ENTITLED

EFFECT OF SUBSTRATE ON CHARACTERISTICS OF EVAPORATED THIN DIELECTRIC FILMS

A THESIS

Submitted to

Ain Shams University

in Partial Fulfilment of the Requirements for the Degree

Of

MASTER OF SCIENCE

By

Hoda Shehata Soliman

Demonstrator in Physics

Faculty of Education

Ain Shams University

1978

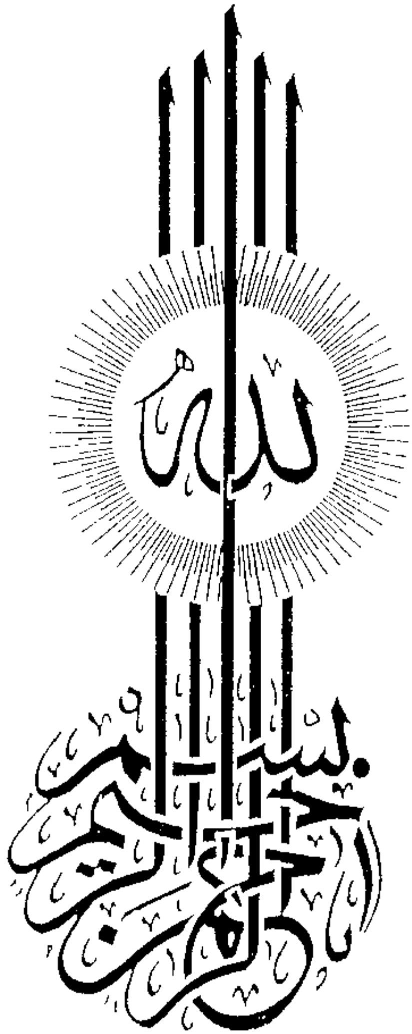
ACKNOWLEDGEMENT

I would like to express my deep thanks to Professor Dr. M. Barakat for suggesting the point of research and for his kind and helpful supervision.

My deep thanks to Professor Dr. F. El-Bedewi, Head of the Physics Department, Faculty of Science and Professor Dr. A. Labib, Head of the Department of Physics and Chemistry, Faculty of Education, for their kind interest and encouragement.

I wish to express my sencere thanks and appreciation to Dr. A. F. A. El-Shazly, Ass. Prof. of Physics, Faculty of Education, for his efforts, advice and assistance which were constantly offered through every stage of this work.

Finally, I wish to thank my colleagues in the Department of Physics and Chemistry, Faculty of Education Ain Shams University, where this work was completely fulfilled.


بسم الله الرحمن الرحيم

NOTE

Beside the work conducted in this thesis, the candidate had studied advanced M. Sc. Courses in Physics during one year.

1- Computer
2- Numerical analysis
3- Electronics
4- Interference
5- Spectroscopy
6- Non linear optics
7- Solid state physics
8- Fiber optics
9- Application of laser beam

She had successfully pased an exam. in these courses.

C O N T E N T S

Page

CHAPTER III: EXPERIMENTAL RESULTS

Page

S U M M A R Y

The effect of substrate on characteristics of evaporated thin dielectric films is investigated applying an ellipsometric method, a method which has proved to be a useful tool for determining the refractive index (n_1) and the geometrical thickness (d_1) of thin dielectric films deposited on metallic substrates[1,2].

For this purpose, different metallic substrates (Au, Ag, Cr and Sb) are prepared by evaporation technique. The optical constants (the refractive index n_2 and the absorption index k_2) of such substrates are determined at certain wavelength (λ = 5500 Å). Then, thin dielectric film (ZnS) is deposited simultaneously on the four different metallic substrates. The refractive index (n_1) and the geometrical thickness (d_1) of the dielectric thin film on each substrate are determined. Hence the effect of the substrate on the determination of these two parameters (n_1 and d_1) is studied.

Investigating the effects of the experimental errors on the obtained results, it was found:

A metallic substrate made of silver affects strongly the determination of both the refractive index(n_1) of the dielectric film and its geometrical thickness (d_1), i.e, a small error in measuring either the angle of incidence(ϕ) or the azimuth angle (ψ) gives a big error in determining n_1 and d_1. But , when a metallic substrate made of gold is used, the same error in ϕ or ψ yields a big error in determining n_1 and a relatively small error in d_1.

While, the same error in ϕ or ψ when Sb or Cr is used as a metallic substrate gives a relatively small deviation in determining both n_1 and d_1 .

Therefore, for determining the refractive index n_1 and the geometrical thickness d_1 of thin dielectric film deposited on a metallic substrate, it is of more benefit to use a metallic substrate made of either antimony or chromium.

INTRODUCTION

The role of dielectric thin films whether present as a single film or multilayers is acquiring increasing importance in many fairly modern fields, as an example, reflectors in laser resonators, in optical wave-guides and in some aspects of microelectronics. It is, for this reason, benefitial to determine the refractive index and the geometrical thickness of such nonabsorbing thin films. The method utilized in this work is the ellipsometric method where the exact formulas are used. The high accuracy in determining both the refractive index and the geometrical thickness of the investigated thin dielectric films is the result of selecting the suitable metallic substrate.

