Magnetostriction of the 2D Orthogonal Dimer Spin System $SrCu_2(BO_3)_2$ under Pulsed High Magnetic Fields

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Abstract. We have measured the magnetostriction on the 2D orthogonal dimer system $SrCu_2(BO_3)_2$ under pulsed magnetic fields up to about 55 T, in order to investigate the lattice instability in the field regions where $1/4$ and $1/3$ magnetization plateaus appear. Theoretically, superstructure is expected to be formed at each plateau region and it is considered that spin-lattice effects are necessary to fully describe the spin density profile of the plateaus. We observe the lattice deformation which accompanies the increase in magnetization.

Keywords: magnetostriction, high magnetic fields, $SrCu_2(BO_3)_2$, spin-lattice coupling
PACS: 75.10.Jm, 75.80.+q

INTRODUCTION

After the discovery of the 2D orthogonal dimer spin system $SrCu_2(BO_3)_2$ [1], a large number of experimental and theoretical research have been done on this material. $SrCu_2(BO_3)_2$ has a dimerized singlet ground state separated from the excited triplet states by a finite gap $\Delta \simeq 35$ K, as reported in the magnetic susceptibility [2] and in inelastic neutron scattering [3]. Application of an external magnetic field changes the density of the triplet excitations. Many interesting phenomena have been observed on this material under high magnetic fields. Experimentally, magentization plateaus were observed at $1/8$, $1/4$ and $1/3$ of the fully saturated moment [4] and the magnetic superlattice for the $1/8$ plateau with broken translational symmetry was dicrectly observed by NMR experiments [5]. The superstructure at each magnetization plateau was proposed theoretically. The $1/3$ and $1/4$ plateaus are expected to have magnetic superstructures of stripe form, while the $1/8$ plateau has a rhomboid cell [6]. Miyahara *et al.* considered the $S = 1/2$ orthogonal dimer model coupled to adiabatic phonons, and suggested that the superstructure in the rhomboid unit cells for the $1/8$ plateau was qualitatively consistent with NMR results [7]. These results indicate a presence of a spin-lattice coupling to $SrCu_2(BO_3)_2$, and it is expected that a lattice deformation occurs under magnetic field with the appearance of a magnetization and the change of the magnetic superstructures for the $1/8$, $1/4$ and $1/3$ plateaus. We report results of magnetostriction experiments on $SrCu_2(BO_3)_2$ under pulsed magnetic fields which reach the $1/4$ and $1/3$ plateau regions.

EXPERIMENT

The high-field magnetostriction of $SrCu_2(BO_3)_2$ was measured at $T = 1.3$ K with strain gauges and a multilayer pulse magnet at KYOKUGEN, Osaka University. The pulsed magnetic field was produced by the discharge of a capacitor bank which has a maximum energy is 1 MJ. The maximum field of the long pulse magnet is 55 T. The pulse duration is about 20 msec. The magnetic fields were applied along the [100] direction and the magnetostrictions along the [100] and [110] directions were measured. The uniaxial magnetostriction was measured using strain gauges glued onto the surface of the sample and a quartz dummy sample. The sample and dummy gauges were connected in series in order to compensate background signals, and remaining field-induced signals were canceled using a compensation coil. Two sets of data were recorded changing polarity of currents and were subtracted to extract the voltage change $\Delta V/V$ due to the magnetostriction ε $(= \Delta L/L)$ of the sample.

RESULTS AND DISCUSSION

The magnetostriction along the [100] and [110] direction show the same tendencies. Figure 1 shows the mag-

CP850, *Low Temperature Physics: 24th International Conference on Low Temperature Physics;*
edited by Y. Takano, S. P. Hershfield, S. O. Hill, P. J. Hirschfeld, and A. M. Goldman

netostriction which is parallel to the [100] direction under pulsed magnetic fields applied up to about 55 T along the [100] direction, at 1.3K, with the magnetization curve of $SrCu_2(BO_3)_2$. There is almost no length change below about 11 T. The magnetostriction begins to increase monotonically from 11 T to about 35 T. Comparable hysteresis is observed in the magnetostriction and the magnetization vs magnetic field. While there isn't a plateau at the field region of the $1/8$ magnetization plateau. It is thought that the increase of the magnetostriction which is linearly for magnetic field from 11 T to 35 T is not dominated by the change of the magnetic superstructure but by the appearence of magnetization.

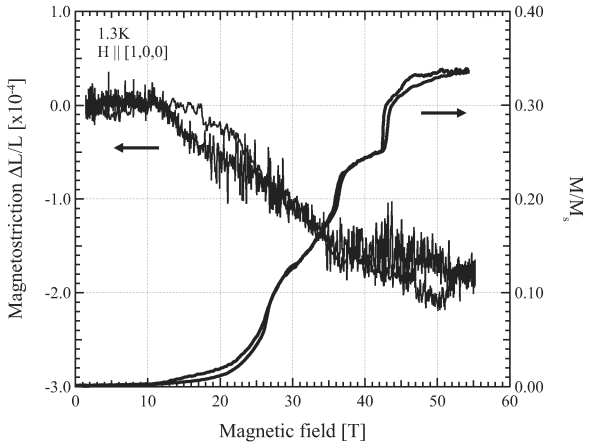

FIGURE 1. The high-field magnetostricition along the [100] direction of $SrCu_2(BO_3)_2$ under magnetic field applied along the [100] direction at $T = 1.3$ K, with the magnetization under the same conditions.

The magnetostriction curve has a plateau from 35 T to 43 T where the $1/4$ magnetization plateau appears and the length change above 43 T is very small. While it exhibits no jumps at 35 T and 43 T where the magnetization jumps. It is suggested that the lattice deformation is small in the field range between the $1/4$ and $1/3$ plateaus. These results support the idea that lattice changes stabilize the magnetization superstructure at the high magnetic field $1/3$ and $1/4$ plateaus. We can observe the change of the structure at each plateau indirectly by measuring the magnetostriction.

ACKNOWLEDGMENTS

This work was supported by The 21st Century COE Program named AgTowards a new basic science: depth and synthesisAh, and by Giant-in-Aid for Science Research from the Japanese Ministry of Education, Science, Sports, Culture and Technology.

REFERENCES

1. H. Kageyama, K. Yoshimura, R. Stern, N. V. Mushnikov, K. Onizuka, M. Kato, K. Kosuge, C. P. Slichter, T. Goto and Y. Ueda, Phys. Rev. Lett., **82**, 3168-3171 (1999).
2. H. Kageyama, K. Onizuka, T. Yamauchi, Y. Ueda, S. Hane, H. Mitamura, T. Goto, K. Yoshimura and K. Kosuge, J. Phys. Soc. Jpn., **68**, 1821-1823 (1999).
3. H. Kageyama, M. Nishi, N. Aso, K. Onizuka, T. Yosihama, K. Nukui, K. Kodama, K. Kakurai and Y. Ueda, Phys. Rev. Lett., **84**, 5876-5879 (2000).
4. K. Onizuka, H. Kageyama, Y. Narumi, K. Kindo, Y. Ueda and T. Goto, J. Phys. Soc. Jpn., **69**, 1016-1018 (2000).
5. K. Kodama, M. Takigawa, M. Horvatić, C. Berthier, H. Kageyama, Y. Ueda, S. Miyahara, F. Becca and F. Mila, Science, **298**, 395-399 (2002).
6. S. Miyahara and K. Ueda, Phys. Rev. B, **61**, 3417-3424 (2000).
7. S. Miyahara, F. Becca and F. Mila, Phys. Rev. B, **68**, 024401 (2003).