fe appears at the low temperature range. With increasing temperature, the magnetization steeply decreases by 20-30 % at the phase boundary (T_{t1}) and the ferromagnetic state with smaller moment ($0.6 - 0.9$ μ_B/Fe) becomes stable. When the Ti concentration exceeds 0.75, the ferromagnetic state with small moment becomes dominant even in the low temperature region.

A transition from the ferromagnetic state with small moment to that with large one can be caused by the intense magnetic field, as reported previously by the authors [4]. Since an itinerant-electron magnet shows a large magnetovolume effect, a remarkable volume expansion can be expected at the transition. We have measured forced magnetostriction using pulsed high magnetic fields.

2. Experimental

Samples of polycyrstal $Sc_{1-x}Ti_xFe_2$ were prepared by the arc melting method and were annealed at 1000 C for a week [1]. An ingot of the sample was cut into discs of 2.5 mm in diameter and 1.2 mm in length.

A volume change can be derived from the results of transverse and longitudinal strictions. High field magnetostriction was measured by a capacitance method in both parallel and perpendicular directions to the magnetic field. Pulsed magnetic fields were generated using a capacitor bank of 60 kJ (3 kV) and a multilayer solenoid coil. Pulse width (a half period) of the field was about 25 ms which is long enough to measure the magnetostriction process precisely.

3. Results and discussion

An example of the volume expansion process in $Sc_{0.25}Ti_{0.75}Fe_2$ is shown in figure 1a together with the magnetization process (Fig. 1b). The observed forced magnetostriction parallel to the magnetic field was nearly equal to that in the perpendicular direction, suggesting that the volume increases isotropicaly. The volume increases around 9 T at 4.2 K and around 15 T at 77 K where the magnetization also increases steeply. The Barkhausen steps were observed at 4.2 K in both magnetization and magnetostriction curves. As for magnetization, the step disappeared at 7 K with increasing temperature [4]. A field induced transition

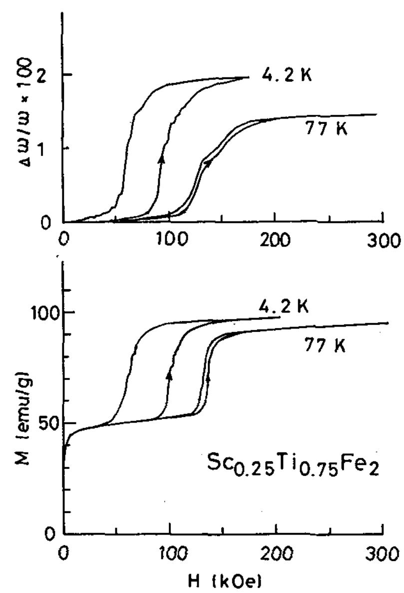

Fig. 1. – Magnetostriction and magnetization processes in $ScTiFe_2$.

from the ferromagnetic state with small moment to that with the large one brings approximately 2 and 1.6 % volume expansion at 4.2 and 77 K, respectively. On the contrary, only a slight change of volume is observed up to 10 kOe in spite of the rapid increase of magnetization, because the ferromagnetic moment of the iron atom is invariant in this range. A displacement of domains and/or rotation of magnetization take place during the initial saturation process.

According to the spin fluctuation theory [5], the magnetovolume effect ω_m is proportional to the local magnetic moment $\left\langle M_{\rm loc}^2 \right\rangle$:

$$\omega_{\rm m} = KC\left(\left\langle M_{\rm loc}^2 \right\rangle\right), \qquad (1)$$

where K is the compressibility and C the magnetoelastic constant. Since the saturation moment increases from 0.67 to 1.4 μ_B/Fe at 4.2 K, KC is calculated to be 1.3×10^{-2} $(\mu_B)^{-2}$ $\left(1 \times 10^{-10}\ ({\rm mol/emu})^2\right)$. The observed KC is almost equal to that derived from the temperature induced ferro- to ferromagnetic transition in $Sc_{0.35}Ti_{0.65}Fe_{1.95}$ [2]. A large change was not observed up to 77 K in the proportionality constant KC.

In figure 2 the volume change $\Delta\omega$ is plotted against $\left(M^2 - M_{\rm sms}^2\right)$ for various magnetic fields, where $M_{\rm sms}$ is the saturation magnetization at the ferromagnetic state with small moment. A linear relation between $\Delta\omega$ and $\left(M^2 - M_{\rm sms}^2\right)$ was found below and above the transition, the plotted points being on the same straight line going through the origin. The magnetoelastic coupling constant KC takes a comparable value in both ferromagnetic states.

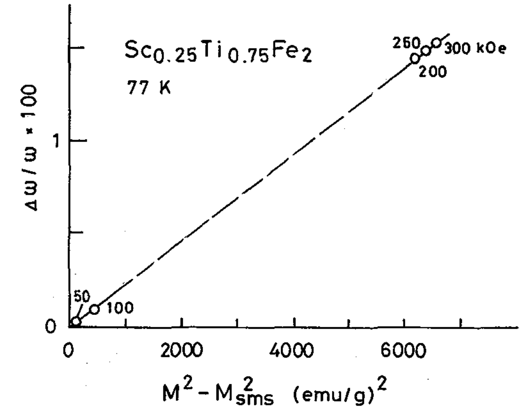

Fig. 2. – Volume change plotted against $\left(M^2 - M_{\rm sms}^2\right)$ for various magnetic fields. The ferro- to ferro-magnetic transition occurs between 100 and 200 kOe.

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