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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 to 200 K. The concentration dependence of Cr^{3+} ions was observed from $x = 0$ to 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.

Keywords: ESR; Frustration; Dilution; Kagomé; Pyrochlore; g-value

1. Introduction

Geometrically frustrated antiferromagnets have attracted the great interest in which they exhibit a 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 that have the kagomé lattice consisting of antiferromagnetic interacted Cr^{3+} ($S = \frac{3}{2}$) 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 $Ba_2Sn_2Ga_3ZnCr_7O_{22}$ has been 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 that of SCGO. 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 $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ are presented.

2. Experimental

High field ESR measurements have been performed by using a Gunn oscillator (120 GHz) and pulsed magnetic fields at temperatures from 4.2 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 5.0. The detailed description of our experimental devices can be found in Ref. [4].

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 to 200 K. At 200 K, the g-value of 2.001 was obtained. The resonance field didn't change between 20 and 200 K. Below 20 K, the resonance field shifted to the lower field side and the ESR spectrum became broad as the temperature was decreased. The analysis of the line width in a high temperature region was performed as it was performed for SCGO compounds [5,6]. The broadening of the typical EPR line width is as follows:

$$\Delta H(T) = \Delta H_\infty (1 - \theta/T), \tag{1}$$

which ΔH_∞ is the half line width in the limit of finite temperature, θ is Weiss temperature. Fig. 2 shows the temperature dependences of the half line width. The solid line shows the best fit curve by Eq. (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 in the high temperature region.

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. Figs. 2 and 3 show the temperature dependences of the half line width and g-value. And the concentration dependences of the half line width and g-value at 4.2 K were inserted, respectively. As Cr^{3+} ion concentration is decreasing, that is, x changes from 0 to 5, the broadening of the half line width and the shift of g-value was suppressed. For the samples with smaller Cr^{3+} ion concentration, the broadening of the ESR spectrum was still observed, however, the shift of g-value was not observed. As critical percolation threshold is $p_c = 0.65$ in 2D-kagomé lattice, critical percolation concentration for $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ is $x = 2.45$. The concentration dependences of the half line width and g-value at 4.2 K seems to divide at $x = 2.45$.

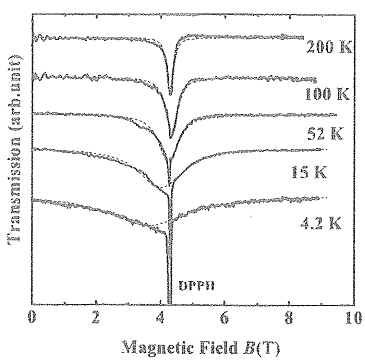

Fig. 1. The temperature dependences of $Ba_2Sn_2Ga_3ZnCr_7O_{22}$ ESR absorption using 120 GHz. DPPH is a standard sample. The broken lines are best fit curves that are calculated by Lorentzian line shape.

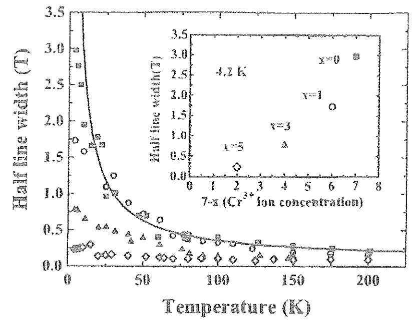

Fig. 2. The temperature dependences of the half line width of ESR spectra in $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ using 120 GHz. The solid line represents Eq. (1).

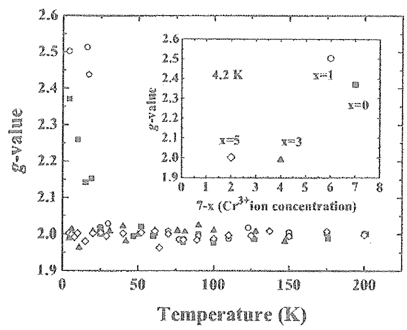

Fig. 3. The temperature dependences of g-value in $Ba_2Sn_2Ga_{3+x}ZnCr_{7-x}O_{22}$ using 120 GHz.

The effect by the dilution of Cr^{3+} ion suppressed the change of the line width and g-value. And its change showed the two different regimes. For more detailed discussion, the measurements using several samples with different Cr^{3+} ion concentration are required.

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