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Strong uniaxial crystal field and ising like exchange interaction of ferromagnet $CeAgSb_2$

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Abstract

Neutron scattering experiments have been performed to reveal the magnetic excitation in ferromagnet $CeAgSb_2$. Crystalline electric field excitations were observed at 5.2 and 12.5 meV in the paramagnetic state. Our analysis concluded that $|\pm\frac{1}{2}\rangle$ is the ground state. The observed ferromagnetic moment is in good agreement with the ground-state saturation moment, $g_J\mu_B J_z \sim 0.43\ \mu_B$. The spontaneous moment along the c-axis decreases with increasing the field perpendicular to the c-axis, and disappear at the critical field H_c, where the magnetization curve shows the kink behavior.

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Keywords: $CeAgSb_2$; Crystal field; Spin wave; Ferromagnet; Neutron scattering

$CeAgSb_2$ with tetragonal crystal structure orders at $T_c = 9.6$ K with a small net ferromagnetic component of 0.37 μ_B/Ce parallel to the c-axis. The in-plain magnetization below T_c increases linearly with magnetic field and reached about 1.2 μ_B at 3 T [1]. This induced moment is much larger than the spontaneous moment along the c-axis. Therefore, the antiferromagnetic (AFM) and/or complex magnetic structure was suggested to be the origin of the unusual magnetic properties. However, no AFM peak has been reported from neutron diffraction experiment [2]. Our neutron diffraction experiment also revealed only the ferromagnetic moment of 0.41 μ_B along the c-axis.

In this work, we carried out the neutron scattering experiments at the research reactor JRR-3 in JAERI. We conclude that $CeAgSb_2$ is ferromagnet and unusual magnetic properties are well explained in the framework of simple ferromagnet.

Fig. 1 shows the neutron inelastic scattering spectrum on the polycrystalline sample of $CeAgSb_2$ at 12 K. We observed remarkable excitation peaks at $\Delta E = 5.2$ meV. In addition to this clear excitation peak, a very weak excitation at $\Delta E = 12.5$ meV was also observed, as shown in the inset of Fig. 1. The q dependence of the intensity of these peaks is more or less consistent with the square of the 4f magnetic form factor in the Ce^{3+} ion. This means that these inelastic peaks are due to the crystalline electric field (CEF) excitations. Recently, these two CEF excitations were also observed by Adroja et al. [3]. These CEF excitations corresponds to the excitation from the CEF ground state $|\pm\frac{1}{2}\rangle$ to 1st and 2nd excited state $\sim|\pm\frac{3}{2}\rangle$ and $\sim|\pm\frac{5}{2}\rangle$, respectively. The magnetic moment of the ground state, 0.428 μ_B, is in good agreement with the observed ferromagnetic moment of 0.41 μ_B. The CEF level scheme determined by the present study is very similar to the result of the recent study by Takeuchi et al. [4].

The spin wave dispersion, not shown, has been measured with the use of a single-crystalline sample.

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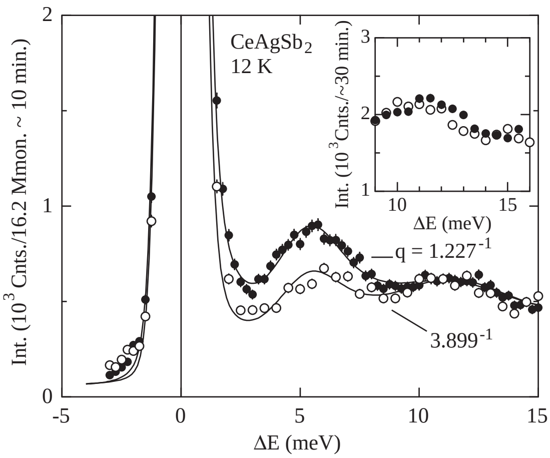

Fig. 1. Inelastic neutron scattering spectra measured for a polycrystalline sample of $CeAgSb_2$ at 12 K.

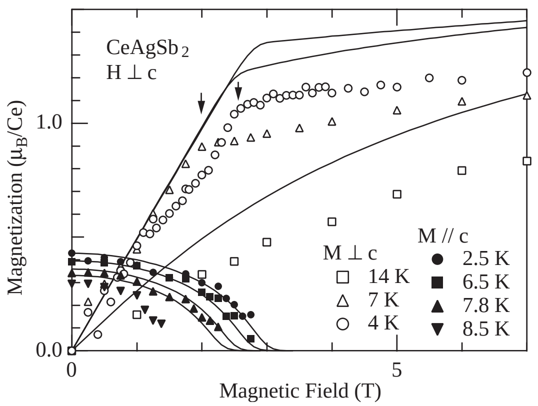

Fig. 2. In-plane magnetization ($M \perp c$, open marks) and the ferromagnetic moment ($M \| c$, solid marks) are plotted as a function of magnetic field perpendicular to [0 0 1].

The interaction coefficient, obtained from the analysis of the dispersion relation, for the z-component of J is about 10 times larger than that for the in-plane component of J, indicating the existence of ising like exchange interaction.

The open marks in Fig. 2 show the in-plane magnetization measured from the neutron diffraction. The kink, denoted by arrows, appears below T_c, which is consistent with the experimental results of magnetization [1]. We note that the weak ferromagnetic scattering is superimposed on the strong nuclear scattering, therefore it is difficult to distinguish that the magnetization curve at 4 K (open squares) is linear or show anomaly around 2 T. On the other hand, the closed marks in Fig. 2 show the ferromagnetic moment along the c-axis with the magnetic field parallel to [1 1 0] measured from the neutron diffraction intensity at the (1 1 0) peak position. With this configuration, the in-plane magnetization does not contribute to any magnetic scattering, because the induced in-plane magnetic moment is parallel to the scattering vector q. Therefore only the ferromagnetic component along [0 0 1] was observed. The ferromagnetic component along [0 0 1] exhibits a gradual decrease with increasing in-plane magnetic field, and disappears at the critical field H_c where the in-plane magnetic moment shows a kink behavior. Our data indicate that H_c is the field where the ferromagnetic moment switches its direction from parallel to perpendicular relative to [0 0 1]. This feature is well reproduced by the calculation based on the CEF and ising like exchange interaction, as shown in Fig. 2.

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