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Determination of the Thickness and Optical Constants of Metal Oxide Thin Films by Different Methods

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ABSTRACT

Calculation of optical parameters (complex index of refraction, that is a function of the wavelength and thickness) of thin films from measurement data is a typical inverse non-linear problem. Hence, in this paper we study several models for determination of optical constants such as index of refraction, absorption coefficient and physical thickness of metal oxide thin film onto transparent substrate (glass). We applied Swanepoel, Selmeier and Cauchymodels. We show the advantage for their models, compared to above methods together.
KEYWORDS: thin film, Metal Oxide, optical constant.

INTRODUCTION

Recently, many different methods for measuring the optical constants and the thickness of semiconductor and dielectric various thin films onto substrate have been published. Minkov used the reflectance spectrum for different angels incidence of non polarized or s (p) polarized light to compute the optical parameters and the thickness. Moreover optical constants and the layer thickness of a layer coated on a semi finite transparent layer were estimated using transmission spectrum alone by Manifacier [1].Swanepoel improved this method further in the case of finite substrate thickness [2].In addition, the optical constants have been corresponded with the functions versus the light wavelength,such as: Cauchy relation, sellmeierexpression,Sqaure function. in this paper for computation of the optical constants of Metal Oxide thin film had been used from the swanepoel, Cauchy, sellmeierand Squarefunctions.

Swanepoel model

In this section, we consider Metal Oxide thin film deposited on a thick transparent substrate(glass substrate). Assuming normal incident and taking into account interference due to multiple refractions at film/substrate and air/film interfaces,Swanepoel [3] has shown that the total transmission$T$ is given by,

$$T(\lambda) = \frac{Ax}{B - CxCos\varphi + Dx^2} \qquad (1)$$

Where

$A = 16ns^2$, $B = (n+1)^3(n+s^2)$

$$C = 2(n^2-1)(n^2-s^2)$$
$$D = (n-1)^3(n-s^2)$$
$$\varphi = \frac{4\pi nd}{\lambda}$$
$$x = e^{-\alpha d}$$

Where n is the index of refraction of the film, s is the refractive index of the substrate (s=1.52 for glass), $d$is the thickness, $\varphi$is the phase difference between the direct and the multiple reflectedtransmitted beams, $x$is the absorbance and $\alpha$is the absorption coefficient. Also we see that the extreme points of in Eq. (1) occur for$\varphi = 2\pi m$ or

$$2nd = md \qquad (2)$$

The $m$values are rounded to the nearest integer or half integer. Then, the refraction of index in the spectral domain of the medium and strong transmission is calculated using the Swanepoel model [4] by creating smooth envelopes, The refractive index is first approximated by [5]:

$$n = [N + (N^2 - s^2)^{\frac{1}{2}}]^{\frac{1}{2}} \qquad (3)$$

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Where

$$N = 2s\frac{T_M - T_m}{T_M T_m} + \frac{2s^2 + 1}{2}$$

In this expression, T_M and T_m are the maximum and the minimum transmission at the same wavelength, one being measured and the other calculated from the envelope function. In this range wavelengththe absorption coefficient can be calculated using the expression [6]:

$$\alpha = -\frac{1}{d} ln \frac{(n-1)(n-s)(\frac{T_M}{T_m}+1)^{\frac{1}{2}}}{(n+1)(n+s)(\frac{T_M}{T_m}-1)^{\frac{1}{2}}} \quad (4)$$

Too, ifthe refractive indices are obtained at the maxima or minima of the transmissionspectrum, the thickness of the film can be deduced. Assuming n_1 and $n_2$be indexes of refraction at two adjacent maxima (or minima) at $\lambda_1$andλ_2[2], it follows from Eq. (2) that:

$$d = \frac{\lambda_1 \lambda_2}{2(\lambda_1 n_2 - \lambda_2 n_1)} \quad (5)$$

Cauchy and sellmeier models

Most dielectric materials are transparent in visible spectral wavelengths.Hencea simple dispersion relation is often used to describe optical properties for many materials in non-adsorbing regions for dielectrics and semiconductors. The Cauchy and sellmeier relationships represents the index of refraction n and extinction coefficient k as slowly varying functions of wavelength,λ, with an exponential to represent a short wavelength absorption tail, respectively[7,8]:

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \quad (6)$$

$$n = \sqrt{A + (B - \frac{C}{\lambda^2})^{-1}} \quad (7)$$

Where$A$, $B$and C are parameters to be determined which these constants can be computed. the objective is to solve the following minimization problem[9,10]:

Minimize $\sum(n_{meas} - n_{theo})^2$

RESULTS AND DISCUSSION

Fig. 1 shows the optical transmission spectrum of metal oxide thin films. The envelopes of the transmission spectrum, T_M and T_m have been observed from this figure. We can observe that from Fig.1 transmittance spectrum computed by Cauchy model andSellmeier. The values of n are calculated for both samples using Eq. (1) at different wavelengths corresponding to tangent points (T_M and T_m) as has been described earlier. On the other hand, the data on the dispersion of the index of refraction,$n(\lambda)$have been calculated using the Cauchy and Sellmeier models in the UV–regions of wavelength [11, 12]. From these results, it is clear that the values of $n(\lambda)$from Fig.2 and Fig.3 there is a good agreement between the results obtained by Swanepoel method, Cauchy model andSellmeier model. To determine the film thickness, d, a number of thicknesses are calculated using Eq. (5) and then the average of d is calculated which is about 80nm.

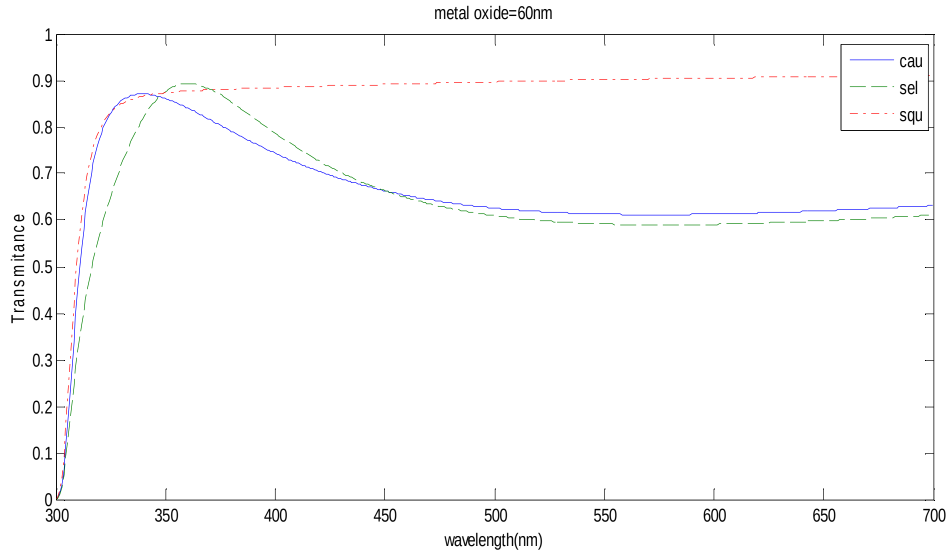

Fig.1.Transmission spectrum for metal oxide calculated by Swanepoel, Cauchy and Selmeir.

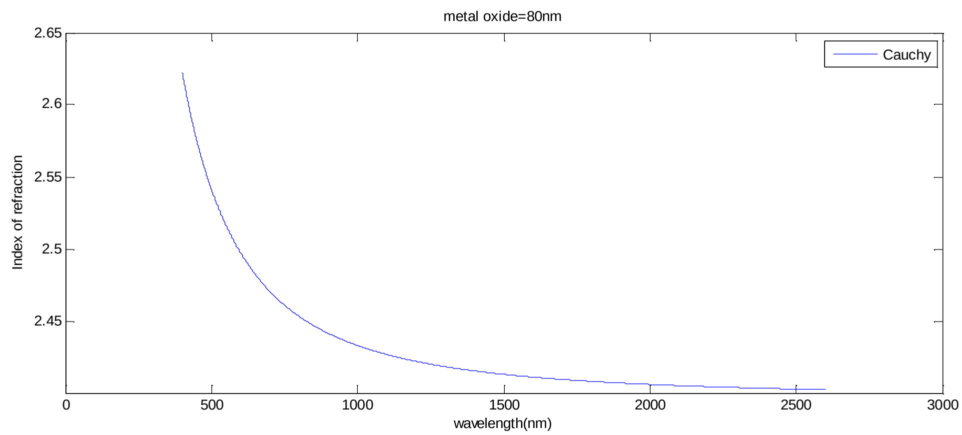

Fig.2. index of refraction for metal oxide calculated Cauchy model.

