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Spin-Glass Transition in the $RCoGaO_4$ (R=Lu, Yb) Layered Cobaltites

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The frequency, temperature, and the dc and ac dependences of the magnetic susceptibility of the $YbCoGaO_4$ and $LuCoGaO_4$ single crystals are investigated. The $YbCoGaO_4$ behaves like an *Ising* spin glass with a strong uniaxial anisotropy. In contrast $LuCoGaO_4$ is *Heisenberg*-like spin glass. Dynamical scaling reveals a three dimensional phase transition near *Tg* and yields critical exponent values between those of *Heisenberg*- and *Ising*-like systems.

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1. Introduction

Magnetic properties of spin-glasses with strong single-ion anisotropy are extensively studied for their interesting phase diagrams depending on the magnitude of the crystal field acting on the magnetic moments. The theory [1, 2] predicts spin-glass ordering for the longitudinal ($H \parallel c$) configuration and not for transverse one when the easy-axis crystal field is large enough with respect to the exchange coupling. Such behaviour of magnetization was observed in our previous paper [3] devoted to the problem of spin-glass transition in the $YbCoGaO_4$ single crystals. In this case a sharp cusp is seen in the longitudinal susceptibility measured with the field directed along the c axis, whereas a paramagnetic behavior is observed in transverse direction. It was suggested [3] that both Yb^{3+} and Co^{2+} are Ising-like ions with quantization axis along the c direction.

The main purpose of this paper is to check this suggestion. For this $LuCoGaO_4$ single crystals were grown and their magnetic properties were compared with those determined in $YbCoGaO_4$. The $LuCoGaO_4$ was chosen because its magnetic properties are determined only by Co^{2+} ions without any rare-earth contributions.

2. Experimental

The single crystals of $YbCoGaO_4$ and $LuCoGaO_4$ were grown by floating zone image furnace techniques [4]. The crystallographic axes were determined from x-ray analysis. The phase purity of the crystals and their structure were determined by x-ray diffraction. The magnetic susceptibility measurements were performed using a commercial superconducting quantum interference device squid magnetometer MPMS-7 XL (Quantum Design). Measurements were made on each crystal under various applied fields either parallel or perpendicular to the c axis. We did not specify the field direction within the plane perpendicular to the c axis. Data were measured either by cooling with the field applied (FC) or by applying field after cooling in zero field (ZFC).

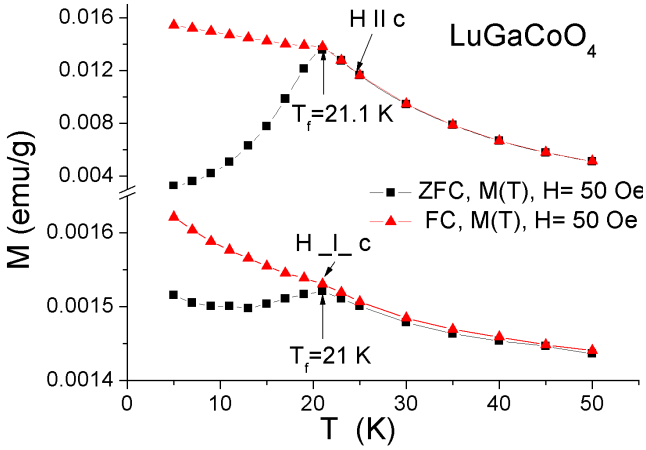

Fig. 1. Temperature dependence of the ZFC (squares) and FC (triangles) magnetization in magnetic field $H = 50$ Oe applied along the c axis and perpendicularly to this axis.

Figure 1 shows the temperature dependence of the zero field-cooled and field-cooled magnetization of $LuCoGaO_4$, recorded in FC and ZFC regimes in a small magnetic field of $H = 50$ Oe applied in different directions. As seen in the Fig. 1, a cusp is observed near $T = 21$ K when H is applied along both directions. In the case of $YbCoGaO_4$ [1] a cusp is observed only when H is applied along the c direction, and no cusp is observed for $H \perp c$. This Ising-like anisotropy is the complete

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opposite to Heisenberg-like character of the phase transition observed in $LuCoGaO_4$ single crystals and is characteristic for the low anisotropy uniaxial systems. Results presented in Fig. 1 indicate on:

- Co^{2+} ions in $RCoGaO_4$ (R-rare earth) family of compounds are low anisotropy ions
- Ising-like character of spin glass in $RCoGaO_4$ family is due to R^{3+} ions rather than due to Co^{2+} ones, as suggested in [3].

