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# The influence of the substrate temperature on optical constants for chromium layer in visible spectral range*

Elżbieta Idczak, Lucyna Rachwalska

Institute of Physics, Technical University of Wrocław, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland.

In the paper the dependence of optical constants of chromium layers upon the substrate temperature was examined. The chromium layers were obtained by the method of vacuum evaporation. Optical constants were measured within the visible range of the spectrum by ellipsometric method. In calculations of the optical constants the existence of the intrinsic oxide on the chromium layer has been encountered. The differences in the values of refractive index and absorption index for layers obtained at different temperatures seem to be associated with the more perfect structure of the crystal layers.

## 1. Introduction

The examinations of the thermal oxidation process occurring on the chromium layers obtained by vacuum evaporation [1] have shown that the thickness and refractive index of the growing oxide layer can be determined ellipsometrically for the layers oxidized in the oxide atmosphere and in the air at temperature of 673 K and that these parameters become undeterminable at the oxidation temperature equal to 873 K.

This fact provoked detailed examinations of the dependence of optical constants of the chromium layers obtained in our lab upon the substrate temperature.

## 2. The production of chromium layers and the calculation of their optical constants

The chromium layers were obtained in a NA 500 vacuum unit (produced by the Vacuum Equipment Works in Bolesławiec, Poland). The original material was a spectrally pure chromium of IMC 703 production. The layers were evaporated from the tungsten basket in vacumm of order of $1.33 \cdot 10^{-4}$ Pa ($10^{-6}$ Tr) onto polished quartz plates. The substrates were heated by a special heater, the temperature being measured by a Pt-Pt-Rh thermo-couple. The substrate temperature might be regulated from 308 K to 873 K.

Our observations [2], being consistent with those of other authors [3, 4] have shown that the flux of molecular chromium exhibits some gettering pro-

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perties. This phenomenon has been exploited in production of the layers. The first portions of chromium were deposited on the diaphragm covering the substrate. When the vacuum reached about $1.33 \cdot 10^{-5}$ Pa ($10^{-7}$ Tr) the diaphragm was removed and the chromium deposition process begun. The process was finished when the chromium contained in the heater was not entirely evaporated. This trick allows to obtain more pure chromium layers, which is, at least, free from both easily and difficult melting imperfections. A similar technology was applied in [4].

The chromium layers exhibit high adhesion to quartz and glass substrates, particularly when the chromoium is deposited on heated substrates. This property allows to use them as the intermediate layers when producing the layers of materials of low adhesion to the substrate.

The layer deposition rate was determined by measuring the evaporation time and the thickness of the layers obtained. The thickness measured by the interference method amounted to 150–200 nm. The chromium layers were evaporated at the rate of 1 nm/s. The optical constants of the examined layers were measured in the visible spectrum range by the ellipsometric method [5, 6]. The measurements were performed in the air room temperature for two rays of different incidence angles (65°, 70°). Next the mean values of optical constants were calculated.

It is well-known from the literature [7, 8] that a passive oxide layer that appears on the chromium layer surface is 1.5–5 nm thick. When calculating the optical constants by the successive approximation method this passive oxide layers is taken into considerations. In the calculations the value of the refractive index was assumed to be 2.55, while its thickness — 2 nm.

## 3. Dependence of the optical constants for chromium layers upon the substrate temperature

The examined chromium layers, practically of the same thickness (150–200 nm), were produced with a constant rate (1 nm/s) on the quartz substrates at different temperatures. The measured temperature of substarte ranged from 308 K to 873 K.

The results of examinations have shown that when the substrates were not heated additionally or when their temperature was not too high (of order of 473 K) the optical constants of chromium layers were little sensitive to the substrate temperature. On the other hand, for the substrate temperatures of order of 573 K to 673 K and higher a distinct influence of the substrate temperature on the optical constants of obtained chromium layers is observed, whereby both the refractive index and the absorption index increase with the increase of the substrate temperature (fig. 1).

The above values were taken from the literature [7, 8] but are attributed to the chromium layers deposited on the unheated substrates. So far passive

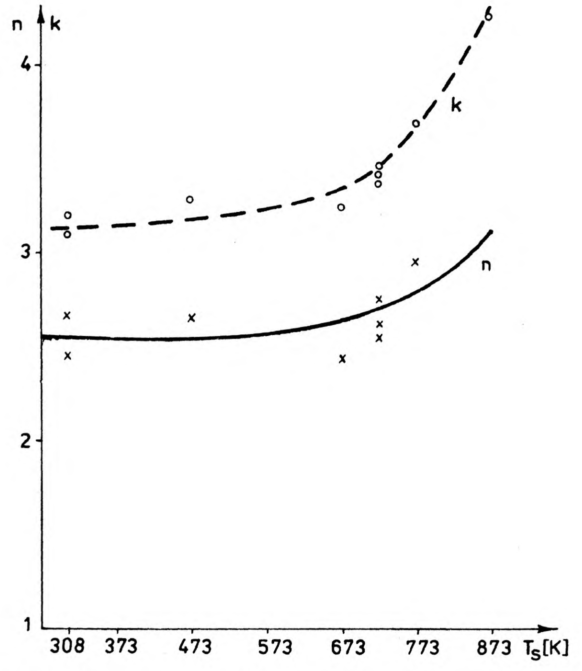


Fig. 1. Dependence of the optical constants of chromium layers on the substrate temperature at the moment of their deposition ($\lambda = 550$ nm, $\nu = 1$ nm/s)

