High field ESR measurements of pyrochlore slab antiferromagnets $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$

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Abstract

High field ESR measurements of pyrochlore slab antiferromagnets $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ have been performed in the millimeter wave region at temperatures from 4.2 K to 200 K. The concentration dependence of Cr^{3+} ions was observed from $x = 0$ to $x = 5.0$. For $Ba_2Sn_2Ga_3ZnCr_7O_{22}$ ($x = 0$), the pyrochlore slab is fully filled with Cr^{3+} ions, the line width of the ESR absorption lines increased and the resonance fields shifted as the temperature was decreased. These tendencies were suppressed as the Cr^{3+} concentration was decreased.

Key words: ESR ; frustration ; dilution ; kagomé ; pyrochlore ; g-value

1. Introduction

Geometrically frustrated antiferromagnets have attracted the great interest in which they exhibit an unique behavior. They tend to be in unusual ground states such as a spin glass and a spin liquid instead of classical Néel order. In the family of geometry frustration antiferromagnets, the kagomé lattice in two dimensions and the pyrochlore lattice in three dimensions have attracted special attentions both experimentally [1] and theoretically [2].

$SrCr_xGa_{12-x}O_{19}$ (SCGO) is one of the most studied substances which has the kagomé lattice constructing of antiferromagnetic interacted Cr^{3+} ($S = 3/2$) ions. The SCGO has two kagomé layers that sandwiches the sparse triangular layer in between. This sandwich structure forms a pyrochlore slab lattice. Each pyrochlore slab is weekly connected by a magnetic inter layer.

Recently $Ba_2Sn_2Ga_3ZnCr_7O_{22}$ was discovered by Hagemann et al [3]. It is known to be pyrochlore slab antiferromagnets, which does not have an interlayer between pyrochlore slabs like SCGO. The pyrochlore slab is fully filled with magnetic ions Cr^{3+}. The distance between pyrochlore slab lattices of $Ba_2Sn_2Ga_3ZnCr_7O_{22}$ is larger than one of SCGO. A spin glass transition was observed at the temperature $T_g = 1.5$ K. In order to investigate the frustration effect by the dilution of magnetic ion, magnetic ions Cr^{3+} are replaced by nonmagnetic ions Ga^{3+} in $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$. Each Cr^{3+} ion is replaced to Ga^{3+} ion at random. In this paper, the results of the millimeter wave ESR measurements of $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ is presented.

2. Exprimental

High field ESR measurements have been performed using a Gunn oscillator (120 GHz) and pulsed magnetic field at temperatures from 4.2 K to 200 K with a powder sample of $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ compounds on the dilution of Cr^{3+} ions. The concentration dependence of Cr^{3+} ions was observed from $x = 0$ to $x = 5.0$. The details of our experimental devices can be found in refs. [4].

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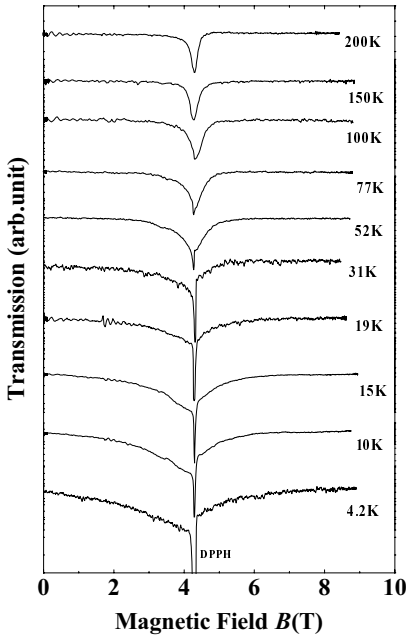

Fig. 1. The temperature dependences of $Ba_2Sn_2Ga_3ZnCr_7O_{22}$ ESR absorption using 120 GHz. DPPH is a standard sample.

3. Results and discussion

Fig. 1 shows ESR spectra using 120 GHz of $Ba_2Sn_2Ga_3ZnCr_7O_{22}$. Only one resonance line has been observed at temperatures from 4.2 K to 200 K. At 200 K, the g-value of 2.001 was obtained. The resonance field doesn't change between 20 K and 200 K. Below 20 K, the resonance field shifts to the lower field side and the ESR spectra becomes broad as the temperature is decreased. To obtain more information, the analysis of half line width was performed. The broadening of the typical EPR line width is as follows [5],

$$\Delta H(T) = \Delta H_\infty (1 - \theta/T), \qquad (1)$$

which ΔH_∞ is the half line width in the limit of finite temperature, θ is Weiss temperature. Fig. 2 shows the temperature dependence of the half line width. The solid line shows the best fit curve by the equation (1). The parameters $\Delta H_\infty = 0.09$ T was obtained by using the Weiss temperature $\theta = -300$ K from our magnetic susceptibility measurements. The temperature dependences of the half line width were fitting well between 20 K and 200 K. Below 20 K, it deviated from the solid line.

ESR measurements of $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ that diluted Cr^{3+} ions with Ga^{3+} ions have been performed under the same condition. Fig. 2 and Fig. 3 show the temperature dependences of the half line width and g-value. As Cr^{3+} concentration is decreasing, that is, x changes from 0 to 5, the broadening of

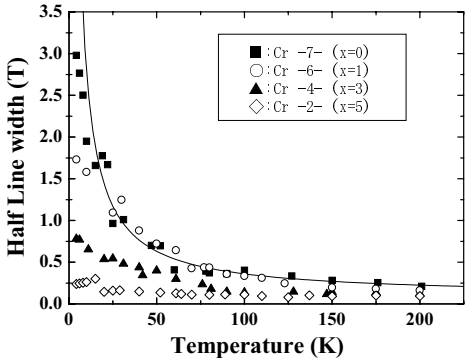

Fig. 2. The temperature dependences of the half line width of ESR spectra in $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ using 120 GHz. The solid line represents equqtion (1).

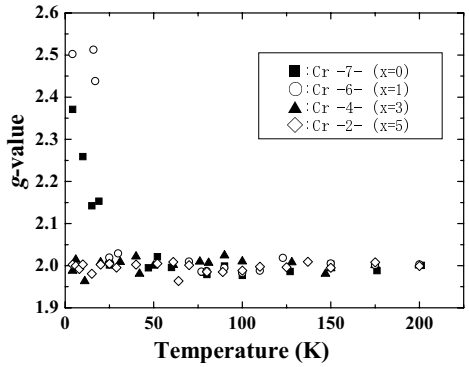

Fig. 3. The temperature dependences of g-value in $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ using 120 GHz

the half line width and g-value was suppressed. For diluted substance ($x = 3$), the broadening of the ESR spectrum was still observed but the shift of g-value was not able to observe. And for the substance ($x = 5$), the temperature dependencies of both almost did not observe any changes.

For the ESR measurements of SCGO, the similar anomalies of g-value and the line width were reported. at low temperatures. It is thought that these anomalies is typical properties of the pyrochlore slabs system.

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