Magnetic Domain Structure of Growth Temperature-Gradient $Sm_2Mo_2O_7$ Thin Film Investigated by Scanning SQUID Microscopy

Tae-Youb Kim [a,1], Jun Nishimura [b], Tomoteru Fukumura [a,b], Masashi Kawasaki [a,b,e], Tetsuya Hasegawa [a,c], Hideomi Koinuma [a,c], Yasujiro Taguchi [d], Yoshinori Tokura [d,e]

[a] *COMET, Advanced Materials Laboratory, National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044 Japan*
[b] *Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577 Japan*
[c] *Materials and Structures Laboratory, Tokyo Institute of Technology, 4259 Nagatsuta, Midori-ku, Yokohama 226-8503 Japan*
[d] *Department of Applied Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656 Japan*
[e] *Correlated Electron Research Center (CERC), Tsukuba 305-0046, Japan*

Abstract

Recently spin frustrated pyrochlore $A_2B_2O_7$ has attracted much attention. In this study, we have observed the domain structure of pyrochlore molybdate $Sm_2Mo_2O_7$ epitaxial thin film fabricated with growth temperature-gradient method by a scanning SQUID microscope for the first time. The temperature dependence of domain structure has been investigated in detail.

Key words: pyrochlore-type molybdate; combinatorial thin film; scanning SQUID microscopy; growth temperature-gradient; magnetic domain structure

Geometrical frustration is one of the key concept in the pyrochlore-type structure with general formula $A_2B_2O_7$ [1]. The pyrochlore-type structure $A_2B_2O_7$ is well known as a geometrically frustrated lattice and is composed of two sublattices, where both A site and B site, respectively, form infinite three-dimensional (3D) network of corner-sharing tetrahedral [1-3], and may be viewed as a three-dimensional realization of a triangular lattice [4]. Recently, several scanning probe microscopic techniques for studying local magnetic properties, which detect the magnetic field from the sample surface, have been developed, such as the magnetic-force microscope (MFM), the scanning hall probe microscope (SHPM) and the scanning superconducting quantum interference device (SQUID) microscope (SSM). The SSM has advantages that can measure with high sensitivity and without the substrate effect for the specimen. Here, we report on the SSM of a temperature- gradient $Sm_2Mo_2O_7$ thin film at various temperatures below Curie temperature, T_C. The relation between the maximum B_Z value and the Brillouin function was also investigated.

$Sm_2Mo_2O_7$ epitaxial film was deposited by pulsed-laser deposition (PLD). $Sm_2Mo_2O_7$ target was ablated by KrF excimer laser pulses (248 nm, 20 ns). The film was grown on polished YSZ (111) substrate at 1000 °C at growth rate of ~ 0.01 nm/pulse. The x-ray diffraction spectra of the film showed (111) oriented pyrochlore structure without any impurity peaks. The detail of fabrication is described elsewhere [J. Nishimura et al., unpublished]. A spontaneous magnetization was observed by a scanning superconducting quantum interference device (SQUID) microscope (SSM) under zero magnetic field below T_C. In SSM measurements, the distance between pickup coil and sample surface is an important parameter governing both spatial and magnetic resolution. Here, this distance was kept constant at $\sim 3\mu m$ by carefully adjusting the z-height of the stage. In the present sensor-sample geometry, SSM

[1] Corresponding author. Present address: Tokyo Institute of Technology, R3-307, 4259 Nagatsuta, Midori-ku, Yokohama 226-8503 JAPAN E-mail:tykim@oxide.rlem.titech.ac.jp