The additional confirmation of the above conclusions are the results of electron paramagnetic resonance (EPR) measurements. These results (not shown here) indicate that the EPR spectrum practically does not depend on the orientation of the applied external field.

In addition to the dc magnetization measurements, the ac susceptibility studies (an example is presented in Fig. 2) have been performed. Both crystals exhibit a fairly large frequency dependence for $H \parallel c$. For $H \perp c$ such behavior is observed only for $LuCoGaO_4$ crystals.

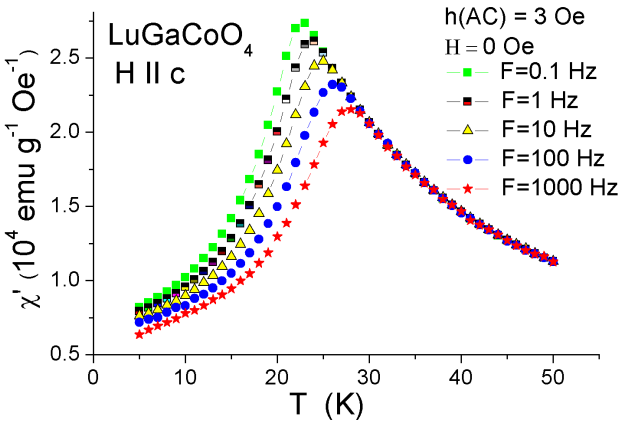

Fig. 2. The real part of the ac susceptibility vs temperature at different frequencies F.

Both studied crystals exhibit typical dynamical features of spin glasses. Among them the most important is the following dynamic scaling equation [5, 6]:

$$\chi'' T/\omega^{\beta/z\nu} = f(\varepsilon/\omega^{1/z\nu}), \qquad (1)$$

where $\varepsilon = T/Tg - 1$, β is a critical exponent, $z\nu$ is a dynamic exponent and $f(x)$ is a scaling function.

Using fitting parameters $z\nu = 20.5$, $\beta = 0.9$ and $T_g = 13$ K, all $\chi''(\omega)$ vs T curves should collapse onto the same curve (see Fig. 3). The same scaling procedure gives for $YbCoGaO_4$ the following parameters: $z\nu = 18.0$, $\beta = 0.9$.

The dynamical scaling reveals for both crystals a three dimensional phase transition near T_g and yields the critical exponent values between those of Heisenberg- and Ising-like systems, albeit slightly closer to the Ising case. Similarity of the fitting parameters obtained for the studied crystals suggests that dynamical properties of $RCoGaO_4$ spin glasses are determined by Co^{2+} ions while R^{3+} ions are responsible for the character of the phase transition.

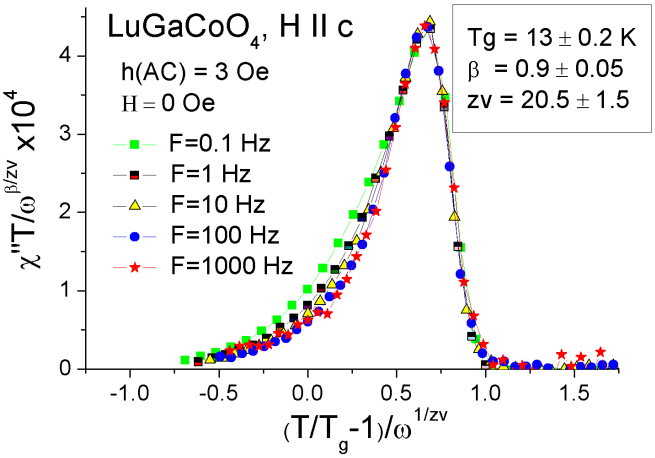

Fig. 3. Scaling of $\chi''(\omega, T)$ performed according to the relation (1) for $LuCoGaO_4$crystals.

4. Conclusions

It has been shown that Co^{2+} ions in both studied crystals are the low-anisotropy ions and do not determine the character of spin glasses. It is determined mainly by the Ising-like R^{3+} ions.

Acknowledgments

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