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Letter to the Editor

An explanation of the untypical dependence of the refractive index upon the thickness of very thin ytterbium oxide layers on chromium*

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In the previous paper [1] the refractive index of the ytterbium oxide layers obtained by thermal evaporating on the substrate of opaque chromium layers has been determined. Then, an increase in refractive index of Yb_2O_3 layers with the diminishing of their thickness has been observed. The untypical character of the n versus d dependence discovered in [1] may be explained by the presence of a thin chromium oxide layer situated between Cr and Yb_2O_3.

The ytterbium oxide layers have been produced by electron gun on the opaque chromium layers used as the substrates. To determine the refractive index and thickness of the ytterbium oxide layers an ellipsometric method due to Shklyarevskii [2] has been employed. This method requires the determination of ellipsometric angles of the Cr substrate $-$ Yb_2O_3 layer system and the optical constants n_3, k_3 of the substrate. The ellipsometric angles were measured with an ellipsometer of El-6 type of Archer's system [3]. The optical constants of the substrate have been calculated from ellipsometric angle measurements performed earlier for the layers of pure chromium on the substrate of BK-7 glass. The refractive index and the thickness of the ytterbium oxide layers have been determined by graphic Shklyarevskii's method described in [1]. In many typical dielectrics, for instance in ZnS, CdS, and cryolit, the refractive index decreases with the decrease of the layer thickness [2, 4, 5]. On the contrary the ytterbium oxide layers show an increase of the refractive index with the decreasing layers thickness. In order to explain this untypical dependence of the refractive index upon the thickness it has been assumed that the layer examined may be represented as a set consisting of metallic substrate Cr, chromium oxide layer and ytterbium oxide layer (fig.). Given: the optical constants of the substrate n_3 and k_3, the refractive index

$n_1,\ k_1 = 0,\ d_1$	1
$n_2,\ k_2 = 0,\ d_2$	2
$n_3 - ik_3$	3
glass BK-7	4

Figure. Assumed model of the examined layer: 1 — ytterbium oxide layer, 2 — chromium oxide layer, 3 — chromium layer, 4 — glass BK-7

n_2 of the chromium oxide layer and its thickness d_2, the refractive index of the ytterbium oxide layers n_1 and the refractive layer thickness d_1, we may calculate the ellipsometric angles Δ and Ψ for such a system [6].

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In accordance with the literature [7, 8] it has been assumed that the intermediate layer of chromium oxide may have two different values of the refractive index and two different thicknesses. The calculations have been performed for four possible combinations of refractive index and the chromium oxide layer thickness, namely: $n_2 = 2.33$, $d_2 = 5$ nm; $n_2 = 2.23$, $d_2 = 2$ nm; $n_2 = 2.55$, $d_2 = 2$nm; $n_2 = 2.55$, $d_2 = 5$ nm. For the calculations the value of the refractive index of the ytterbium oxide has been taken to be the same as that of the Yb_2O_3 layers of thickness above 20 nm, i.e. $n_1 = 1.85$ [9]. By comparing the calculated

Table

A comparison of the ellipsometric angles for layers of ytterbium oxide and different thicknes measured experimentally with those calculated under assumption of a model of double layer (wavelength $\lambda = 550$nm, incidence angle $\varphi = 70°$)

Thickness of Yb_2O_3 [nm]	Δ_{exp}	Δ_{calc}	Ψ_{exp}	Ψ_{calc}
3.5	98°25′	94°48	23°26′	23°52
7.8	90°25	93°48	25°10	24°00
8.5	88°57	87°13	25°24	25°34
9.0	92°18	91°50	25°12	23°37
14.0	84°40	79°53	27°28	27°29

ellipsometric angles (table) of the accepted model with those measured experimentally it is easy to note that the best agreement has been obtained for the system with the chromium oxide layer of 2.55 refractive index and 5 nm thickness (table). On the base of such comparison it was shown that the assumed model of the layer examined seems to be satisfactory.

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