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MAGNETIC PROPERTY OF THE SUPERPARAMAGNETIC FLUID CONTAINING $Ni_{0.5}Co_{0.5}Fe_2O_4$ NANOPARTICLES

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Annotatsiya: Ushbu ishda $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanozarralar asosidagi magnit suyuqliklar kimyoviy kondensatsiya usulda olingan. $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanozarralarning morfologik tahlili, element tarkibi va magnit suyuqlikning magnitlanishi, elektron mikroskop (TEM), energiya-dispers rentgen nurlar tahlil (EDX) va tebranishli magnetometr bilan o'rganildi.

Kalit so'zlar: superparamagnit suyuqlik, nanozarra, magnetometr, EDX tahlil, morfologik tahlil.

Аннотация: В данной работе магнитные жидкости на основе наночастиц $Ni_{0.5}Co_{0.5}Fe_2O_4$ были получены методом химического соосаждения. Морфологический анализ, элементный состав наночастиц $Ni_{0.5}Co_{0.5}Fe_2O_4$ и намагниченность магнитных жидкостей было изучено с помощью просвечивающего электронного микроскопа (ПЭМ), энергодисперсионного рентгеновского анализа (ЭДС) и вибрационного магнитометра (ВМ).

Ключевые слова: суперпарамагнитная жидкость, наночастица, магнитометр, ЭДС анализ, морфологический анализ.

Abstract: In this work the magnetic fluids based on the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles have been obtained by the chemical co-precipitation method. Morphological analysis, elemental composition of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles and magnetization of the magnetic fluid were studied by transmission electron microscope (TEM), energy-dispersive X-ray (EDX) analysis and vibrating sample magnetometer (VSM).

Key words: superparamagnetic fluid, nanoparticle, magnetometer, EDX analysis, morphological analysis.

Introduction. In recent years, the magnetic properties of magnetic fluids containing Ni, Co, Fe nanoparticles are studied with interest. Magnetic fluids are a colloidal solution consisting of single-domain ferro or ferrimagnetic nanoparticles dispersed in a carrier liquid[1]. Due to their magnetic, viscosity, electrical properties these fluids are using in medicine, electronics, industrial fields, machinery and other fields[2,3]. Nowadays, there are different methods of synthesizing magnetic fluids: for example, sedimentation, hydrothermal, sol-gel, thermal decomposition, solvothermal, sonochemical, electrochemical, mechanical milling and other methods[3,4,5]. Due to simplicity, convenience, low cost, and most importantly, the

ability to control the size of the particles the chemical co-precipitation method was used to the synthesis of the magnetic fluid containing $Ni_{0.5}Co_{0.5}Fe_2O_4$.

If we consider the width of the field of application of magnetic fluids, the study of the dependence of its physical properties on external influences is actual. For this purpose in this research work magnetic fluid based on $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles were synthesis and morphology, element composition, magnetization of this fluid were studied.

Materials and methods. The two-step method was used to synthesize the $Ni_{0.5}Co_{0.5}Fe_2O_4$ magnetic fluid [6]. Initially, the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles were synthesized using chemical co-precipitation method. Each of the salts of $Fe(NO_3)_3 \cdot 9H_2O$, $Co(NO_3)_2 \cdot 6H_2O$, $Ni(NO_3)_2 \cdot 6H_2O$ with the molar ratio of $Ni^{2+}: Co^{2+}: Fe^{3+} = 0.5 : 0.5 : 2$ were dissolved separately in 100 ml of double distilled water. Afterward 1M NaOH as the precipitating agent was slowly added to the resulting salt solution drop by drop until the pH 10 and stirred at 100 ^{0}C 1 hours. Thereafter, the metal ions are converted into hydroxides, and then under the influence of temperature, the hydroxides are transformed into ferrites (eq.(1), (2)) [7]. Then the precipitated nanoparticles were washed with double-distilled water several times to remove the impurities. Then 0.02 gr/ml of sodium oleate was added to the sediment as a surfactant, then mixed well at 80 ^{0}C for 1 h (eq.(3)):

$$0.5Ni^{2+} + 0.5Co^{2+} + 2Fe^{3+} + 8OH^- \Rightarrow 0.5Ni(OH)_2 \cdot 0.5Co(OH)_2 \cdot 2Fe(OH)_3 \quad (1)$$

$$0.5Ni(OH)_2 \cdot 0.5Co(OH)_2 \cdot 2Fe(OH)_3 \overset{100^0C}{\Rightarrow} Ni_{0.5}Co_{0.5}Fe_2O_4 + 4H_2O \quad (2)$$

$$Ni_{0.5}Co_{0.5}Fe_2O_4 + C_{17}H_{33}COONa \overset{80^0C}{\Rightarrow} (Ni_{0.5}Co_{0.5}Fe_2O_4) \cdot (C_{17}H_{33}COONa) \quad (3)$$

Morphological analysis of the nanoparticles of the magnetic fluid have been examined using a transmission electron microscope (model: TEM LEO 912 AB) and elemental composition of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ powder were studied by energy dispersive X-ray spectroscopy (EDX, model : X-ACT Silicon Drift Detector). The magnetization of the fluid was measured with a VSM magnetometer.

1. Results and discussion

1.1. TEM studies.

The shape, size and morphology of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles were investigated using transmission electron microscope. The obtained results are shown in Fig.1. From TEM images it can be seen that almost all of the particles of the fluid are spherical in shape. Also the average size of the particles are 10 – 35 nm.

