Preparation Antireflection Coating Using Plasma Technique

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Abstract: ***In this research, MgO thin films deposited on glass substrate with different thicknesses (68, 88, 100 and120) nm at room temperature by DC plasma technique. Process using magnesium oxide target under Ar gas pressure to prepare single layer antireflection coating. The optical properties and structural have been determined. The optical performance was computed with the aid of MATLAB over the visible and near infrared region with optical thickness in1.25L. Results shows that can be obtained the best wide band optical performance for AR'Cs at 100nm thickness nanostructure single layer.***

Keywords: Antireflection coating, DC plasma technique**,** MgO, sputtering

1. Introduction

An optical coating is composed of a combination of thin film layers that create interference effects used to enhance transmission or reflection properties within an optical system, many common types of coatings are used on precision optics, including Anti-Reflection (AR) Coatings [1].

The primary application of an AR coating is to reduce reflection and increase visibility, thereby increasing light transmission. Reduction of unwanted light reflection from a surface of a substance is very essential for improvement of the performance of optical and photonic devices [2, 3].Antireflection prevents any reflections from causing interference and blurring the image. Most AR coatings are also very durable, with resistance to both physical and environmental damage. For these reasons, the vast majority of transmissive optics includes some form of anti-reflection coating [4].

The performance of AR dependent upon the number of layers, the thickness of the individual layers, and the refractive index difference at the layer interfaces.

There are different techniques are required for the deposition of optical coatings on glass substrates.

Plasma processes enable the deposition of optical thin films at room temperature, therefore suitable for substrates.

This work appears synthesis single layer AR'Cs depends on plasma deposition, in different deposition times. The optical properties and structural characterization of layer coating have been studied.

2. Basic Theoretical

1. Characteristic Matrix

The tangential of electric E and magnetic H components are shown in Figure 1. The characteristic matrix for thin film single layer is [5]:

$$\begin{pmatrix} B \\ C \end{pmatrix} = \begin{pmatrix} \cos\delta & i\sin\delta / N_1 \\ iN_1 \sin\delta & \cos\delta \end{pmatrix} \begin{pmatrix} 1 \\ N_s \end{pmatrix} \quad (1)$$

When

$\delta = 2\pi N_1 d / \lambda$ (Phase thickness)

d=thickness layer

λ =design wave length

N_1= refractive index of coating material, (N_1 =n-ik) n as the real part of the refractive index and (k) as the extinction coefficient.

N_s= refractive index of substrate

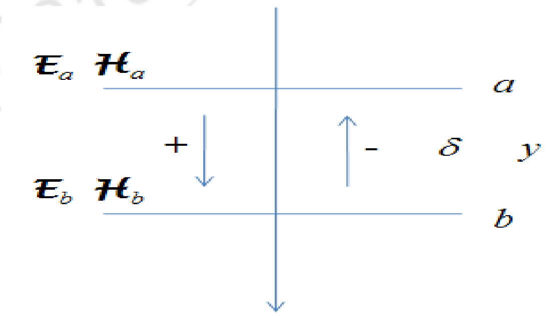

Figure 1: The components electric E and magnetic H waves

Therefore, we can write the reflectance (R), the transmittance (T) and absorbance (A) in terms of B and C as follow [5]

$$R = \left(\frac{N_0 B - C}{N_0 B + C}\right)\left(\frac{\mathbf{N_0 B - C}}{\mathbf{N_0 B + C}}\right)^* \quad (2)$$

$$T = \frac{4N_o R_e(N_s)}{(N_o B + C)(N_o B + C)^*} \quad (3)$$

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$$A = \frac{4N_o R_e (BC^* - N_s)}{(N_o B + C)(N_o B + C)^*} \qquad (4)$$

When

N_0= is the refractive index of air (or the incident medium).

The extinction coefficient K, which is related to the exponential decay of the wave as it passes through the medium, is defined as [6, 7]:

$$K = \frac{\alpha\lambda}{4\pi} \qquad (5)$$

where (λ) is the wavelength of the incident radiation and (α) is the Absorption Coefficient, is defined as:

$$\alpha = 2.303 \frac{A}{d} \qquad (6)$$

When the fall of the rays of monochromatic light a section vertically from the surface, the part of this reflected beam (R), and part of it is absorbed and run out the remaining portion(T) of the film and related to the absorbance (A) reflectivity (R) and transmittance (T) as in the following relationship [8].

