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Study of the Magnetic Properties of Fluorescent Composite Nanoparticles

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Abstract:

Luminescent magnetic nanostructures are used in various fields of science and technology. Modern industrial production actively uses metal structural materials to create innovative devices and components. To prevent emergencies, non-destructive testing methods are used to detect material defects, which allows you to identify problem areas without stopping the production process, or to observe or eliminate them. The aim of the work is to develop methods for obtaining fluorescent composite nanoparticles of iron oxides of various dispersions, including SiO_2, with a shell, and to study their magnetic and spectral-optical properties. A modification of the aging method is proposed, which consists in carrying out the synthesis without nitrogen foam, with gentle mixing. The principles of obtaining a SiO_2shell on the surface of iron oxide nanoparticles (Fe_3O_4, γ- Fe_2O_3) of various dispersions are determined. The dependence of the shell thickness on the concentration of the SiO_2 shell precursor and the mechanical mixing time was determined. A method for the coupling of iron oxide nanoparticles (Fe_3O_4, γ- Fe_2O_3) with a fluorescent derivative (fluorescein ethyl ether-O-bromoethyl) via the aminated surface of the nanoparticles with both thin sorbed 3-aminopropylanthriene and shelfoxylanthrie was proposed. Thicknesses up to 35 nm were achieved by a modified Stoeber method.

Keywords: *magnetic, fluorescence, iron oxides, composite, nanostructures*

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INTRODUCTION

The research area is determined by analyzing the literature data on the topic of the article. The selection of research objects is carried out. Magnetic nanoparticles and their modifiers were taken to create fluorescent composite nanoparticles based on iron oxide. The properties of the materials used are presented, the methods used for the analysis of the obtained experimental samples are presented, and the synthesis methods are determined. The structural properties, magnetic, thermal and luminescent properties of the obtained experimental samples are presented. The properties depend on the size of the nanoparticles. Iron oxide (Fe_3O_4) nanoparticles were obtained by aging with different dispersions: from 20 to 110 nm. A modification of the aging method is proposed, excluding the nitrogen bubbling stage with gentle mixing during the synthesis process, which allows obtaining nanoparticles of iron oxides with a size of 20 nm (Fig. 1).

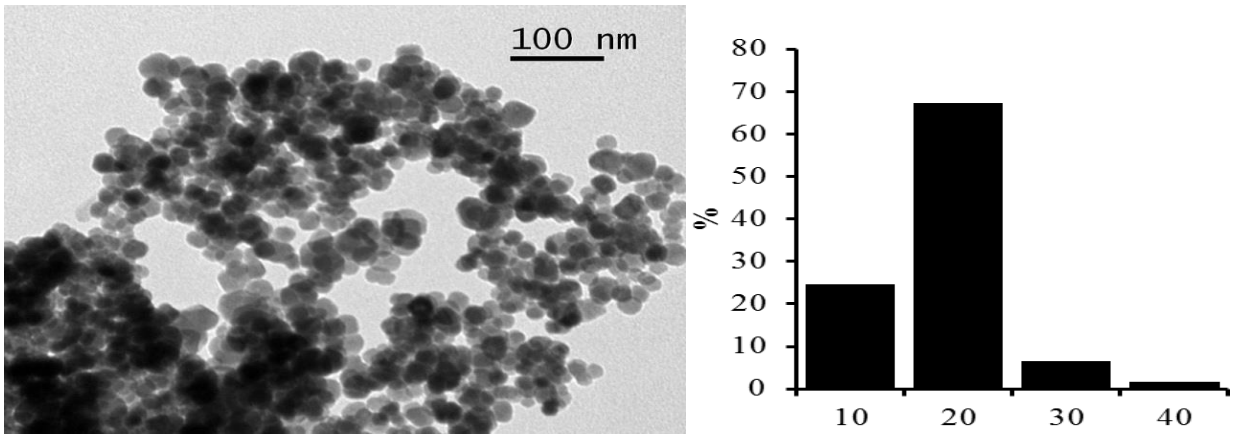

Figure 1 – TEM image of iron oxide nanoparticles obtained without nitrogen blowing with gentle stirring at Tc=20°C

The effect of size on the coercive force of nanopowders obtained using a single-phase Fe3O4 structure was determined by thermostating under different synthesis conditions. (Figure 2). X-ray diffraction studies of the resulting nanopowders showed that all samples have a single-phase Fe3O4 structure.