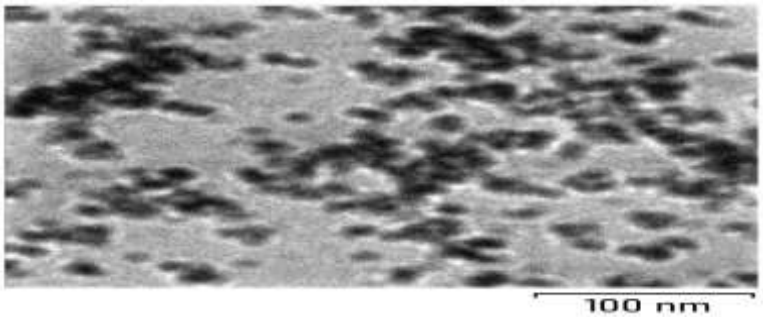

Fig.1. TEM images of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles

1.2.Chemical composition studies

The elemental compositions of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles were analyzed by the energy dispersive X-ray (EDX) measurements. The measurement results are shown in Fig.2**.** As can be seen from the

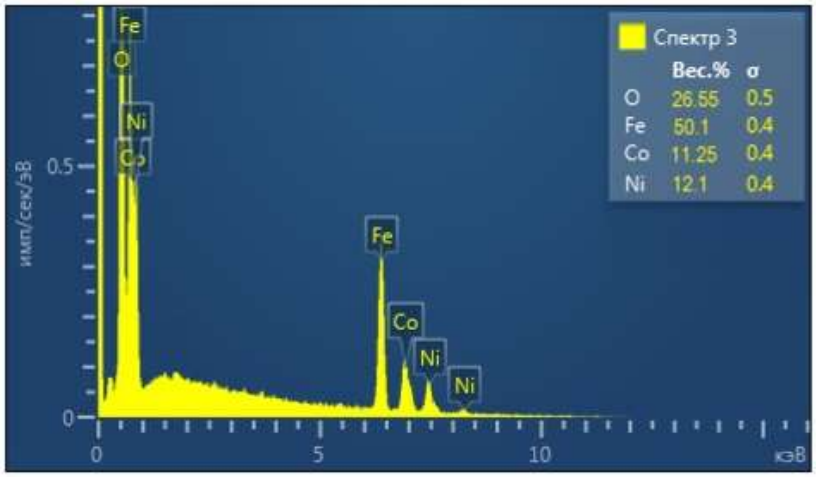

Fig.2. EDX spectra of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ powder.

Fig.2 the presence of Fe, Co, Ni and O elements in the $Ni_{0.5}Co_{0.5}Fe_2O_4$ powder and weight percentage values of the Fe and O are higher than Ni and Co.

1.3.Magnetic properties

The dependence of the specific magnetization of the magnetic fluids of concentration 1 vol % of $Ni_{0.5}Co_{0.5}Fe_2O_4$ on the magnetic field was measured at the room temperature by vibrating sample magnetometer. The results of the measurements are shown in Fig.3. From the magnetization hysteresis loops of the Fig.3 we can determine the saturation magnetization, remnant magnetization and the coercivity values. The saturation magnetization value for the $Ni_{0.5}Co_{0.5}Fe_2O_4$ magnetic fluid is 2,26 emu/g.

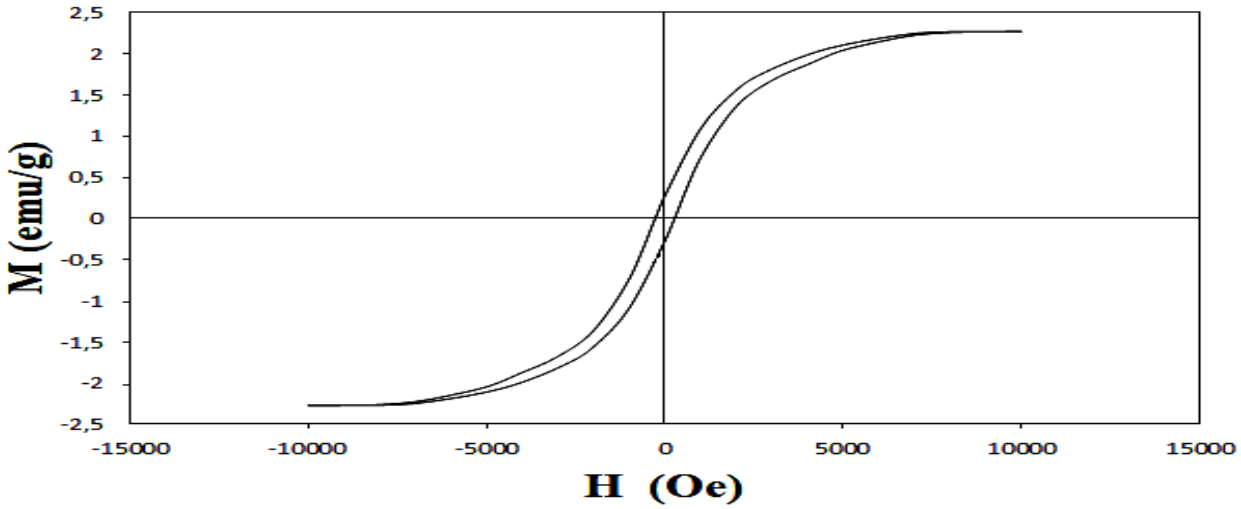

Fig.3. Hysteresis loops of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ magnetic fluid

2. Conclusion

Magnetic fluids based on $Ni_{0.5}Co_{0.5}Fe_2O_4$ synthesized at were obtained by the chemical co-precipitation method. Based on EDX analysis it was confirmed that the synthesized particles were $Ni_{0.5}Co_{0.5}Fe_2O_4$. TEM measurements revealed that the

sizes of the $Ni_{0.5}Co_{0.5}Fe_2O_4$ nanoparticles of the magnetic fluid are about 10 – 35 nm. We have also revealed that the magnetite magnetic fluid shows superparamagnetic nature, and the saturation magnetization value of its was 2,26 emu/g.

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