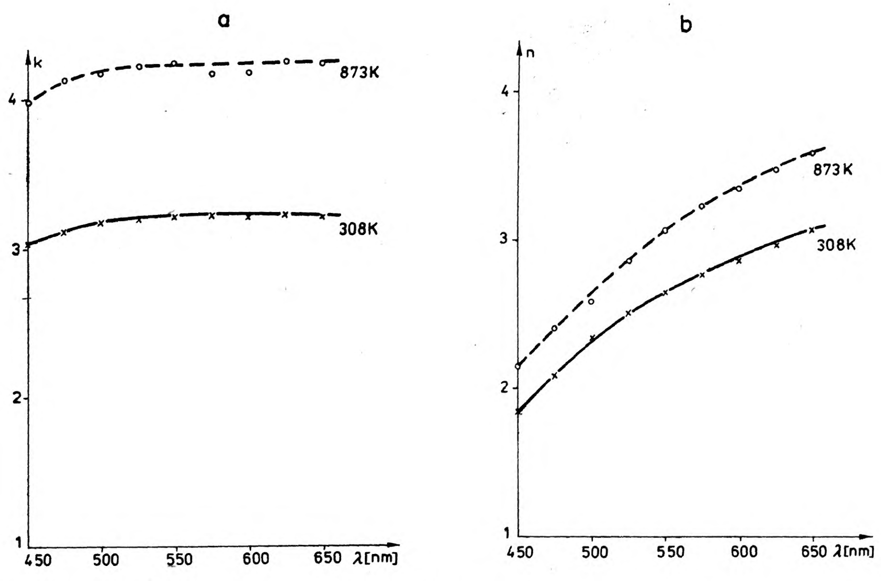


Fig. 2.a. Spectral dependence of chromium layer refractive index for visible spectrum region (solid line — substrate temperature 308 K, broken line — substrate temperature **873 K**, $\nu = 1$ nm/s). b. Spectral dependence of the absorption index for chromium layers in visible spectrum range (solid line — substrate temperature 308 K, broken line — substrate temperature 873 K, $\nu = 1$ nm/s)

chromium oxide layers on the chromium layers deposited on the heated substrates have not been investigated, while our layers were evaporated also on the substrates heated up to the temperature of 873 K. Thus it may be assumed that in our work the values of optical constants, at least, for layers on the substrates of higher temperature (673–873 K), may be slightly lowered because the exact value of the thickness of the oxide layer appearing under these conditions in not known.

The spectral dependence of optical constant for visible spectrum region is shown in fig. 2. Solid line corresponds to chromium layers produced on the substrate not heated additionally, while the broken line represents the layers deposited on the substrate of temperature of 873 K. As it follows from the graph both the refractive index and the absorption coefficient for layers deposited on substrates at 873 K temperature are higher than for the layers deposited on unheated substrate.

The measurements of specific conductivity [6] have shown that it is also greater for layers produced on the substrate at temperature of 873 K than at 308 K. This indicates a more perfect crystal structure of these layers. The chromium layers obtained by us on substrate heated to the temperature ranging within 573–873 K have probably more perfect crystal structure than the layers evaporated on the substrates unheated additionally.

## References

[1] IDCZAK E., OLESZKIEWICZ E., Optika i Spektr. (Moskva—Leningrad), in press.
[2] IDCZAK E., Optika i Spektr. **15** (1963), 107.
[3] MIKHAILOV G. S., Optika i Spektr. **16** (1964), 176.
[4] KOSTYUK V. P., SHKLAREVSKII I. N., Optika i Spektr. **16** (1964), 305.
[5] IDCZAK E., Thin Solid Films **34** (1976), 407.
[6] IDCZAK E., OLESZKIEWICZ E., Optica Applicata **IX** (1979), 233.
[7] HILL R. M., WEARER Ch., Trans. Faraday Soc. **54** (1958)
[8] ALESSANDRINI E. I., BRUSIC V., J. Vacuum Sc. Technol. **9** (1971), 83.

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### Влияние температуры подложки на оптические постоянные плёнок хрома для видимой области спектра

Проведены исследования оптических зависимостей плёнок хрома от температуры подложки. Плёнки хрома были получены методом вакуумного настаивания. Оптические постоянные измерялись в видимой области спектра методом эллипсометрии. При расчёте оптических постоянных была учтена существующая на поверхности хрома плёнка природной окиси. Существующие разницы в значениях коэффициента преломления и показателя абсорбции плёнок, полученных при различных температурах, связаны с более совершенной кристаллической структурой плёнки.