RESEARCH METHOD AND RESULTS.

This process significantly depends on the concentration of the silicon oxide precursor. However, with a further increase in the amount of tetraethoxysilane in the system, a decrease in the shell thickness was observed: a core with a size of 23 nm reduced the shell thickness to 20 nm, a core with a size of 80 nm. decreased to 17 nm, and a core with a size of 100 nm reduced to 10 nm. In concentrated systems, the rate of formation of the initial shell ceases to limit the rate of the heterogeneous reaction, and the kinetics of polycondensation is already distorted by the process of recondensation through the homogeneous phase at the initial stage. The kinetic dependences for such systems are characterized by a decrease in the content of the most "active" oligomers and a constant increase in the content of highly polymerized forms at a relatively small and slightly changing monomer concentration. In this case, at the same initial concentration of the precursor, the rate of heterophase polycondensation will

depend not only on the initial concentration of the precursor, but also on the magnitude of the current supersaturations

The effect of mixing time on the formation of a shell on the surface of 100 nm Fe_3O_4 nanoparticles was investigated. The synthesis was carried out by adding TEOS at a concentration of 0.027 M. The mixing time varied from 2 to 24 h. It was shown that after 2 h of mixing, no shell was formed. After 4 h, the surface of the nanoparticle appeared to be eroded and a thin shell with a thickness of 8 nm was formed. Then, the shell was completed, gradually increasing to 15 and 20 nm after 6 and 8 h, respectively. Then, after 18 h of mixing, the thickness remained constant. As previously mentioned, the average shell thickness after 24 h of mixing was determined by the analysis of the corresponding hysteresis properties of the $Fe_3O_4/\ SiO_2$ nanopowders, which are characterized by an increase in coercivity. The strength (Hc increases from 130 ... 150 Oe to 150 ... 240 Oe) compared to uncoated Fe_3O_4 powders, which confirms the possibility of increased interactions at the "magnetic core" boundary (non-stoichiometric magnetite).

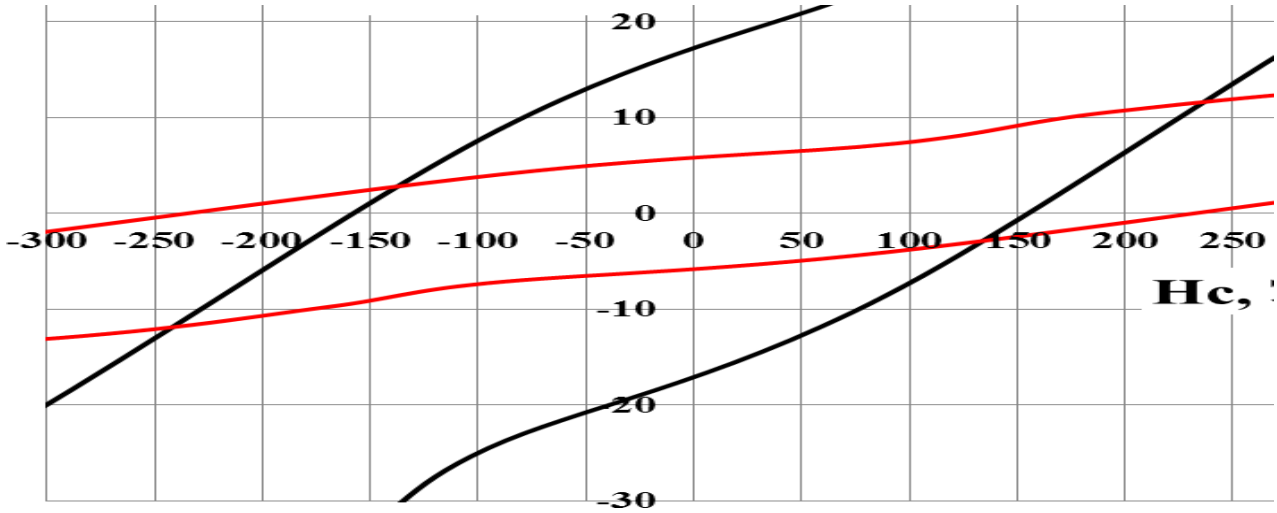

Figure 2 - Field dependences of saturation magnetization forFe_3O_4 and $Fe_3O_4/\ SiO_2$ nanopowders

