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Interferometric thickness determination of thin metallic films

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The deposition of thin metallic films on substrates is a common procedure, with a great number of different techniques, for a variety of practical and scientific applications. One of the most important properties to adjust is the thickness of the film. In special applications like MBE, this is made up *in situ* and during the growth with a precision of one atomic layer. Many technical applications on the contrary require just passing over a minimum thickness. In the present paper we report on the design and construction of an optical interference system, which allows us to monitor and determine the thickness of metallic films after deposition. For this purpose, a calibration based on the comparison of two patterns is applied: the patterns are generated by the substrates with and without a deposited film on it. The thickness of the film is determined as a difference of measure of the patterns.

Keywords: deposition, interference, layer thickness, growth, filters.

1. Introduction

The study of the physical properties of thin metallic films is important due to its multiple technological applications [1-4].

Among the variety of methods used for the growing of thin metallic films, high-vacuum thermal evaporation, has proved to be an efficient technique and widely used in both research and industry [5,6].

After having fulfilled the growing of the film, one of the following tasks is to determine its thickness.

In Puebla University, our work team has designed and built a high-vacuum evaporation system for thin metallic films. This system reaches pressures of the order of 10–4 Pa and uses a high current source (until 150 A, with thyristoric control mode per phase angle), to increase the temperature of the heater element, in this case tungsten wire [7].

The high-vacuum thermal evaporation system, that has been built, allows growing up thin films for a variety of applications. For example metallic films grown up have been used as telescope mirror layers and for semi-mirrors as UV radiation filters.

In the past, measurement of thin film thickness was achieved by our group by using a Talystep-Sloan Dektak II device, through needle sweeping with bidimensional displacement [7].

However, it was necessary to develop an alternative method which allows knowing the thickness of the film that has been grown up.

The use of an interferometer allows to measure thin film thickness. This method, using a radiation source, has as a limit the wavelength of the radiation applied.

In this work we report the results of measurements of thin films thickness, grown up on glass substrates by using an optical arrangement which uses an interferometer and a laser as a source of radiation. Comparison between two patterns of interference is taken into a count for the measurement of film thickness. These patterns are generated by substrate without and with film.

2. Experiment

Copper and aluminum metallic films, used in this work, were grown up with a pressure of $2x10^{-3}$ Pa, on glass substrates of 0.026 m X 0.076 m, and thickness of 0.001m. The contribution material had a mass of 0.0001 kg, in every case.

The separation distance between tungsten wire and substrate allows film thickness control. In order to obtain a temperature of 1200 centigrade in the heater turn, a current of 60 A was administrated in all cases.

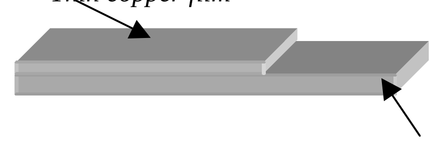
A Helium-Neon laser with a wavelength of 632.8 nanometers was applied as a source of radiation. The optical system applied to measure the thickness of the films uses a Michelson interferometer with even arms.

In the interferometer, one of the mirrors was substituted by a flat glass plate, in which a thin film was grown up in one single portion of substrate, in such a way that a step is formed.

Due to the fact that in some cases the film, that has been grown up, has a poor reflection, the plate has an aluminum metallization, making the plate work as a mirror, with a step of the thickness of the metallic coating which is to be measured.

The following scheme shows the sequence of the growing on a glass plate, to grow up the measured step.

i) Film is placed on a glass plate to be measured.



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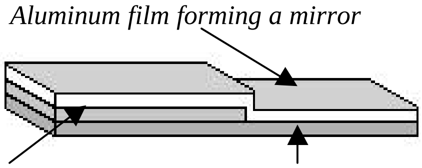
ii) Metallization with aluminum to form the mirror with step



To measure the source wavelength, at the beginning, the interferometer was used without changing any mirror.

Then, one of the interferometer mirrors was replaced with a step-mirror, obtaining in this way a double interference pattern, displaced one from the other.

Film thickness forming the step, is calculated using the data of the source wavelength and the shift in the interference patterns.

The following scheme shows the setting up of a step-mirror inside the interferometer.