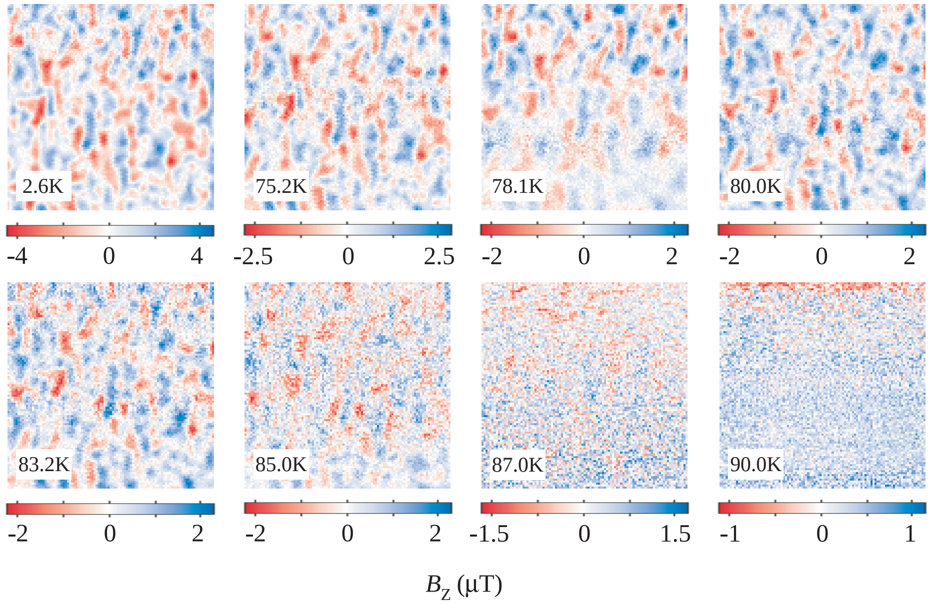

Fig. 1. Scanning SQUID images of $Sm_2Mo_2O_7$ epitaxial thin film obtained at various temperatures. The image sizes are $200 \times 200\mu$m. The color bars indicate the B_Z scales in units of μT.

maps the magnetic flux perpendicular to the sample surface B_Z.

Figure 1 shows the magnetic images of $Sm_2Mo_2O_7$ epitaxial thin film obtained at various temperatures. The color bar indicates the measured magnetic field perpendicular to the sample surface, B_Z. The relative magnitude of spontaneous magnetization decreases as increasing temperature. From the images, the magnetic domain size seems unchanged with temperature below 83 K, but the B_Z values quickly decrease. The ferromagnetic transition temperature T_C is evaluated to be about 90 K, which is slightly higher than previously reported values for the single crystal and polycrystalline samples [4].

Figure 2 shows the maximum B_Z value, B_{Zmax} obtained from each magnetic image in Fig. 1. In general, the decrease in B_{Zmax} is attributable to the reduction of either M or the domain size. As is well known, the magnetization of ferromagnet can be expressed by the Brillouin function,

$$\frac{M}{M_S} = \frac{2J+1}{2J} \coth \frac{2J+1}{2J}\alpha - \frac{1}{2J} \coth \frac{1}{2J}\alpha,$$

where $\alpha = Jg(H + NM)/kT$, J is the angular moment, and M_S is the saturated magnetic moment at zero temperature. The overall feature of B_{Zmax}(T) was well described by the Brillouin function assuming T_C = 87 K, while the domain size is almost temperature independent, as already pointed out.

In summary, we have shown the domain structure of $Sm_2Mo_2O_7$ epitaxial film fabricated with growth temperature-gradient method by a SSM for the first time. The relative magnitude of spontaneous magnetization decreases as increasing temperature and the magnetic domain size seems unchanged with temperature below 83 K. The Curie temperature, T_C was determined as $\sim$ 90 K.

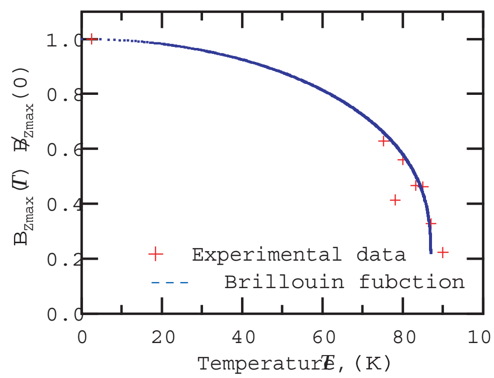

Fig. 2. Maximum field B_{Zmax} obtained from the scanning SQUID images as a function of temperature. The dotted line denotes the Brillouin function with T_C is near 87 K.

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