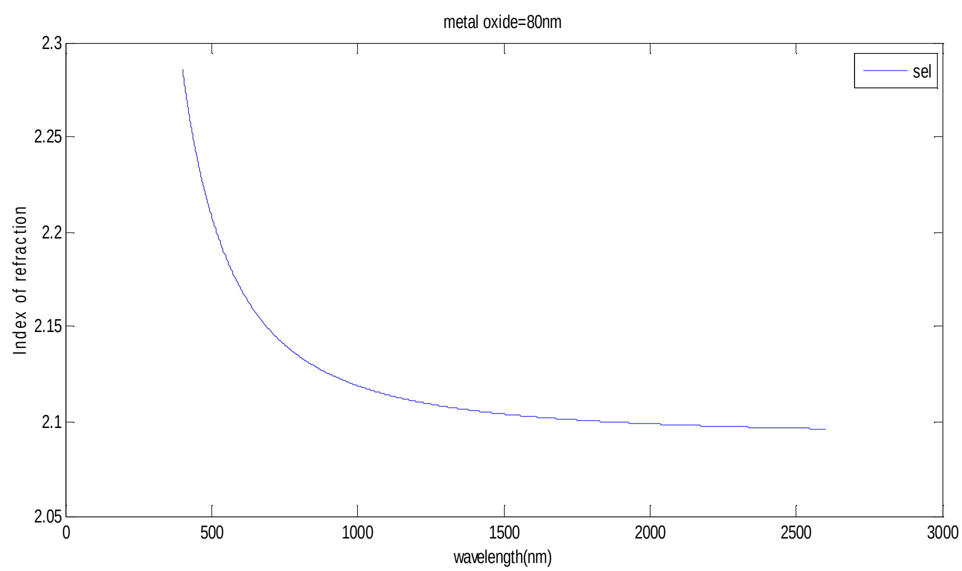

Fig.3. index of refraction for metal oxide calculated selmeir model.

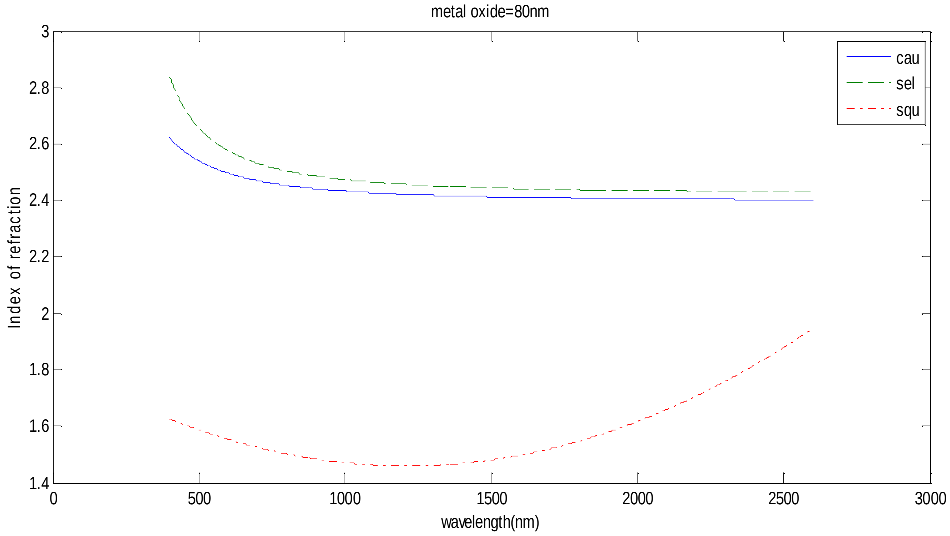

Fig.4. index of refraction for metal oxide calculated by Swanepoel, Cauchy and selmeir.

Conclusion

The optical properties of Metal Oxide thin films have been measured and calculated from the transmission spectra. Optical constants such as the refractive index *n* and extinction coefficient *k* were determined from the transmittance spectra in the UV–regions using the envelope method. The thicknesses of the films were calculated from interference of the transmittance spectra.Also, we by using a algorithm in Matlab program have shown that the results calculated on the film have a good agreement at measurement data such as the index of refraction, physical thickness and transmittance spectrum.

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