A+ R+T= 1(7)

3. Experimental Part

MgO thin films were prepared by DC sputtering technique with a magnesium oxide target of 99.99% purity on glass substrates. System of DC plasma consist of a discharge chamber made of glass with a height of 33cm and diameter 25cm, include (cathode for MgO sputtering target with diameter of 2.5cm and thickness of 0.5cm fixed at the top of the discharge chamber, and anode consist of aluminum disc with diameter of 7.5cm). The glass substrate put on the anode, the inter electrodes distance is 3cm.The sputtering chamber was evacuated down to 10^{-3}mbarr. A plasma is created by ionizing a sputtering under argon gas pressure= 0.2 mbarr, Power=80 watt, using 1000 volt applied voltage, with different deposition time (30, 45, 60 and120) min. Argon gas ions bombards the target atom and sputters of the material, The ejected atoms are deposits onto the substrate, as shown in Figure (2)

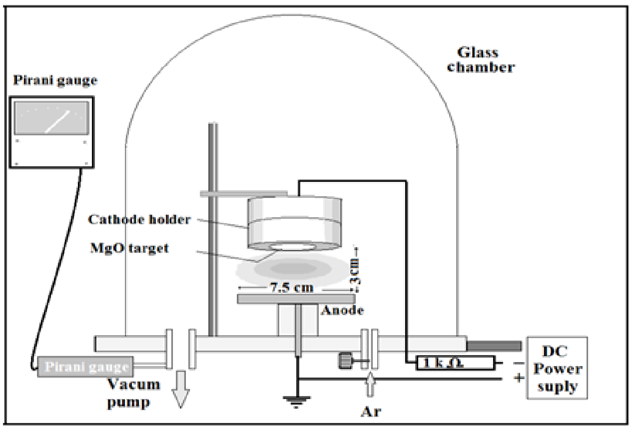

Figure 2: DC Sputtering Schematic

The optical properties of the MgO thin film was determined by the UV-VIS spectrum (SP-8001 PC) used to study transmittance**,** and the structural characterization determined by AFM.

4. Results and Discussion

1. Effect Preparation Conditions on Thickness Layer

Thin films are prepared in room temperature at the preparation condition using the different times of sputtering (30, 45, 60 and 120) min.

There is a problem to control thickness of layer coating in DC sputtering technique. To solve this problem we an experimental study giving the relation between variable preparation conditions and thicknesses of thin films coating are done. In DC deposition technique the optimum preparation condition as shown in Figure 3

Table 1 and Figure 3 show the relation between variable conditions (deposition time) and thickness of layer coating in DC method.

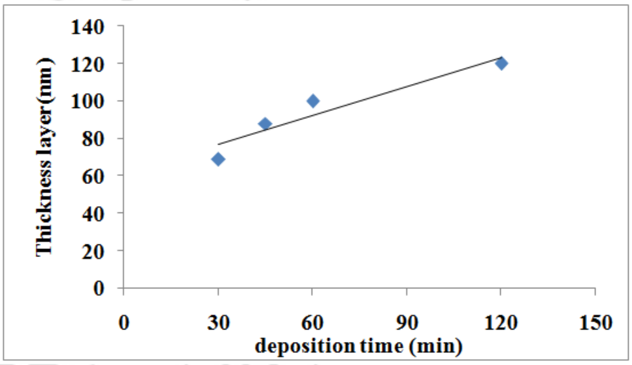

Figure 3: Thicknesses layers as a function of deposition time

Table 1: Deposition time and thicknesses layers

Deposition time(min)	Thicknesses layers(nm)
30	68
45	88
60	100
120	120

Optical Properties

The transmittance spectrums of MgO films for different thicknesses (68, 88, 100and120) nm have been determined by UV-Visible transmission spectrum in the spectral range (300-1100) nm at RT, as shown in Figure 4.

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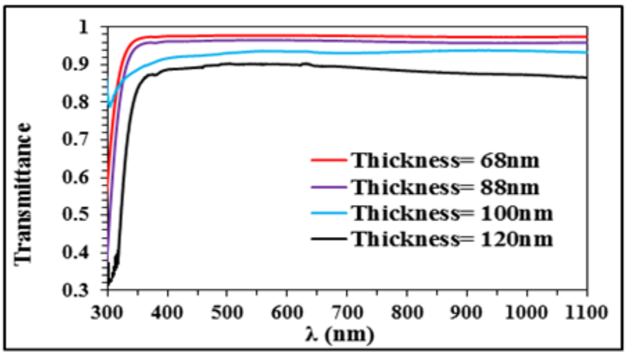


Figure 4: Transmittance as a Function of Wavelength for MgO Films of Different Thicknesses

Figure 4 shows the average transmittance of the spectra (300-1100nm) is about (87-97%). It is observed that the optical transmittance decreases slightly with increasing of film thickness. The optical transmission is above 97% for MgO thin film with 68nm thick, which decreased to 87% upon increasing the thickness to 120nm.This behavior, is attributed to increase the number of atoms with increasing the thickness which leads to increase the number of collision between incident radiation and atoms.

