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Magnetic Anisotropy of Ultra-small Nanocrystals of $CoFe_2O_4$

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Ferrimagnetic nanoparticles of $CoFe_2O_4$ with dimensions of 4-16 nm were synthesized by pyrolysis of a mixture of acetylacetonates of iron and cobalt. In the temperature range 300-500 K investigated field dependence of magnetization up o 18 kOe. Found a significant contribution of "surface" anisotropy to the effective anisotropy of the nanoparticles.

Keywords: Ferrimagnetic, Nanoparticles, Effective anisotropy, Cobalt spinel.

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1. INTRODUCTION

To study the magnetic anisotropy field various methods, static and resonance, are used. Analysis of the available published data on the problem of the effective magnetic anisotropy demonstrated the ambiguity of the results obtained by different methods of measurements on powder samples. In the present work to determine the effective magnetic anisotropy field (H_a^{ef}) two well-known method based on the analysis of magnetization curves (method of Asti-Rinaldi [1] and the Akulov method [2]) are used, and the assess by coercitive force were made.

2. ANISOTROPY FIELD OF COBALT FERRITE

The object of the study was a $CoFe_2O_4$ ferrite. The selecting of this object first of all caused by that the cobalt ferrite has the highest magnetocrystalline anisotropy due to the large single-ion contribution of Co^{2+} ions, which are localized in the octahedral sites of the crystal lattice of ferrite [2]. In addition, in the temperature range (300-550) K anomalous sharp decrease of magnetocrystalline anisotropy field from 20 kOe to near zero is observed. It is interesting to investigate the effective magnetic anisotropy field, where, along with the contribution of the magnetocrystalline anisotropy specific for small particles of the other two contributions - the "surface" anisotropy (H_a^{surf}) and the anisotropy of particle shape (H_a^{dem}) can play an important role:

$$H_a^{ef} = H_{ak} \pm H_a^{surf} - H_a^{dem} \qquad (1)$$

Nano-dispersed powder sample was obtained by pyrolysis of a mixture of acetylacetonates of iron and cobalt [3]. The parameters of the crystal structure, phase composition and dispersion of the synthesized samples were investigated using X-ray analysis and the method of transmission electron microscopy (Fig. 1).

Investigation of the basic magnetization curves and hysteresis loops was carried out on laboratory-type pendulum magnetometer (H = 0.1-18 kOe, T = 300-500K). At each fixed temperature the measurements were made on thermally demagnetized samples.

For all magnetization curves in the range 300 - 500 K two effects that are characteristic for small particles were observed. It's – high-field unsaturation and underestimate (compared with the macroscopic analogue)

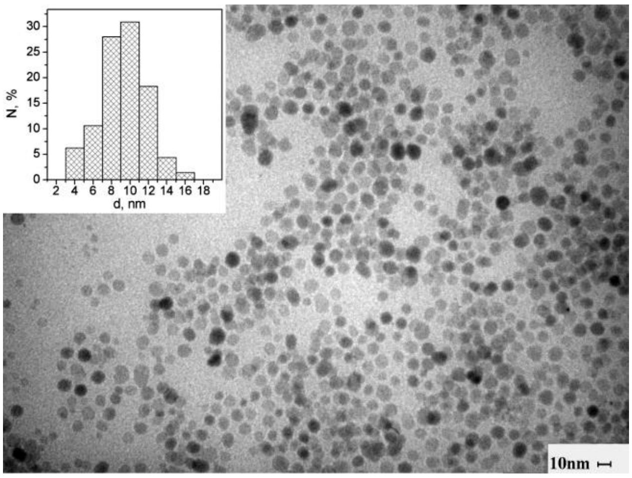

Fig. 1 – Electron micrograph and distribution by particle diameter of $CoFe_2O_4$ ferrite

values of the magnetization in fields that are comparable or even much higher than the magnetocrystalline anisotropy field (Fig. 2).

