STRUCTURAL AND MAGNETIC PROPERTIES OF THE $ErNi_{1-x}Cu_xAl$ SERIES*

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The pseudo-ternary series $ErNi_{1-x}Cu_xAl$ has been studied by means of X-rays and magnetization. Structure parameters exhibit a sudden "jump" between $x = 0.5$ and 0.6. The samples in the initial region with $x \leq 0.2$ undergo two phase transitions and co-existence of F and AF ordering is possible. The samples with $x \geq 0.4$ are already rather ferromagnets.

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1. Introduction

The RNiAl and RCuAl compounds belong to a large group of RTX compounds (R = rare earth, T = transition metal, X=p-metal). They crystallize in the ZrNiAl-type hexagonal structure, space group $P\bar{6}2m$ (group No. 189), which consists of two types of layers. One of them contains all the rare-earth atoms and one third out of the transition-metal atoms. The p-metal and two out of the three transition metal atoms are included in the second, nonmagnetic layer separating the first one.

Interesting study was performed for $TbNi_{1-x}Cu_xAl$ series [1]. In comparison to that case, the boundary stoichiometric concentration compounds in the $ErNi_{1-x}Cu_xAl$ series behave in the similar way with additional difference in the directions of magnetic moments. ErNiAl is an antiferromagnet with

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magnetic moments arranged within the basal plane below 6.2 K [2], while ErCuAl is a simple ferromagnet with moments aligned in the c-axis direction with the ordering temperature of 6.8 K [3]. The change of magnetic-ordering type and also reorientation of the moments is expected.

2. Experimental

The polycrystalline samples have been prepared by arc-melting in mono-arc furnace under protection of argon atmosphere. The initial materials consisted of pure elements with the purity of 99.9% for Er and Co, 99.995% for Ni and 99.999% for Cu and Al. All of the samples have been analyzed by X-ray powder diffraction at room temperature. Moreover, the quality of the selected samples has been proved by the microprobe experiment.

The DC-magnetization measurements have been performed using the PPMS instrument and on a SQUID magnetometer (both Quantum Design). The powder consisting of randomly oriented grains fixed by nonmagnetic glue in a small ampule has been used.

3. Results

The X-ray study of the $ErNi_{1-x}Cu_xAl$ series at the room temperature showed that the lattice parameters radically "jump" between $x = 0.5$ and 0.6 while keeping the volume without any sudden change (Fig. 1).

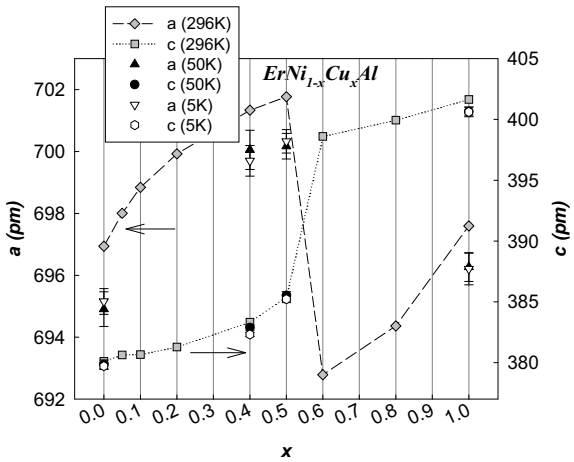

Fig. 1. The concentration dependence of the lattice parameters in the $ErNi_{1-x}Cu_xAl$ series, for several concentrations measured in low temperatures.

The lattice parameters measured on several samples ($x = 0.0; 0.4; 0.5;\ 1.0$) at the temperatures down to 5 K show, that a and c follow the same type of concentration dependence at low temperatures as that at the room temperature.

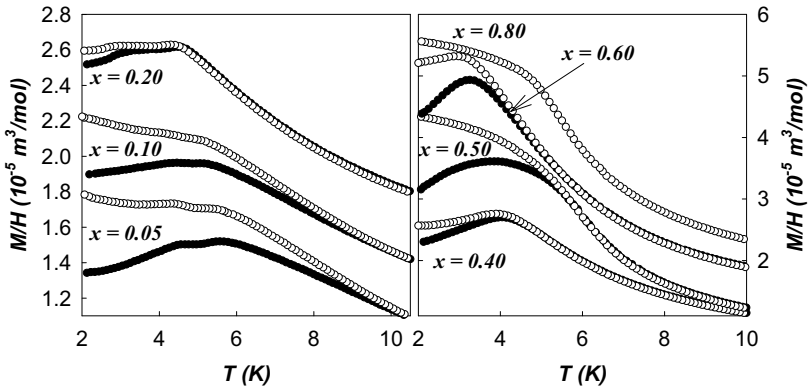

Fig. 2. The low-temperature dependence of M/H in the $ErNi_{1-x}Cu_xAl$ series. The full and open symbols represent zero-field cooled and field cooled regime, respectively. The values for different concentrations x are shifted for better view.