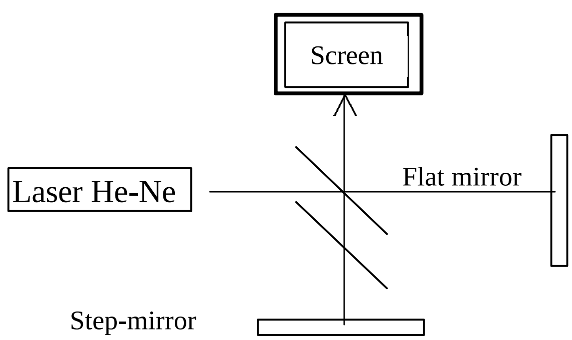


Figure 1. *A Michelson interferometer is used to measure a film thickness, replacing one of its mirrors with a step-mirror.*

The optical system applied in this work is shown in figure 2.

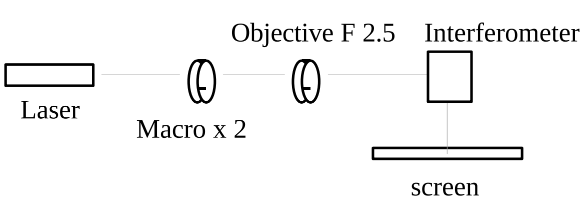


Figure 2. *Experimental arrangement to determine film thickness.*

Figures 3 and 4 show pictures for two interference patterns of different films. The shift can be observed between two patterns. Film thickness measurement can be calculated using theses shift.

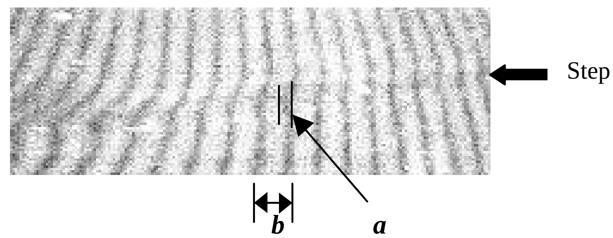


Figure 3. Comparison between patterns for Cu2 film with a thickness of 111 nanometers.

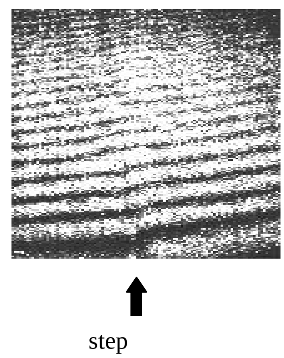


Figure 4. *Comparison between patterns for Cu3 with a thickness of 79 nm.*

3. Results

The following table shows data obtained by using four aluminum samples and six copper samples. The letter *a* means the shift between interference fringes; *b* means the fringe width, as is shown in figure 3.

Copper	***a* (mm)**	***b* (mm)**
Cu-1	0.45	2.4
Cu-3	1.15	3.4
Cu-2	0.9	3.75
Cu-4	1.6	4.4
Cu-6	1.6	2.6
Cu-5	1.8	3.0
Aluminum	***a* (mm)**	***b* (mm)**
Al-1	Step not visible	
Al-2	Step not visible	
Al-3	0.4	2.8
Al-4	Step not visible	

Using the equation for the thickness

$$g = (a/b)(\lambda/2),$$

where λ is the laser wavelength [8], the thickness of the layer grown up can be measured as function of: interference bandwidth, shift between bands and wavelength of the source.

The following table shows thickness obtained for different samples.

Copper	**Thickness**	**Aluminum**	**Thickness**
Cu-1	61 nm	Al-2 -	Undetermined
Cu-2	79 nm	Al-1	Undetermined
Cu-3	111 nm	Al-3	47 nm
Cu-4	119 nm	Al-4	Undetermined
Cu-5	196 nm		
Cu-6	202 nm		

4. Discussion and conclusions

By interferometric method we obtained thickness of thin metallic films, grown up through a high-vacuum evaporation system.

Accuracy limits of this method depend directly on the radiation source wavelength that is being used.

According to this wavelength and to the thickness of the film grown up, differences between interference patterns of studied films, can be observed or may not be noticed.

Differences between interference patterns will be no longer evident to films with small thickness compared with the wavelength of the source.

According to this work, the lowest resolution limit to analyze films grown up, is ranked in the order of 40 nanometer, and the highest one in the order of incident radiation wavelength, 633 nm in this case.

That is why aluminum films grown up, have an undetermined thickness, since interference patterns appear as a continuum without step presence. Reason for this lays in the fact that film thickness is lower than 40 nm.

In conclusion, it is possible to use this method for measuring thin metallic layers, as long as there is a noticeable shift in the interference fringe between both patterns compared.

Film thickness measurements will be used for the study of thin film physical properties, such as transmission and reflection.

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