The absorbance spectra of MgO thin film in the spectral range (300-1100) nm on glass substrate as shown in Figure 5

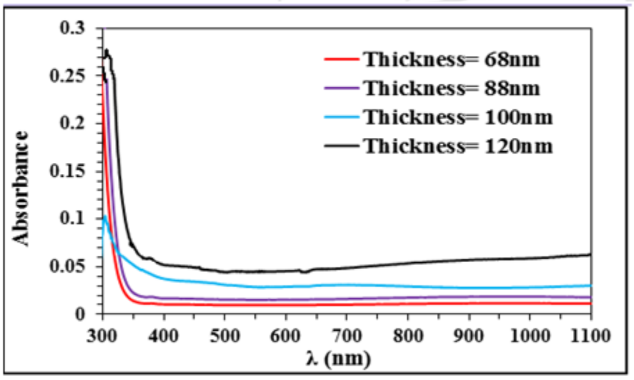


Figure 5: Absorbance as a Function of Wavelength for MgO Films for Different Thicknesses

This figure shows the absorbance spectrum of MgO films increase with increase thicknesses [9].

The relation of the refractive index (n) as a function of the wavelength (λ) in the range (300-1100) nm for MgO thin films at different thicknesses (68, 88, 100 and120) nm, as shown in Figure 6 From this figure we can see that the refractive index increases with increasing films thicknesses [10], and become high stability over (visible - near IR) region have value in range (1.4-1.707).

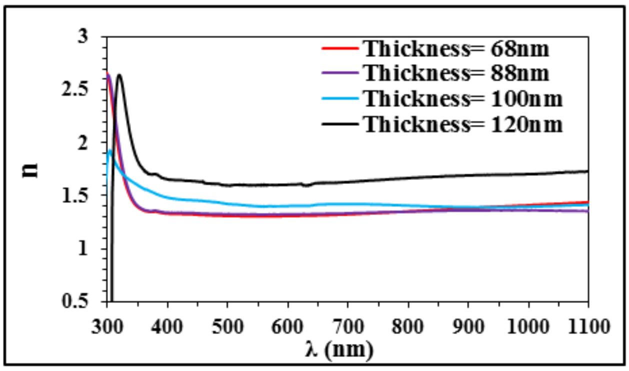


Figure 6: Refractive Index as a Function of Wavelength for MgO Films of Different Thicknesses

The relation between extinction coefficient and wavelength for MgO films deposited at different thicknesses are shown in Figure 7

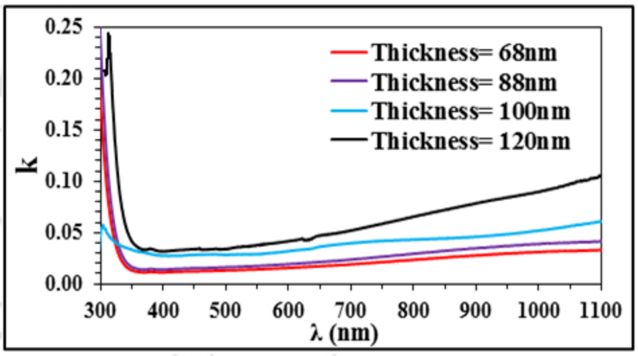
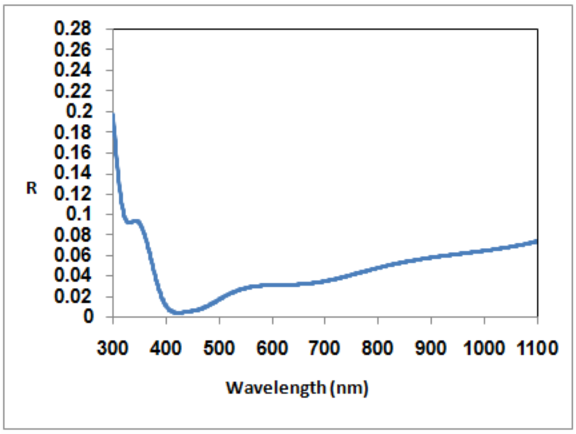


Figure 7: Extinction Coefficient as a Function of Wavelength for MgO Films of Different Thicknesses

The extinction coefficient K is calculated by using equation (5), From this Figure it can be noticed that the extinction coefficient (k) increases with increasing thicknesses layers [11, 12].