The analysis of the IR spectra showed that all elements contain Fe-O bonds (573, 584 and 577 cm-1). The peak at 855 cm-1 indicates the presence of a low-intensity C-C bond due to strong O-H interactions. O-H stretching vibrations (3396 cm-1) and low-intensity peaks of C-O and C=O (1109 and 1657 cm-1, respectively) confirm the modification of the surface of the nanoparticles. Strong stretching vibration peaks of Si-O-Si (1095 cm-1) and Si-C (463 and 806 cm-1) and C-C (953 cm-1) appeared in the spectrum of nanoparticles covered with SiO_2 shell. proves the formation of a shell of silicon oxide on the surface of the nanoparticle. The obtained aminated iron oxide nanopowders, in comparison with $Fe_3O_4/\ SiO_2$ nanostructures, are characterized by the appearance of two peaks (2854 and 2929 cm-1) corresponding to the asymmetric stretching vibrations of the –CH2– bond. The double peak in the region from 3000 to 3500 cm-1 indicates the formation of the –C–NH2 (primary amine) bond. Otherwise, the nature of the spectrum of nanoparticles with an aminated surface

coincides with that of $Fe_3O_4/\ SiO_2$ nanocomposites, which indicates the formation of a thin SiO_2 shell on the surface of the nanoparticles and allows us to talk about the formation of . Fe_3O_4.Visual inspection of the cross-linking of the fluorescent dyes ethyl ether-O-bromoethylfluorescein and fluorescent isothiocyanate with the surface of Fe_3O_4 nanoparticles and $Fe_3O_4/\ SiO_2$ structures was carried out. Figure 3 shows a micrograph of a $-Fe_3O_4/\ SiO_2$NH–ethyl ether–O–[ethyl] fluorescein nanopowder sample. Studies were conducted on the effect of the core size of Fe_3O_4/SiO_2 composite nanoparticles on the luminescence intensity of ethyl ester-O-[ethyl]fluorescein. It was found that as the core size of the nanoparticles increases, the luminescence intensity nearly doubles. In all samples, the peak intensity is observed around the 550 nm region. To examine the necessity of the SiO_2 shell as a connecting layer between the nanoparticles and the phosphor, iron oxide nanoparticles of various sizes were investigated.

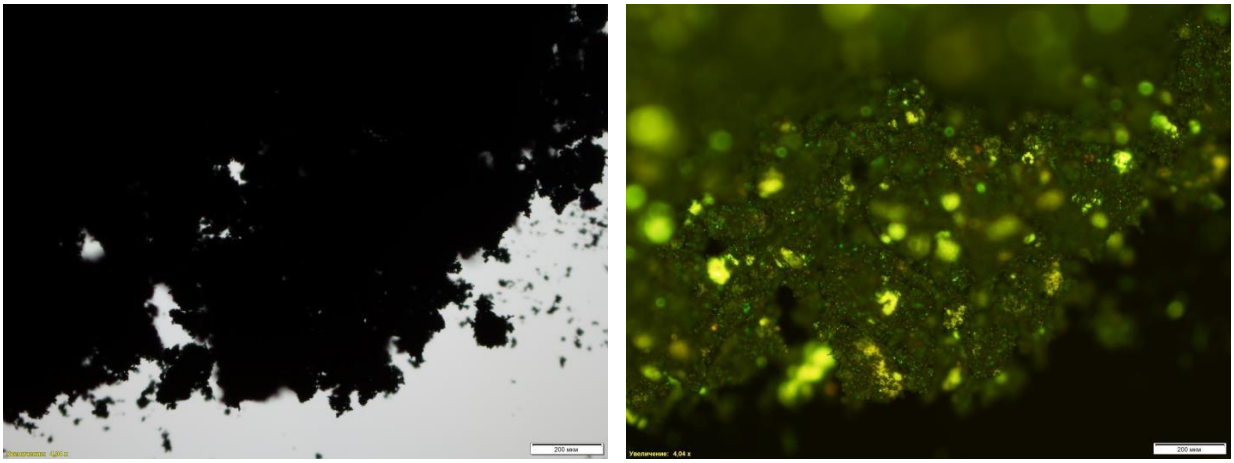

Figure 3– Microphotographs of $Fe_3O_4/\ SiO_2$ –NH–ethyl ether–O–[ethyl]fluorescein nano powder sample

