REFLECTIONLESS ABSORPTION OF ELECTROMAGNETIC RADIATION IN OPTICAL MEDIA

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ABSTRACT

The existence of reflectionless absorption for resonance type dispersion frequency range of incidence radiation in the system of dielectric-metal is established. This phenomenon takes place under strictly determined radiation frequency and layer length. Calculations for these selective quantities and also for selective absorption bandwidth of wave were done for layer of rhodamine dye molecules.

Keywords: antireflection coatings, resonance dispersion, optical reflection, thin films.

I.INTRODUCTION

Thin films are used to reduce the reflectance of an electromagnetic radiation of wavelengths from the ultraviolet to the microwave [1,2]. They can have either discrete or graded layers with different refractive indices. Thin film antireflection coatings are commonly applied to lenses , solar ceels, lasers, fiber optic components and on more exotic applications.It is of interest the study of electromagnetic wave propagation in layered systems also to understand physical processes in distributed feedback lasers, in nanosize structures and photonic crystals [3-5].

Analysis of electromagnetic radiation interaction in layered systems is quite complex. This problem was solved for trasparent layered structures or for absorbing layer in metallic substrate or semi-infinite non- absorbing substrate [6,7].

In this paper in the optical range of wavelength the reflection of normal incident plane polarized light in absorbing dielectric covered by metal substrate have been investigated.

II.THEORY

For given two layered system the complex reflection coefficient is well known

$$\hat{R}=\frac{\hat{r}_1+\hat{r}_2\exp(2ikl)}{1+\hat{r}_1\hat{r}_2\exp(2ikl)} \qquad (1)$$

where $\hat{r}_1=(n_1-\hat{n})/(n_1+\hat{n})$, $\hat{r}_2=(\hat{n}-n_2)/(\hat{n}+n_2)$ are the ratios of reflected waves amplitude to the incident; $\hat{n}$ is complex refractive indice of the absorbing layer; n_1, n_2 are refractive indices of the medium indicence and the substrate; ℓ is the physical thickness of the layer.

In (1) wave number k is complex quantity

$$\mathrm{k}=\frac{2\pi}{\lambda}(n-i\chi)=\frac{2\pi n}{\lambda}(1-iy) \qquad (2)$$

where λ is wavelength of incidence radiation, $\mathrm{y}=\chi/n$, χ is the absorption coefficient which is a measure of the energy absorption.

In [6-8] the conditions of reflectionless absorption of electromagnetic radiation in dielectric layer covered by metal substrate were found. For the selective quantities of coating n and χ were obtained

$$y=\frac{\ln(1/r_1)}{\pi(2N-1)-\varphi} \qquad (3)$$

where $r_1=\sqrt{\frac{(1-n)^2+\chi^2}{(1+n)^2+\chi^2}}$, $\varphi=arctg\frac{2\chi}{1-n^2-\chi^2}$

reflection coefficient and phase factor for incident interface.

It is known that the optical parameters of coating n and χ in (3) may be expressed by ε' real and ε'' imaginary parts of dielectric constant .

$$\varepsilon'=n^2-\chi^2 \quad ,\varepsilon''=2n\chi \qquad (4)$$

Reflectionless absorption of radiation in dielectric of thickness l_0 takes place for minimum number N in the reflection coefficient dependence on thickness of layer when reflection coefficient is equal to zero.

For to have reflectionless absorption the thickness l_0 may be determine from next equation

$$\frac{l_0}{\lambda} = \frac{1}{n}\left(\frac{2N-1}{4} + \Delta\right) \qquad (5)$$

where $\Delta = -\varphi / 4\pi$.

To calculate the selective quantities λ_0, ℓ_0 it is necessary to know absorption spectrum of the coating material [6,9].

From the dispersion formula for optical frequencies we have

$$\varepsilon' = n_\infty^2 + \frac{4\pi N_0 q^2}{m} \cdot \frac{\omega_1^2 - \omega^2}{\left(\omega_1^2 - \omega^2\right)^2 + \gamma^2\omega^2} \quad ,$$

$$\varepsilon'' = \frac{4\pi N_0 q^2}{m} \cdot \frac{\gamma\omega}{\left(\omega_1^2 - \omega^2\right)^2 + \gamma^2\omega^2} \qquad (6)$$

where n_∞ is indice for far from the resonance frequency; q , m are charge and mass of electron; N_0 is concentration; γ is damping constant; ω is angular frequency [2].

For condenced medium resonance frequency ω_1 in (6) is connected with ω_0 in the following way

$$\omega_1^2 = \omega_0^2 - \frac{4\pi N_0 q^2}{m} \qquad (7)$$

Resonance dispersion, as rule, takes place in the vicinity of a resonance frequency ω_1. That is why for dependence ε''on ε' in this approach may be obtained equation of circle with radius $R = \frac{2\pi N_0 q^2}{m\omega_1\gamma}$, which centered at point (n_∞^2,R)

$$\left(\varepsilon' - n_\infty^2\right)^2 + \left(\varepsilon'' - R\right)^2 = R^2 \qquad (8)$$

Equations (3) and (8) have been used to determine selective quantities of the coating parameters which takes place total absorption of incident radiation.Then from equation (5) one can determine the selective quantity of coating thickness. Calculations were made for optical frequencies to obtain total absorption in coating material which consist of dye solutions of rhodamine having different concentrations.

Dependences ε'' on ε' as two family of curves have been represented in Fig. Curves a have been obtained accordingly to equations (3) and (4).Results of equation (8) present as curves b.Coordinates of the crossing points of this curves ε'' and ε' are selective quantities.Then using these quatities of ε'' and ε' we can find selective thickness l_0 of coating and wavelength λ_0 for given material.

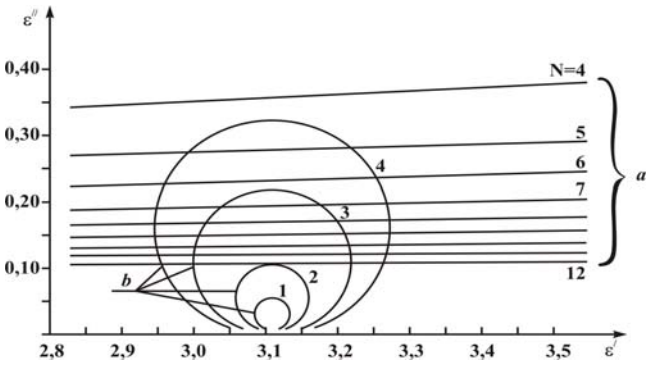

Fig. Dependece ε'' on ε' for antireflection coating.

a) for antireflection absorption of light; N is number of minimum in dependence of reflected radiation amplitude on thickness of material.

b) resonance dispersion of rhodamine dye molecules solution for concentrations 1(1), 2(2),4(3),6(4) $\cdot 10^{21} 1/см^3$.

III. CONCLUSIONS

Electromagnetic radiation reflection in dielectric layer covered by metal substrate in the optical wavelength range have been investigated.The existence of reflectionless absorption for resonance type dispersion frequency range of incidence radiation in the system of dielectric-metal is established. This phenomenon takes place under strictly determined radiation frequency and layer length. Calculations for these selective quantities and also for selective absorption bandwidth of wave were done for layer of rhodamine dye molecules.It is shown that total absorption of optical radiation in considered coating materials takes place if its thickness is a quarter of wavelength multiple by five and more.

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