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Birefringence and dichroism in magnetic fluids with different aggregative stability

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In magnetic fluids, when exposed to a magnetic field, optical effects are observed: birefringence, dichroism, changes in optical density, change of the intensity of scattered light, and others. The nature of these effects depends on the particle size, size distribution, chemical composition, solid phase concentration, temperature, etc. Studying the influence of magnetic particle aggregates on optical effects that are sensitive to the polarization of light is important and interesting. The purpose of this study is to study the features of the effects of birefringence and dichroism in magnetic fluids with different aggregative stability.

We studied two magnetic fluids with magnetite nanoparticles in kerosene. Sample No. 1 was resistant to the formation of aggregates. The average radius of magnetite particles is 6.7 nm. Sample No. 2 was aggregatively unstable. The average radius of magnetite particles is slightly larger, around 13.7 nm. In sample No. 2, when exposed to a magnetic field of about 8 kA/m, aggregates with sizes of 60-80 nm are formed. In sample No. 1, no aggregates are formed in the same field. We examined samples of these magnetic fluids diluted to a volume concentration of 0.01%.

We studied dichroism and birefringence in the samples using the Ellipse-1891 spectral ellipsometric complex. The samples were placed in glass cuvettes 5 mm thick. The magnetic field was created by an electromagnet mounted on the object stage of an ellipsometer. We measured the ellipsometric parameters ψ and $\triangle$ in transmitted light. We also measured the dependence of these parameters on the wavelength of light and the magnetic field strength. Based on the ellipsometric parameters, we calculated the characteristics of birefringence and dichroism using the formulas:

$\triangle k = k_{\parallel} - k_{\perp} = \frac{\lambda}{2l\pi} \ln \tan \psi$

$\triangle n = n_{\parallel} - n_{\perp} = \frac{\lambda}{2l\pi} \triangle$

where $k_{\parallel}$ and $k_{\perp}$ are light attenuation coefficients, and $n_{\parallel}$ and $n_{\perp}$ are the refractive indices of light for rays polarized parallel and perpendicular to the field, λ is the wavelength of the incident light, l is the thickness of the magnetic fluid layer.

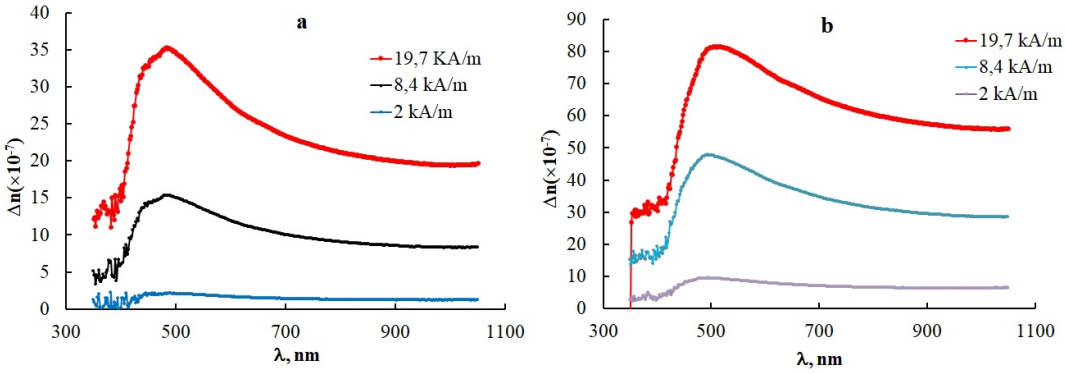

Figure 1: Fig. 1. Spectra of the birefringence effect in samples No. 1 (a) and No. 2 (b).

Figure 1 shows the birefringence spectra for the samples. Characteristic features of the spectra are the presence of a maximum of the birefringence effect at a wavelength of 490 nm, which becomes more pronounced with increasing magnetic field strength. The graph shows that in sample No. 2, which is less resistant to the formation of aggregates, the magnitude of the birefringence effect is 2.5 times greater than in sample No. 1.

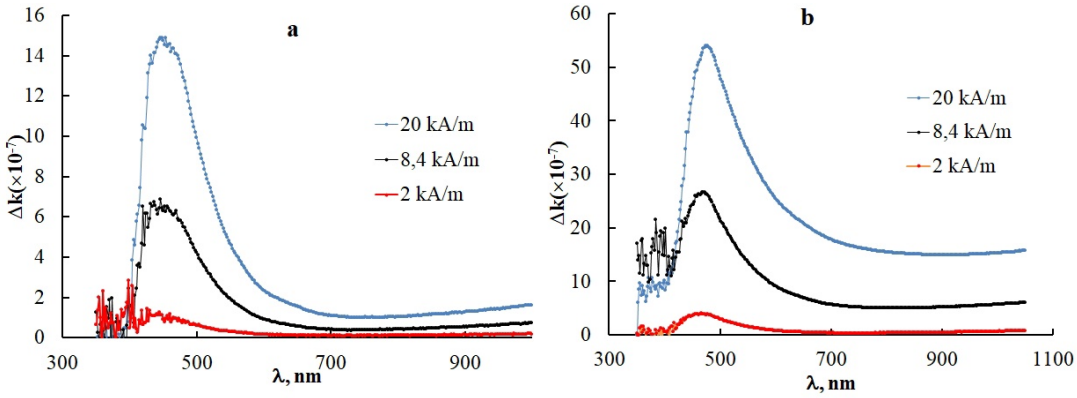

Figure 2: Fig. 2. Dichroism spectra in samples No. 1 (a) and No. 2 (b).

Figure 2 shows the dichroism spectra for the samples. The spectra have a pronounced maximum in the region of 470-480 nm and a minimum in the region of 740-750 nm. The action of a magnetic field changes the dichroism spectra. In sample No. 1, the effect of the field makes the minimum in the region of 750 nm more pronounced and increases the amplitude of the maximum in the short-wave region, and in sample No. 2, an increase in the field leads to an increase in dichroism in the near-IR region and the almost complete disappearance of the minimum in this region. The increase in dichroism in the long-wavelength region in sample No. 2 is much more significant than in the short-wavelength region.

We believe that the observed features of the birefringence and dichroism spectra depend on the presence of nanoparticle aggregates in the samples. This is especially noticeable in dichroism spectra. We believe the reason for this is the strong dependence of the light attenuation coefficient on particle size. Our estimates give the ratio of light attenuation cross sections for 14 nm and 70 nm particles as 1:270. Particle aggregation affects the birefringence spectra only slightly. The observed differences can be explained by different particle sizes in samples No. 1 and No. 2.

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