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Optical characteristics of Al_2O_3 oxide coatings on copper mirrors made by diamond microgrinding

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Abstract. Ellipsomety examination of dielectric sheetings and measured of reflection spectrum at normal incidence there carried out. A film of Al_2O_3 on a surface of copper mirrors of a diamond microgrinding was deposited. The thickness and index of refraction of coatings are determined.

Keywords: reflectivity, parameters of ellipsomerty, index of refraction, copper mirrors, aluminium oxide, diamond microgrinding.

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The basic elements of modern optical technics are reflecting components. Most useful are metall mirrors [1], because they withstand thermal and deformation action. They do not have hromatic abberation and permit to optimize the size of devises [2]. The important case is the situation when using of reflecting surfaces stipulated on technical requiriments. The copper mirrors are widely aplied in IR specrum range, like reflectors in resonators to the laser on CO_2 with wavelength of generation $\lambda = 10.6$ μm. Often the surfaces are exposed to negative exterior influences (mechanical, chemical, light etc). For this reason, mirrors protection from aggressive factors is urgency. The optimal solution of this problem is depositing protective layers on the reflection surface [3]. In addition, correctly calculated thickness and material of a film can provide increasing of reflection in a desired spectrum range.

Dielectric Al_2O_3 coating deposited on copper mirrors prepared by the method of diamond microgrinding was studied in our work. Such combination of materials can ensure the high reflectivity combined with mechanical strength and good heat removal (it is very important in high power technics). The aim of the work was development of the precise method for determining main parameters of a reflecting system and their optimization for specific requirements. Whereas measurement of only reflection spectrum do not give the necessary information, therefore we used a procedure of ellipsometry. Helped us to get necessary dependence of reflection coefficient, index of refraction of coating and substrate, thickness of deposited layer with the highest accuracy.

For achievement of reflectivity increasing we studied the wavelength dependings of reflection coeffecient R(l) in wide spectrum range, for samples with different thickness of coating. We measured 12 initial samples. They were copper substrate on which layer of oxide aluminium was deposited by electron beam method. The predicted thickness of coating was from 200 to 300 nm. It was controled by quartz thickness measurer. Experimental equipment was created on the spectrofotometer SF8 with hydrogen lamp or tungsten lamp. Recording of reflectivity $R(\lambda)$ was carried on wavelenght 0.2–2.5 μm. Obtained results associated with etalons [4,5,6] represented on Fig. 1, also show curve for massive copper without coating. For samples with protective layer we observed increasing of mirror reflectivity on certain wavelengths, which is obvious compared to etalon mirror. From the Maxwell formula, according to [7], maximum of the realized reflection satisfies the conditions of the phase shift due to lightwave reflection on the interfaces environment-coa-

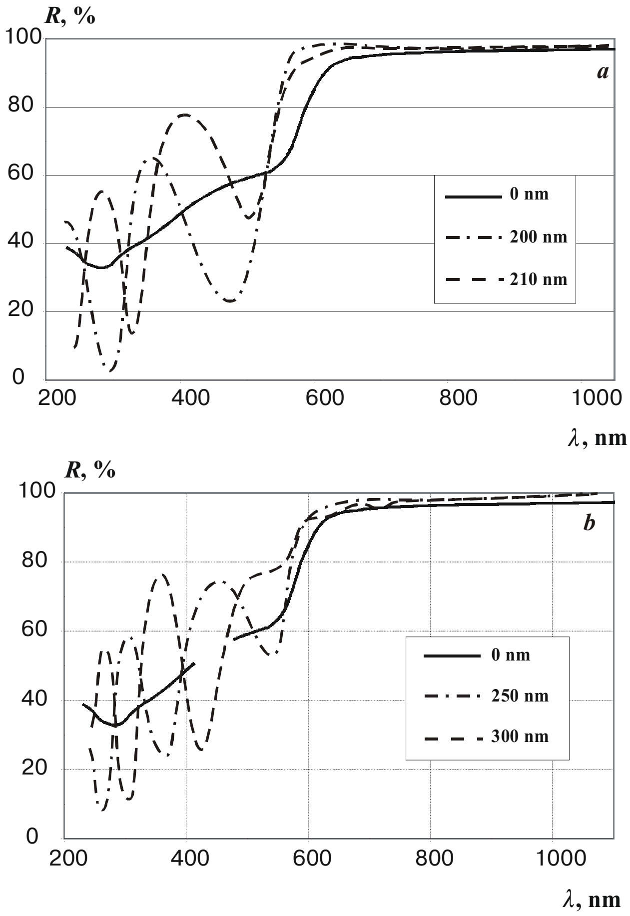

Fig. 1. Reflection spectrums of copper mirrors with a sheeting from Al_2O_3. The thickness of a coating (in nanometers) is indicated on the graph.

ting and coating-substrate. It was determined by the formula:

$$\Phi^{\max} = \frac{4\pi dn}{\lambda} + \Delta\Phi = 2k\pi \qquad (1)$$

were n, d – index of refraction and thickness of oxide aluminium layer, λ – wavelength, $\Delta\Phi$ – summary shift of phase due to reflection on interfaces, $k = 1,2,3\ldots$ – order of interference. Correspondingly, the minimum of reflection was determined by the formula:

$$\Phi^{\min} = \frac{4\pi dn}{\lambda} + \Delta\Phi = 2(k + \frac{1}{2})\pi \qquad (2)$$

According to calculations, the dispersion of refraction index of coating in given spectrum range, neglible small, i.e. it is constant, independent on wavelength.

