High field ESR measurements of quantum spin system under high pressure

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Abstract

We have developed a new high field and low temperature ESR system under high pressure. Using this system, several different quantum spin systems have been studied. We will report about the result of the high field ESR measurements of hexagonal ABX_3-type compound $CsCuCl_3$ for B//c under pressure. The increase of the critical field was observed for the first time by our high field ESR measurment under 3.2 kbar. The origin of the increase of the critical field by pressure in $CsCuCl_3$ will be discussed.

Key words: ESR, high pressure, quantum spin systems, $CsCuCl_3$

1. Introduction

We have developed a high field and low temperature ESR system under pressure using the pulsed magnetic field up to 16 T [1]. As the effect of pressure to quantum spin systems is very interesting, we have been studying several quantum spin systems by ESR measurements under presssure, such as spin-Peierls system $CuGeO_3$ [1] and S=1/2 spin ladder system CHpC [2]. In this paper, we will deal with $CsCuCl_3$ which shows a quantum-fluctuation-induced phase transition for B//c.

$CsCuCl_3$ is a well-known hexagonal ABX_3-type compound which forms a triangular lattice in the c-plane. The spin has weak easy plane anisotropy and there are strong ferromagnetic exchange interactions J_1=23 K along the c-axis while there are weak antiferromagnetic interchain exchange interactions J_2=3.8 K in the c-plane. The magnetic ordering takes place at T_N =10.5 K. Below T_N the spins form the 120° structure in the c-plane, as well as a long period spiral along the c-axis due to the competition between the ferromagnetic exchange interaction and the Dzyaloshinsky-Moriya interaction. The high field magnetization measurement of $CsCuCl_3$ showed a small jump at B_c =11.4 T for B//c at 4.2 K [3,4]. And we performed the submillimeter wave ESR measurement of $CsCuCl_3$ for B//c and found a change in the ESR mode above B_c [5]. This anomaly cannnot be understood in terms of the mean field theory, because the spins in the ground state should continuously stand up from the c-plane in the case of B//c and no jump of the magnetization is expected in the framework of the mean field theory. However, the theoretical study by Shiba and Nikuni revealed that the anomalous jump observed in the magnetization process of $CsCuCl_3$ is a quantum-fluctuation-induced phase transition [6]. The neutron diffraction measurement under the magnetic field [7] and NMR [8] were also performed to study this anomaly.

The high field ESR measurements of $CsCuCl_3$ for B//c have been peformed at 4.2 K under 1 bar and 3.2 kbar using the pulsed magnetic fields up to 16 T. Observed frequency region is from 270 to 370 GHz. The details of the experimental system can be found in ref.

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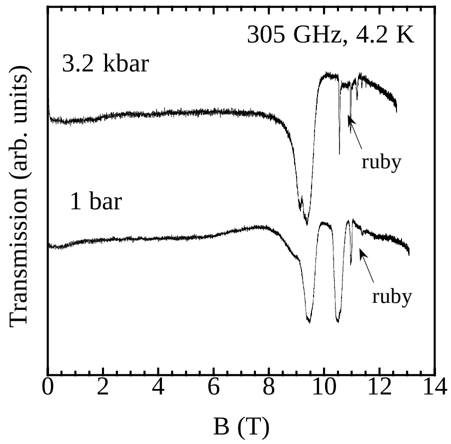

Fig. 1. The absorption lines observed for B//c at 4.2 K under 1 bar and 3.2 kbar. Observed frequency is 305 GHz. Sharp lines around 11 T are the absorption lines of ruby.

[1]. The calibration of pressure at 4.2 K was performed by the simultaneous observation of high field ESR of ruby, which was established by our group [9].

