INFLUENCE OF THE SIZE, SHAPE AND CONCENTRATION OF MAGNETIC PARTICLES ON THE OPTICAL PROPERTIES OF NANO NICKEL THIN FILMS

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Abstract. In the present paper, using the discontinuous Ni films as examples we consider theoretically and experimentally the influence of the structural parameters on the optical properties of the ultrafine structures. The optical spectra strongly depend on composition and dielectric constants of particles and matrix. In its turn the dielectric constants are functions of the structural and electronic parameters and can differ from those for corresponding bulk materials. Thus optical spectra investigations can give very useful information about structural parameters of the ultrafine structures. The behavior of the optical spectra of thin Ni films was explained in the framework of the effective medium approximation. These calculations proved a good agreement between the experimental and the theoretical results.

1. Introduction

It is known that the qualities of already explored materials change in the process of their transformation into nanocrystals. This was predictable because these structures contain from some atoms to thousands of atoms and take a middle place between atoms and massive substances, and subsequently, they have properties different from both of them. Consequently, they acquire the set of particular qualities, such as: giant magnetoresistance, giant magneto-impedance, anomalous Hall effect, anomalous optical and magneto-optical effects [1- 3] and etc.

In general, the optical properties of nano-dispersive structures are very different from the properties of the bulk materials and depend on the structural parameters: the occupancy of the volume of the ultrafine medium with nanoparticles (*q*), the size and shape of the particles (f), the order of the particles, the properties of the medium, surrounding nanoparticles (ε_m) [4-7].

In this paper we present theoretically and experimentally the influence of the structural parameters on the optical properties of the nano-dispersive nickel. We interpret the obtained optical spectra in the framework of the effective medium approximation [8].

2. Theory

We have modified the Maxwell-Garnett effective-medium theory to study nano-dispersive medium with optically anisotropic particles (ellipsoids). After generalization of the Maxwell-Garnett theory for nano-dispersive structure which composed of ellipsoidal particles with different dielectric permittivity $\varepsilon_i (i = 1, 2, 3 \cdots, n)$ and matrix with dielectric permittivity ε_m we arrived at formula how to calculate diagonal elements of the dielectric tensor for non-spherical ultrafine particles.

$$\frac{\varepsilon_{ef} - \varepsilon_m}{\varepsilon_m + f(\varepsilon_{ef} - \varepsilon_m)} = q \frac{\varepsilon - \varepsilon_m}{\varepsilon_m + f(\varepsilon - \varepsilon_m)} \tag{1}$$

Where ε_{ef} is effective dielectric permittivity of nano-dispersive structure, q is the ratio of the volume, occupied by particles, to the total volume of the medium and f is the factor of the shape of the ultrafine particles.

The effective dielectric permittivity $\varepsilon_{eff} = \varepsilon_{1eff} - i\varepsilon_{2eff}$ is connected to reflective index n_{eff} and absorption index k_{eff} of nano-dispersive medium by formula

$$\varepsilon_{ef} = (n_{ef} + ik_{ef})^2 \tag{2}$$

3. Experimental

In this work we investigate the optical properties of discontinuous nickel films, the weight thickness d ($d = m / \rho S$, where m -film mass, ρ -metal density and S -film square) of which falls within the interval 4.8-30 nm. Discontinuous films were obtained by evaporation in vacuum of 10^{-5} Torr on glass substrates with a rate of 1 to 5 $\overset{0}{A}$/S. The optical constants were determined using the Avery method [9].

4. Results and discussion

Fig. 1 gives the dependences of optical constants on $\hbar\omega$, calculated for nano-dispersive nickel as given in eqns.(3) and (2). Note that n_m is reflective index of matrix.

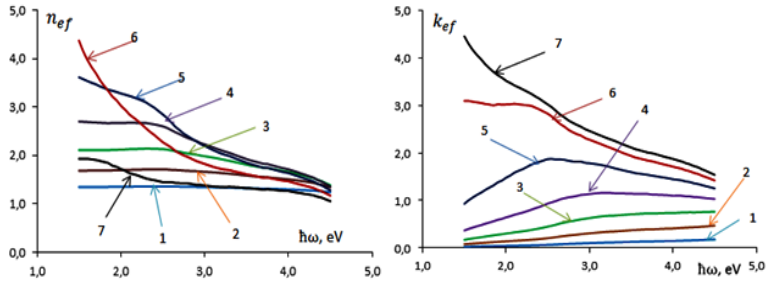

Fig. 1. Dependences of the equatorial Kerr effect on $\hbar\omega$ for ultrafine nickel, calculated by formulas (3) and (2) with q=0,1(1); 0,25 (2); 0,4 (3); 0,55 (4); 0,7 (5); 0,85 (6); 1,0 (7) and n_m=1.15; $f=1/3$.

Comparing experimental results with the theoretical results of fig. 1, we observe that the spectra of the optical constants with weight thicknesses $d = 4.8 - 30$ nm are similar to the spectra computed with different q =0,1-0,85. We have also calculated the dependences of n_{eff} and k_{eff} on the quantum energy of incident light $\hbar\omega$, for nano-dispersive nickel with different n_m. It is evident from the results of these calculations that the optical spectra of nano-dispersive medium strongly depend on the volume fraction of magnetic particles, shape of the particles and dielectric constants of matrix.

Conclusions

The behavior of the optical spectra of thin Ni films was explained in the framework of the effective medium approximation in two cases: q<0.5 and 0.5< q<1. In this approach effective refractive index (n+ik) of the nano-dispersive structures have calculated as a function of the ε_m, q, and particle shapes. Moreover, the experimentally derived data are well compatible with the above discussed theory.

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