We found the conditions that allow changing reflectivity in dependency on system parameters, for example the thickness of a dielectric coating.

However, the problem of determination of the coating thickness and the refraction index of aluminium oxide, remains unsolved. We used the method of ellipsometry to solve of this problem. It is based on mathematical apparatus deduced from the Fresnel formula [8, 9] for light reflected from the metall surface. The background for the method of ellipsometry is the basic equation of ellipsometry containing a ratio of complex reflectivities in two planes: the plane of incidence (p-component) and normal to it (s- component). Its ratio

$$tg(\psi)e^{i\Delta} = R_s / R_p \qquad (3)$$

where $tg(\psi)$ – ellipticity, Δ – shift of phases, R_P and R_S – amplitude reflectivities for p- and s- components elliptically polarized light reflected from a metal. The principal angle Φ is the angle at which $\Delta = \pi/2$. The dependence of ellipticity $tg(\psi)$ on Φ is very obvious and informative. The important advantage (except the highest exactness) of the ellipsometry method is that the measuring of the ratio of complex reflectivities does not require establishing the incident light intensity and do not require the etalon unlike reflection dependence measurement. Unfortunaly, equations for dependence between optical parameters and available measurable data are nonlinear and transcedental. Therefore, mathematical simulation for model of semi-infinite substrate medium was used [10].

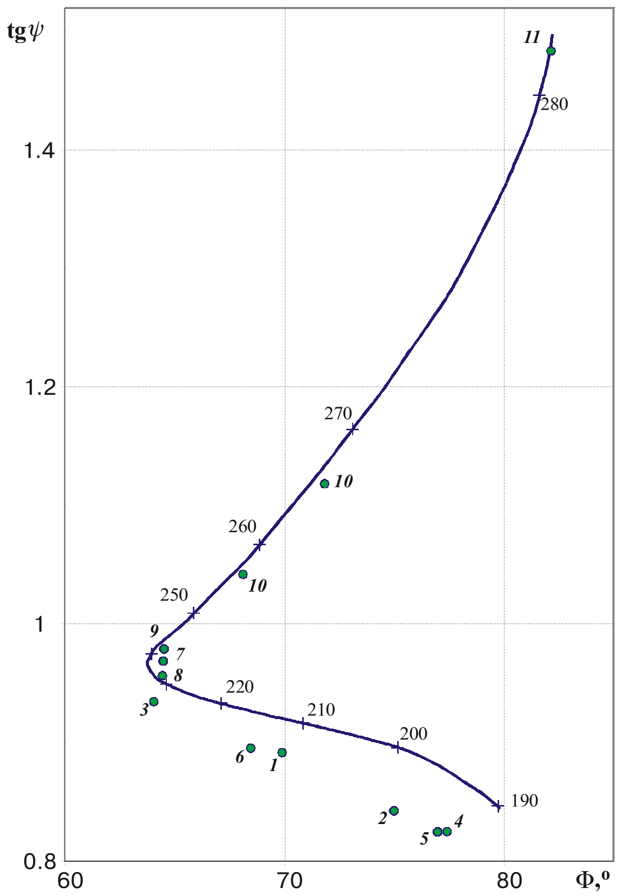

Fig. 2. Magnitudes of a principal angle Φ and ellipticity $tg\psi$ of copper mirrors with a coating. The circles show experimental data for relevant samples, the continuous curve corresponds to theoretical evaluations. The cuts on a curve give thickness of coatings in nanometers.

The measurement and calculation results are represented in Fig. 2. Circles denotes experimental results for corresponding samples and curves – theoretical calculations. Cuts on block curve desingnate thickness of stratum in nanometers. Observed deviation are explained by changing the optical parameters of transition layer between the oxide film and copper substrate in accord with the theoretical model. Using the ellipsometry method we calculated the thickness of the protective film as well as refraction indexes for all components of the reflective system (oxide film, transition layer and metall mirror). For Al_2O_3, it is equal to $n = 1.7$ with wavelength depended uncertainty close to 2 %. It can be also calculated using the reflection spectrum analysis, but accuracy is too small in comparatively with the ellipsometry method.

Thus, optimal method that allow effectively control parameters requirement for increasing (or decreasing) reflectivity was developed. Especially important is the best precision of determined values of basic optical constants.

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