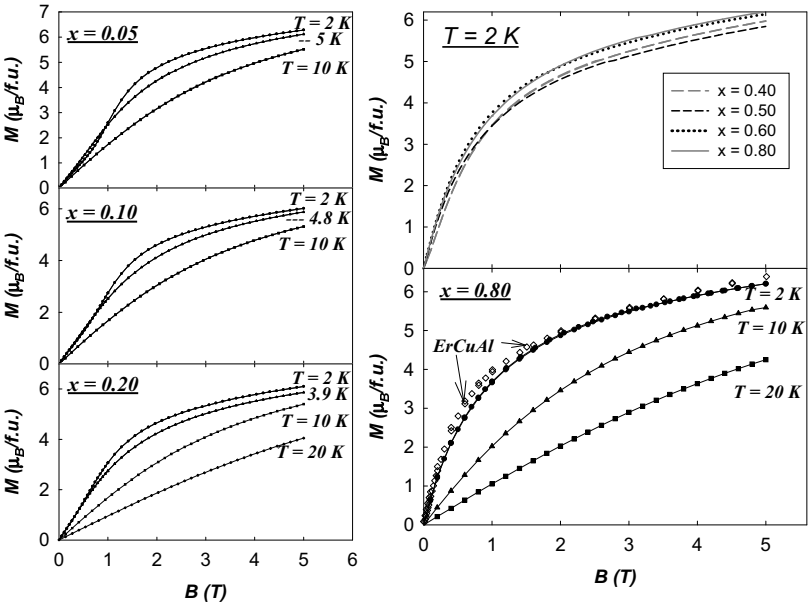

Fig. 3. Magnetization curves of the $ErNi_{1-x}Cu_xAl$ series. In the right part the comparison with ErCuAl sample at 2 K — represented by empty symbols — is added.

By viewing magnetization data, one can think about two concentration regions. In the range of $0.05 \leq x \leq 0.20$ there is possible co-existence of ferro- and antiferromagnetic alignment. The samples with $x = 0.05, 0.1, 0.2$ exhibit two maxima in the temperature dependence of magnetization, what indicates two phase transitions (Fig. 2). These two points of phase transi-

tion have been confirmed by the heat capacity measurements. Also magnetization curves indicate the antiferromagnetic ordering. As it is seen from the double-curvature (Fig. 3), the ferromagnetic component is strengthening while increasing x.

The other region of the concentration of $x \geq 0.4$ contains compounds exhibiting rather ferromagnetic behavior. They have a clear inflection point in low-temperature dependence of magnetization. Heat capacity measurements confirmed them to be phase-transition points. The magnetization curves contain already no double-curved behavior. And because of the similarity to the magnetization curve of the ErCuAl compound (under the same conditions) it is probable, that the $ErNi_{1-x}Cu_xAl$ compounds with $0.4 \leq x \leq 0.8$ are ferromagnets. The ferromagnetism of ErCuAl has been confirmed by neutron diffraction experiments [3].

4. Discussion

From the different alignment of magnetic moments in the ErNiAl and ErCuAl compounds, the change of magnetocrystalline anisotropy and the transition from antiferro- to ferromagnetic order within the $ErNi_{1-x}Cu_xAl$ series is expected. The lattice "jump" can indicate the reorientation of the magnetic moments.

According to the evolution of the M *vs.* H dependencies within the concentration range, it seems that the ferromagnetic component becomes stronger while increasing the concentration parameter x. Also the temperatures of the second maximum in the low-temperature dependencies of M/H drives down with increasing x. So the change from antiferro- to ferromagnetic order happens consequently, without any sudden change.

If the hypothesis that compound with $x = 0.40$ is already ferromagnetic and if the sudden change in the lattice is connected with reorientation of the moments from the basal plane ($x \leq 0.5$) to the c-direction ($x \geq 0.6$) it would mean that the concentrations $0.5 \leq x \leq 0.6$ represent ferromagnetic compounds with magnetic moments within the basal plane. To confirm or negate this idea is the question for the neutron diffraction.

REFERENCES

[1] G. Ehlers, D. Ahlert, C. Ritter, W. Miekeley, H. Maletta, *Europhys. Lett.* **37**, 269 (1997).

[2] P. Javorský, M. Diviš, H. Sugawara, H. Sato, H. Mutka, *Phys. Rev.* **B65**, 014404 (2002).

[3] P. Javorský, P. Burlet, E. Ressouche, V. Sechovský, H. Michor, G. Lapertot, *Physica B* **225**, 230 (1996).