The technique is based on the choice of different metallic substrates whose optical constants (the refractive index and the absorption index) are determined. Then these metallic substrates are over coated simultaneously with thin ZnS film. The refractive index and the geometrical thickness of such film are evaluated. The precision of the method is checked.

Chapter I deals with the litratures review, considering the basis of the ellipsometric method, the basic formulas used in determining the optical constants and the graphical method for determining simultaneously the refractive index and the geometrical thickness of evaporated nonabsorbing film on a metallic substrate.

Chapter II deals with the experimental technique and apparatus used during performing the work.

Chapter III deals with the experimental results including the optical constants of the metallic substrates and the refractive index and the geometrical thickness of the thin dielectric layer coating the metallic substrate. Chapter III also deals with an experimental verification using the interferometric method and the precision of measurement to achieve the suitable choice of the metallic substrate which can be used for accurate measurements of both the refractive index and the geometrical thickness of a thin dielectric film deposited on a metallic substrate.

CHAPTER I

LITERATURES REVIEW

I.1) The ellipsometric method:

It is well known that the ellipsometric method is used for the determination of the refractive index (n_1) and the thickness (d_1) of a nonabsorbing film on an absorbing substrate can be used only in the case when the true values of the complex refractive index $\tilde{n}_2$ ($= n_2 - ik_2$) of the substrate are known precisely[3,4,5].

When a plane polarized light is reflected from an absorbing substrate at nonnormal incidence, it assumes elliptical polarization. The ellipticity of the reflected beam is determined by the relative phase difference Δ and the azimuth ψ where

$$\Delta = (\delta_p - \delta_s) \text{ and } \tan^2\psi = \frac{R_p}{R_s}$$

The subscripts p and s refer to components parallel and perpendicular to the plane of incidence.

Since Δ and ψ are related to the optical constants, a determination of the latter is, in principle, possible from the measurements of Δ and ψ.

I.2) Basic formulas used in determining the optical constants of the metallic substrate:

The ellipsometric method for determining the refractive index (n_2) and the absorption index (k_2) of a metallic substrate is essentially based on the measurement of the phase difference Δ , the azimuth of the reduced polarization ψ and the angle of incidence of light ϕ.

The values of Δ and ψ are dependent on the amplitudes of the coefficients of reflections r_p and r_s for the p - and s - components.

It is well known(6) that:

$$\tilde{r}_s = - \frac{\sin (\phi - \theta)}{\sin (\phi + \theta)} = |r_s| \quad e^{i \delta_s}$$

$$\tilde{r}_p = - \frac{\tan (\phi - \theta)}{\tan (\phi \pm \theta)} = |r_p| \quad e^{i \delta_p}$$

$$\frac{r_p}{r_s} = \frac{\dfrac{\tan (\phi - \theta)}{\tan (\phi \pm \theta)}}{\dfrac{\sin (\phi - \theta)}{\sin (\phi + \theta)}} = \left| \frac{r_p}{r_s} \right| e^{i (\delta_p - \delta_s)}$$

From which

$$\rho e^{i\Delta} = \frac{\cos(\phi + \theta)}{\cos(\phi - \theta)}$$

The previous equation can be written in the form:

$$\frac{1 + \rho e^{i\Delta}}{1 - \rho e^{i\Delta}} = \frac{\cos(\phi - \theta) + \cos(\phi + \theta)}{\cos(\phi - \theta) - \cos(\phi + \theta)}$$

$$= \frac{\cos\phi \cos\theta}{\sin\phi \sin\theta} \qquad (1)$$

As, $\cos\theta = \sqrt{1 - \sin^2\theta}$

and $\sin\theta = \dfrac{\sin\phi}{\tilde{n}}$ (2)

where $\tilde{n} = n - i\,k$

$$\therefore \cos\theta = \sqrt{1 - \left(\frac{\sin\phi}{\tilde{n}}\right)^2} = \frac{1}{\tilde{n}}\sqrt{\tilde{n}^2 - \sin^2\phi} \qquad (3)$$

Using equations (2) and (3) with equation (1) we get:

$$\frac{1 + \rho e^{i\Delta}}{1 - \rho e^{i\Delta}} = \frac{\cos\phi \times \frac{1}{\tilde{n}}\sqrt{\tilde{n}^2 - \sin^2\phi}}{\sin\phi \times \frac{1}{\tilde{n}}\sin\phi}$$

$$= \frac{\sqrt{\tilde{n}^2 - \sin^2\phi}}{\sin\phi \tan\phi}$$

$$= \frac{\sqrt{(n-ik)^2 - \sin^2\phi}}{\sin\phi \tan\phi} = \frac{a - i\,b}{\sin\phi \tan\phi} \qquad (4)$$