Figure 1 shows the absorption lines observed at 305 GHz under 1 bar and 3.2 kbar. Under 1 bar, two absorption lines are observed. On the other hand, the absorption line observed at the higher field side under 1 bar disappeared, and only one absorption line was observed under 3.2 kbar. Figure 2 shows the frequency-field diagram observed at 4.2 K under 1 bar and 3.2 kbar. The change of ESR mode was observed at 10 T under 1 bar. This critical field is smaller than that observed by the previous magnetization or high field ESR measurements [3-5]. However, the discontinious change of ESR mode is definitely coming from the quantum-fluctuation-induced phase transition. Therefore, the observed lower critical field under 1 bar may be due to the small misalignment of the crystal in the pressure cell. We can clearly see that the critical field is increased from 10 T to 10.5 T by increasing the pressure from 1 bar to 3.2 kbar. This increase of the critical field is observed for the first time. There are two possible mechanisms to interpret the increase of the critical field by pressure. As shown by Shiba and Nikuni, the competition between the easy-plane anisotropy and the quantum fluctuations plays an important roll for the quantum-fluctuation-induced phase transition [6]. Therefore, the pressure may affected the easy-plane anisotropy or the quantum fluctuations. Another possibility is that the exchange interaction may increase by pressure. The change of the exchange interaction can be determined by observing the pressure effect on the antiferromagnetic gap, which can be observed by the detailed frequency dependence measurement of AFMR, or the saturation field in the magnetization measurement. In order to check these points, more detailed high field ESR measuremts under pressure are required.

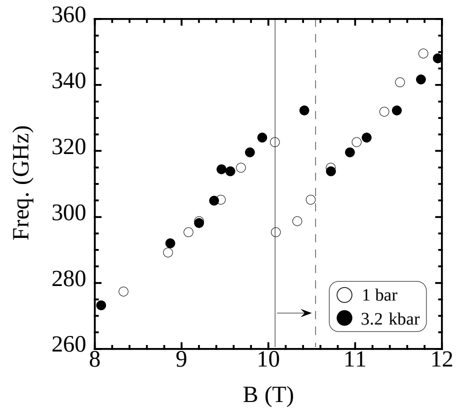

Fig. 2. The frequency-field diagram for B//c at 4.2 K under 1 bar (open circles) and 3.2 kbar (closed circles).

In summary, we observed the increase of the critical field by pressure in $CsCuCl_3$ for B//c at 4.2 K from our high field ESR measurement under pressure.

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References

[1] H. Ohta, S. Okubo, T. Sakurai, T. Goto, K. Kirita, K. Ueda, Y. Uwatoko, T. Saito, M. Azuma, M. Takano and J. Akimitsu, Physica B **294-295** (2001) 624.

[2] M. Saruhashi, T. Sakurai, K. Kirita, T. Kunimoto, S. Okubo, H. Ohta, H. Kikuchi, Y. Uwatoko, EPR IN 21st CENTURY: BASES AND APPLICATIONS TO MATERIAL-, LIFE- AND EARTH- SCIENCE, A. Kawamori, J, Yamauchi and H. Ohta eds. (Elsevier, 2002) 803.

[3] M. Motokawa, presented at the Annual Meeting of Phys. Soc. Jpn. (1978).

[4] H. Nojiri, Y. Tokunaga and M. Motokawa, J. Phys. (Paris) **49** Suppl. C8 (1988) 1469.

[5] H. Ohta, S. Imagawa, M. Motokawa and H. Tanaka, J. Phys. Soc. Jpn. **62** (1993) 3011.

[6] T. Nikuni and H. Shiba, J. Phys. Soc. Jpn. **62** (1993) 3268.

[7] M. Mino, K. Ubukata, T. Bokui, M. Arai, H. Tanaka and M. Motokawa, Physica B **201**(1994) 213.

[8] M. Chiba, K. Ohara, Y. Ahuri and T. Morimoto, J. Phys. Soc. Jpn. **62** (1993) 4186.

[9] H. Ohta, T. Sakurai, S. Okubo, M. Saruhashi, T. Kunimoto, Y. Uwatoko and J. Akimitsu, Proceedings of International Association for the Advancement of High pressure Science and Technology, Beijing, China, 2001.