magnetization itself. Besides, the spectral dependences of magneto-optical effects are similar on the magnetic fluids and on the substance of particles. The experimental and theoretical results of the magnetite magnetic fluids are in good agreement.

We did analogous researches for Faraday rotation. When considering the magneto-optical effects, which are odd function of magnetization, in magnetic fluids, it should be kept in mind that magnetic fluid is a variety of the ultrafine media [3].

The magneto-optical properties of ultrafine media were analyzed in refs. [3, 4]. It was shown that when considering the magneto-optical properties of medium consisting of magnetic colloidal particles the sizes of which are much less than the light wavelength, one should introduce the tensor of the effective dielectric permittivity:

$$\varepsilon_{\text{eff}} = \begin{bmatrix} \varepsilon_{\text{eff}} & -i\varepsilon'_{\text{eff}} & 0 \\ i\varepsilon'_{\text{eff}} & \varepsilon_{\text{eff}} & 0 \\ 0 & 0 & \varepsilon_{0\text{eff}} \end{bmatrix} \quad (2)$$

where, $\varepsilon_{eff} = \varepsilon_{1eff} - i\varepsilon_{2eff}$, $\varepsilon_{0eff} = \varepsilon_{01eff} - i\varepsilon_{02eff}$ and $\varepsilon'_{eff} = \varepsilon'_{1eff} - i\varepsilon'_{2eff}$.

In this case, the tensor components depend on both the properties of magnetic colloidal particles themselves and the properties of the medium in which they find themselves.

Diagonal component of (2) is connected to reflective index n_{eff} and absorption index k_{eff} of ultrafine media by formula:

$$\varepsilon_{eff} = (n_{eff} - ik_{eff}) \quad (3)$$

For magnetic fluids with a low concentration of magnetic colloidal particles and consequently, with no interaction between them, the tensor components of the effective dielectric permittivity within the framework of the theoretical Maxwell-Garnett model of an effective medium can be written as:

$$\varepsilon_{eff} = \frac{2q(\varepsilon_m - \varepsilon_0) + (\varepsilon_m + 2\varepsilon_0)}{(\varepsilon_m + 2\varepsilon_0) - q(\varepsilon_m - \varepsilon_0)};$$

$$\varepsilon'_{\text{eff}} = \frac{9q\varepsilon_0^2\varepsilon'_m}{(\varepsilon_m(1-q) + \varepsilon_0(2+q))^2} \quad (4)$$

where $\varepsilon_m = \varepsilon_{1m} - i\varepsilon_{2m}$ and $\varepsilon'_m = \varepsilon'_{1m} - i\varepsilon'_{2m}$ are the diagonal and non-diagonal tensor components of the dielectric permittivity of the material of magnetic colloidal particles, ε_0 is the dielectric permittivity of the fluid phase, and q is the ratio of the volume, occupied by magnetic particles, to the total volume of the magnetic fluid.

In the research, the Faraday rotation is represented within the framework of the theoretical Maxwell-Garnett model.

The Faraday effect is related to the tensor components of the effective dielectric permittivity as follows [3]:

$$\alpha_F = \frac{\pi}{\lambda} \operatorname{Re} \frac{\varepsilon'_{ef}}{\varepsilon_{ef}^{1/2}} \quad (5)$$

where $\varepsilon_{ef} = \varepsilon_{1ef} - i\varepsilon_{2ef}$ and $\varepsilon'_{ef} = \varepsilon'_{1ef} - i\varepsilon'_{2ef}$.

In this case, considering the following relation $k^2 \prec\prec n^2$ and formula (3), Faraday rotation can be expressed in this way:

$$\alpha_F = \frac{\pi}{\lambda n_{ef}^2} (\varepsilon'_{1ef} n_{ef} + \varepsilon'_{2ef} k_{ef}) \quad (6)$$

Taking into account formulas (4) for real and imaginary parts of the tensor of the effective dielectric permittivity ε'_{ef} together with $k^2 \prec\prec n^2$ and $k_{eff}^2 \prec\prec n_{eff}^2$ formula (6) takes the form:

$$\alpha_F = \frac{\pi q n_0^2}{\lambda} \left[\frac{\varepsilon'_1 n_0 + 4yk\varepsilon'_2}{[y(n^2 - n_0^2) + n_0^2]^2} \right] \quad (7)$$

where, $y = \frac{1-q}{3}$ and n_0 is the reflective index of liquid carrier.

If $n_0 \approx n$, then

$$\alpha_F = \frac{\pi q}{\lambda n^2} [\varepsilon'_1 n + 4yk\varepsilon'_2] \quad (8)$$

Note that we have the following correlation: when $q \prec 0.4$, then $4y \approx 1$. Thus the expression for the Faraday rotation could be written down in the simpler way:

$$\alpha_F(q) = q\alpha_{FM} \quad (9)$$

where, $\alpha_F(q)$ is Faraday rotation for magnetic fluids with the ratio of the volume occupied by magnetic particles q; α_{FM} - Faraday rotation on the material of particles.

It is necessary to say that received results (9) represent truth if only these two conditions are followed: 1) $k^2 \prec\prec n^2$; 2) $n_0 \approx n$.

It follows from the relation obtained that in the specific experimental conditions the amount of Faraday effect is proportional to q and therefore on magnetization itself. Also, the character of spectral dependences of magneto-optical effects, are similar for the magnetic fluids and the substance of particles.

