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THERMAL PROPERTIES OF NIFe2-xAlxO4 SYSTEM

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ABSTRACT. **The magnetic phase transition in the NIFe2-xAlxO4 system was studied trough measurements of thermal diffusivity and thermal conductibility in the range of temperature 100 - 600K. It was proved that the temperature dependence of the thermal diffusivity is adequate to point out the phase transition.**

INTRODUCTION

The NIFe2-xAlxO4 system was studied earlier in detail from electrical and magnetical point of view [1], but thermal measurements was not performed until now.

The present study of NIFe2-xAlxO4 ferrites discusses the thermal properties (thermal diffusivity, thermal conductivity and specific heat) of the system.

It is shown in reference [2] that the temperature-dependence of the thermal diffusivity and thermal conductivity gives also information about the phase-transition temperature.

The aim of this study is to prouve by thermal measurements the existence of magnetic phase transition and also to make clear the thermal conductivity mechanismus.

EXPERIMENTAL

The samples were sinterized using oxides of p. a. purity. A series of samples was prepared with the concentrations x = 2 (I), x = 1. 4 (IV), x = 1. 2 (V), x = 1. 1 (VI), x = 1. 0 (VII). Thermal diffusivity was determined by the optical impulse method [3], specific heat was measured using the method of adiabatic calorimeter [4].

RESULTS AND DISCUSSION

Fig. 1 shows an 1/T dependence of the thermal diffusivity in case of different samples (VII, VI, V). It results that one can distinguish three different domains for samples with reduced concentration of the Al 3+ ion (VII, VI, V) and only two different domains in case of greater

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ion (VII, VI, V) and only two different domains in case of greater concentration of the above-mentioned ion (Fig. 2 - sample I). These domains are characterised by linear variation, while at certain temperature a modification in the slope appears. After Peirels [5], these modifications occur at the Debye temperature, respectively at those temperatures at which the phonon scattering mechanisms modify. According to this theory, thermal diffusivity is described as follows:

$$\lambda = \frac{1}{3}\bar{l}\nu c, \tag{1}$$

where $\bar{l}$ is the mean free path for phonons, ν - the group velocity for phonons, c - the specific heat. The value of $\bar{l}$ is given by different scattering mechanisms, like: the triphononic "u" processes ($\bar{l}_{ff}$), the scattering on defects ($\bar{l}_{fd}$), on electrons ($\bar{l}_{fe}$) and - in case of magnetically ordered materials - on magnons ($\bar{l}_{fm}$). Thus the resulting mean free path is:

$$\frac{1}{\bar{l}} = \frac{1}{\bar{l}_{ff}} + \frac{1}{\bar{l}_{fd}} + \frac{1}{\bar{l}_{fm}} + \frac{1}{\bar{l}_{fe}}. \tag{2}$$

The $\bar{l}_{fd}$ can be considered invariant in the range of high temperatures. Below the high temperature range $\bar{l}_{ff}$ varies like 1/T, while for a low concentration of electrons $\bar{l}_{fe}$ remains constant in a wide temperature range.

It results that the temperature dependence of the mean free path is determined in fact by two phenomena: the triphononic "u" scattering process and phonon - magnon scattering. With regard to the mean free path given by this last mechanism, its variation follows the relation:

$$\bar{l}_{fm} = \bar{l}_0\left(1 - \frac{M(T)}{M(0)}\right)^{-1}, \tag{3}$$

where: M(T) - the magnetisation at temperature T, M(0) - the magnetisation at the perfectly ordered state, $\bar{l}_0$ - the mean free path at the phase transition temperature. One notices that this quantity decreases with increasing temperature until the phase transition. Above this value it remains constant. Returning to Fig. 1., we can assume the following: the first slope modifications (in the low temperature range) for the samples VII, VI, V arises at Debye temperatures.