Figure 4 shows the luminescence spectrum of Fe_3O_4 nanoparticles with a core size of 10 nm. It was found that when the size of the nanoparticles increases from 10 to 110 nm, the intensity increases by 20%, while fluorescent magnetic nanoparticles with a core size of 100 nm exhibit two intensity peaks and a shift in emission wavelengths from 550 nm to 530 nm. Based on the data obtained, it was determined that the SiO_2 shell negatively affects the manifested luminescent properties of the composite NPs, since the intensity of the unshelled NPs is higher and a shift in the UV region is observed.

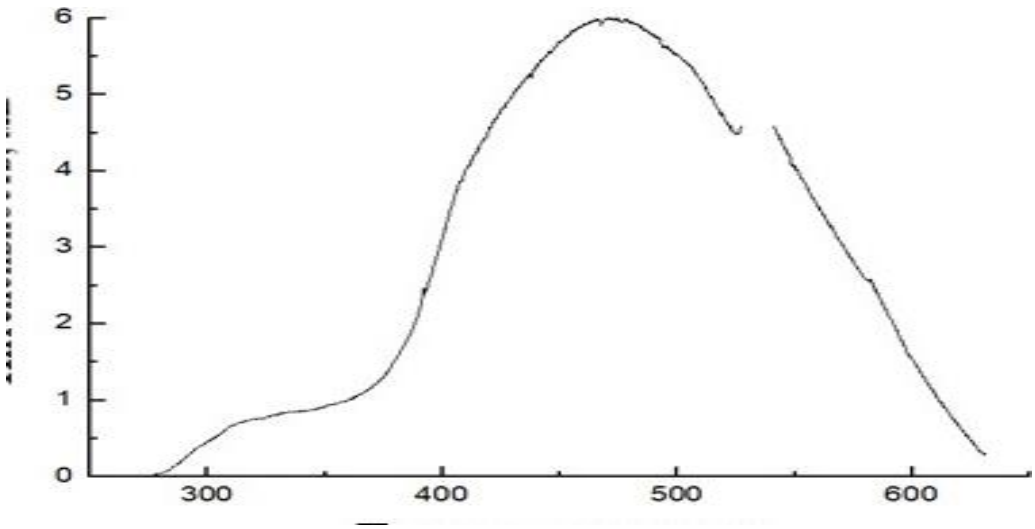

Figure 4 – Luminescence spectrum of NS due to the imidazole derivative FeO//SiO

Samples of composite nanoparticles of iron oxides (Fe_3O_4, γ- Fe_2O_3), suitable for the detection of fine defects in metal parts, were obtained. A defect was detected on the surface of the reference sample, confirming the possibility of using magnetic composite nanoparticles as a basis for penetrant.

CONCLUSION

Iron oxide nanoparticles (Fe_3O_4) were obtained by aging with different dispersions: from 20 to 110 nm. It was found that:

- with increasing concentration of initial reagents, the size of nanoparticles increases from 80 to 110 nm;

- by increasing the temperature control from 40 to 90 °C and reducing the synthesis time to 4 hours, the size of nanoparticles decreases to 40 nm;

-deposition in air (without foaming) leads to a size reduction of up to 20 nm.

The effect of the size of iron oxide nanoparticles on the coercive force of the resulting nanopowders was determined. Regularities were established for obtaining a $\boldsymbol{SiO_2}$ shell with a controlled thickness from 9 to 35 nm on the surface of iron oxide nanoparticles when changing the amount of the $\boldsymbol{SiO_2}$ shell precursor from 0.6 to 1.8 ml. It was found that the size of the nanoparticles does not have a significant effect on the thickness of the shell, all other conditions being equal. It was shown that when a shell is formed on the surface of iron oxide nanoparticles, the coercive force increases from 150 Oe for uncoated to 240 Oe for composite nanoparticles.

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