The table shows the experimental values of the effective magnetic anisotropy field.

Table 1 – Experimental results

T, K	method of determination		
	H_a^{ef}, kOe		
	by H_c	Asti-Rinaldi method	Akulov method
300	4,0	3,2	4,4
350	3,3	3,5	3,6
400	2,5	1,5	2,9
450	1,7	1,0	1,7
500	1,2	1,3	1,6

As the table shows, the data obtained by different methods correspond within acceptable limits. In contrast to the macroscopic analogue (H_{ak}) the dependence of H_a^{ef} (T) in the temperature range (300-375) K does not detect anomalous sharp decrease (Fig. 3).

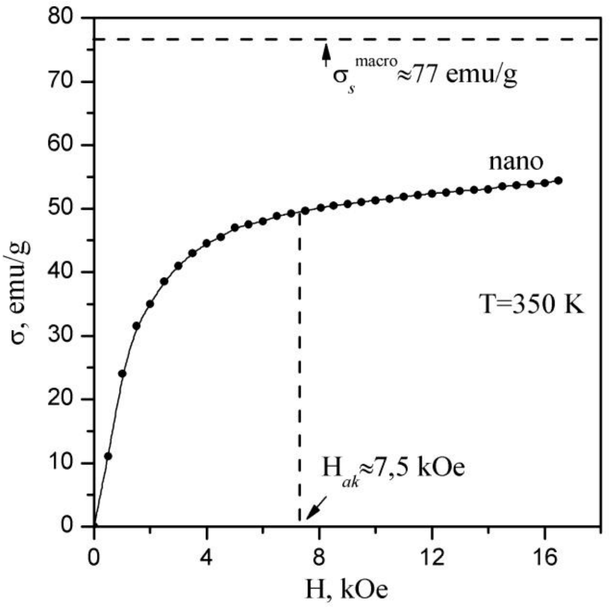

Fig. 2 – The dependence of specific magnetization of $CoFe_2O_4$ nanopowder from magnetic field in comparison with the macroscopic analogue

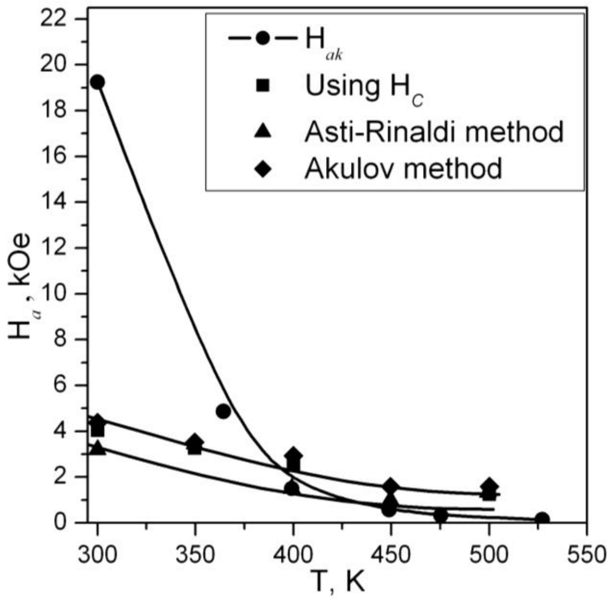

Fig. 3 – Dependence of the effective anisotropy field of $CoFe_2O_4$ nanocrystalline powder of the temperature in comparison with macroscopic analogue.

3. CONCLUSIONS

Considering negligibly small anisotropic contribution Hadem for the octahedral form particles it is possible to make the following conclusion. From two specified in the formula (1) specific for small particles anisotropic contributions, the determining role in the formation of the temperature dependence of H_a^{ef} (300-375) K plays structurally defective near-surface region of the nanoparticles. The same area which has "skewed" magnetic structure [5], is responsible for the lower value of magnetization in the field $H = H_{ak}$ and high-field unsaturation of main magnetization curves.

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