It is well-known that magneto-optical figure of merit F is introduced to draw a comparison between magneto-optical materials. The former is the ratio of twice specific Faraday rotation to the absorption coefficient of the material:

$$F = 2\alpha_F / K \quad (10)$$

Within the framework of the theoretical Maxwell-Garnett model in order to find the link between k and k_{ef} we discuss the formula for imaginary parts of the diagonal components of the tensor of effective dielectric permittivity written in the following way:

$$\varepsilon_{2ef} = q\frac{\varepsilon_2\varepsilon_0^2}{[y(\varepsilon_1-\varepsilon_0)+\varepsilon_0]^2+(y\varepsilon_2)^2} \qquad (11)$$

when $k^2 \prec\prec n^2$ and $\varepsilon_0 \approx \varepsilon_1$ from (11) we can derive a simple relation:

$$k_{ef} = qk \qquad (12)$$

The absorption indicators of the discussed medium k_{ef} and k are linked to natural (decimal) absorption coefficient K_{ef} and K with the formula

$$k_{ef} = \lambda K_{ef}/4\pi\ ,\ k=\lambda K/4\pi \qquad (13)$$

Thus formula (12) could be put as following:

$$K_{ef} = qK \qquad (14)$$

From (11) and (13) formula come:

$$\frac{\alpha_F(q)}{K_{ef}} = \frac{\alpha_{FM}}{K} \qquad (15)$$

As $1/K_{ef} = l_{ef}$ and $1/K = l$ characterise the depth of permeability of light in the medium, we can conclude from the formula (5) that the amounts of Faraday rotation in ultrafine medium and in subsequent bulk magnetic measured in thickness are equal. In the case of $k^2 \prec\prec n^2$ the amounts of magneto-optical figure of merit in the ultrafine medium and bulk magnetic are equal.

3 Results and discussion

Fig. 1 represents the results of calculations of $\alpha_F(q)$ made by means of the formula (5) for magnetite particles in the air (a) and in the liquid silicon-organic compound (b), and by the formula (9) (c). Calculations were carried out for different q. From the fig.1 it is obvious that the magneto-optical maxima for magnetite particles shift to the side of large energies. If we increase ε_0, this shift diminishes, and for the liquid silicon-organic compound ($\varepsilon_0 = 2,56$) the shift approximates to the zero. The results derived from our research indicate that calculations conducted according to (5) for large ε_0 ($\varepsilon_0 = 2,56$), coincide with the calculations carried out by the simplified formula (9).

We did analogous calculations using formula (5) and formula (9) for magnetite particles in order to verify the linear dependence of Faraday rotation on q. Fig. 2 shows the correlations of Faraday rotation to q for magnetite particles, which are calculated by formula (5) and (9) at the quantum energy of incident light $\hbar\omega = 1,7\ eV$.

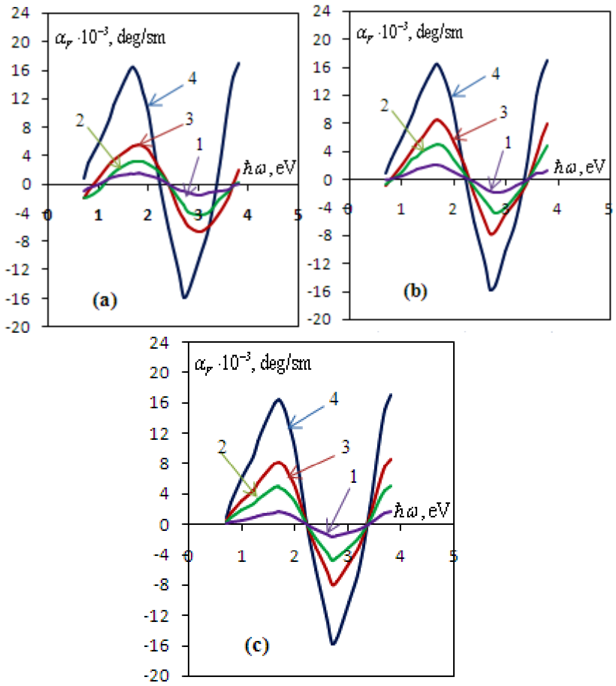

Fig. 1. Dependences of the Faraday rotation on the quantum energy of incident light $\hbar\omega$, calculated by formula (5) for magnetite particles in the air (a) and in the liquid silicon-organic compound (b), and by the formula (9) (c) with q =0,1(1); 0,3(2); 0,5(3); 1(4).

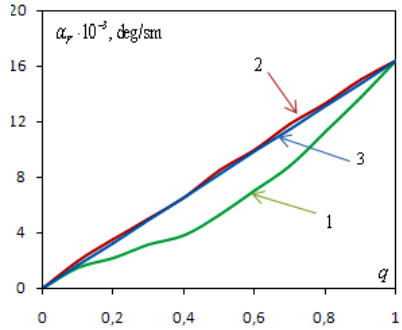

Fig. 2. Dependences of the Faraday rotation on q, calculated by formula(5) for magnetite particles in the air (1) and in the liquid silicon-organic compound (2), and by the formula (9) (3) at $\hbar\omega = 1,7\ eV$.

From the fig. 2 it is obvious that the linear dependences of Faraday rotation on q have been observed only for large ε_0 ($\varepsilon_0 = 2,56$).

Our results are in a good relation with the experiments [5], where Faraday rotation has been studied in magnetite magnetic fluids with different concentrations.

4 Conclusions

In the present paper, on the example of magnetite magnetic fluids we considered Faraday rotation in magnetic fluids based on particles of magnetic oxides.

Within the framework of the theoretical Maxwell-Garnett model the simple relation between the Faraday rotation for ultra-fine medium and bulk material is revealed. The conditions of the magneto-optical experiment were defined for the essential analytical simplification of the subsequently received results.

In conclusion, we would like to underline that this result are expected to be suitable to all magnetic ultrafine medium with the same relation between optical constants: $k^2 \prec\prec n^2$.

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