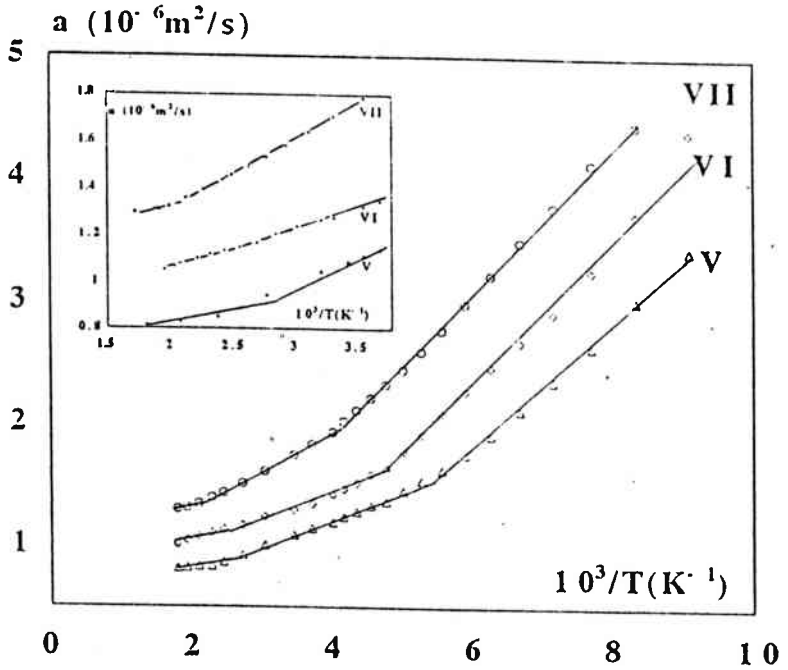

Fig. 1. Thermal diffusivity variation for samples VII, VI, V

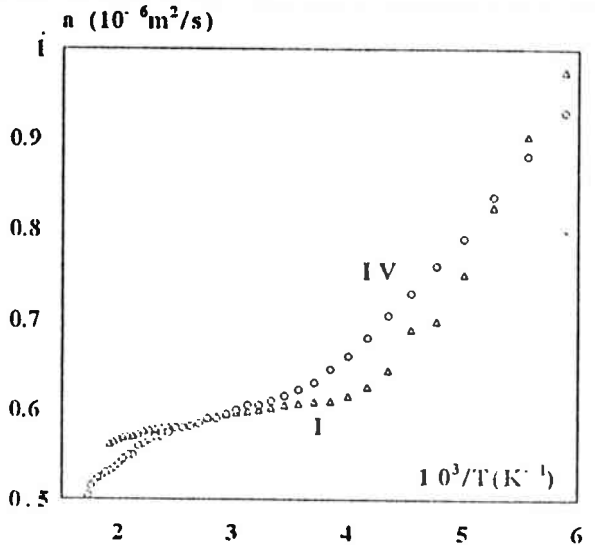

Fig. 2. Thermal diffusivity variation in case of samples I and IV

Their values were confirmed by specific heat measurements. The second slope modification arises at higher temperatures. These values can be determined exactly from the medallion of Fig. 1 Thus, it appears at 464K for the sample VII, at 391K for the sample VI and at 370K in case of sample V. The values determined are in agreement (in terms of the errors of the measurement) with the values determined by L. Kozlowski [2] for the phase-transition. In the case of sample I (Fig. 2), the single slope modification temperature corresponds to the Debye temperature. For the sample IV (Fig. 2), the variation of the diffusivity is no longer linear for the intermediate temperature range. Thus it is not possible to determine the Debye temperature. We consider that this is due to the superposition of the two temperature-regions. The slope-modification for this sample appears at 259K, which corresponds to the phase-transition temperature.

The variation of thermal conductivity is given by:

$$\lambda = a\rho c, \tag{4}$$

where: a - thermal diffusivity, ρ - density, and it is represented in Fig. 3 for samples VII, VI, V and in Fig. 4 for the sample IV. One founds that this variation curve presents a peak at the magnetic phase-transition temperature, peak that can be correlated with an anomaly in the specific heat. With regard to this data, see article [6].

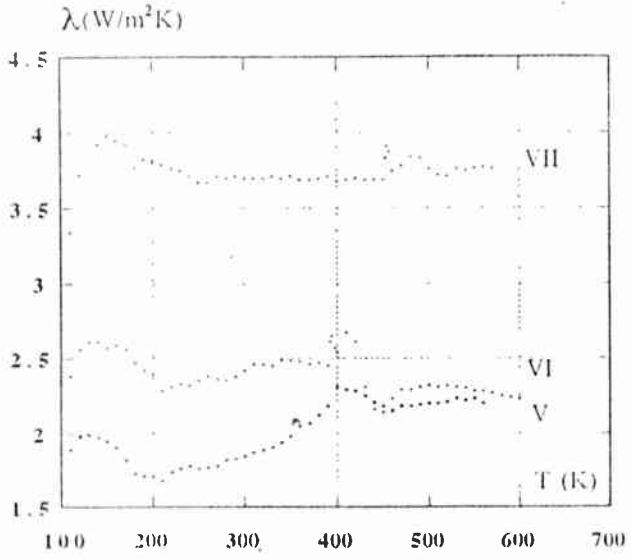

Fig. 3. Thermal conductivity for samples VII, VI, V

As it was shown, the above determined temperatures present coincidence with the data from the paper of Visinevski [1].

From Fig. 3 and Fig. 4 results also that thermal conductivity decreases with increasing Al 3+ concentration. We consider that this decrease arises from the substitution of magnetic Fe3+ ions from the host lattice with Al 3+ ions that have greater scattering section for phonons than Fe3+, as it was shown in [7].

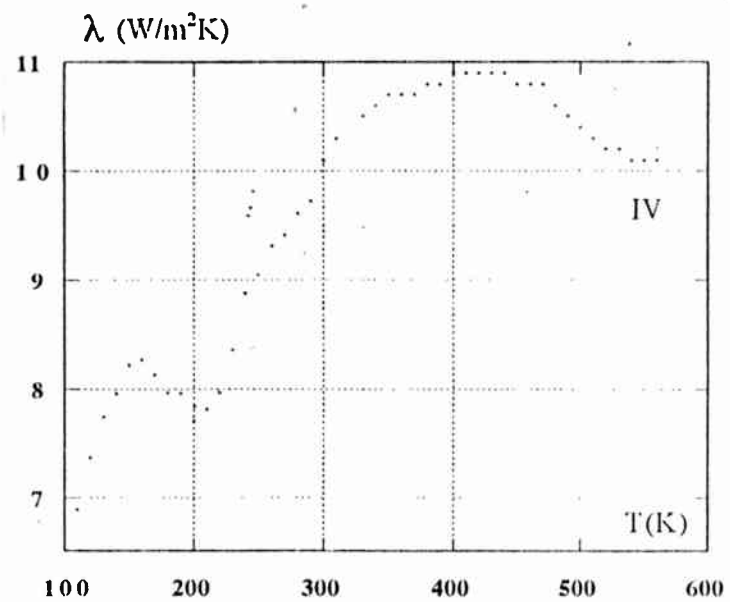

Fig. 4. Thermal conductivity for sample IV

CONCLUSIONS

Magnetic phase transition was put in evidence by thermal data.

It was proved that the thermal diffusivity is an adequate quantity to study the second order phase transition.

It was pointed out that the thermal conductivity varies considerably with the concentration of Al 3+ ions in case of ferrites.

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