Fabricating and Comparing between Experiment and Theoretical Optical Performances of AR'C

The optical performance of AR'Cs at RT with different value of thickness (68, 88, 100and120) nm as shown in Figure 8. This figures show that can be fabricated AR'Cs at visible and near IR region for all samples (68, 88 and 100)nm thickness, except(d) thickness at 120nm.



(a)

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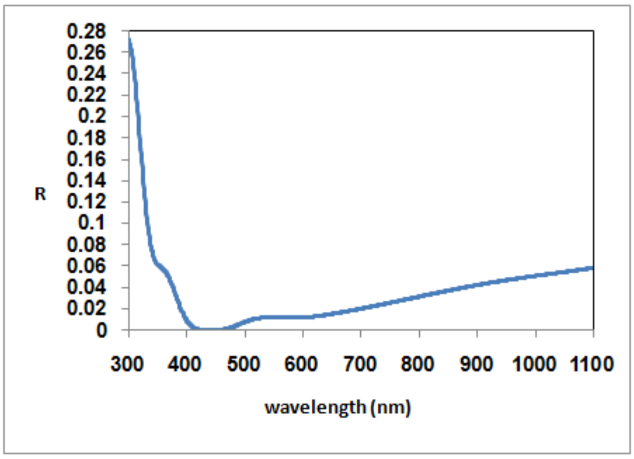
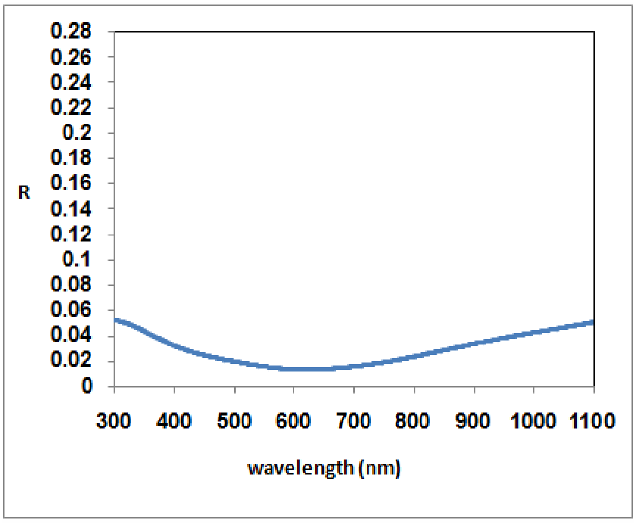
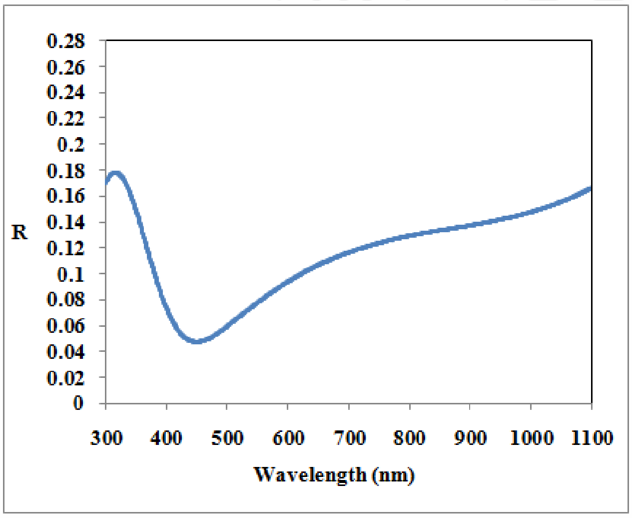


(b)



(c)



(d)

Figure 8: Optical Performance of Single Layer AR'C at R.T for Thicknesses (a:68, b:88, c:100, d:120)nm

Figure 8-c for thickness (100nm) shows that wide band optical performance for AR'C. This result overcomes challenges to get this type of antireflection coating with single layer [13].

The comparison of optical performances between experiment and theoretical results for sample of layer thickness 100 nm as shown in Figure 9.

This Figure shows convergence between experiment and theoretical results in two regions visible and near IR**.**

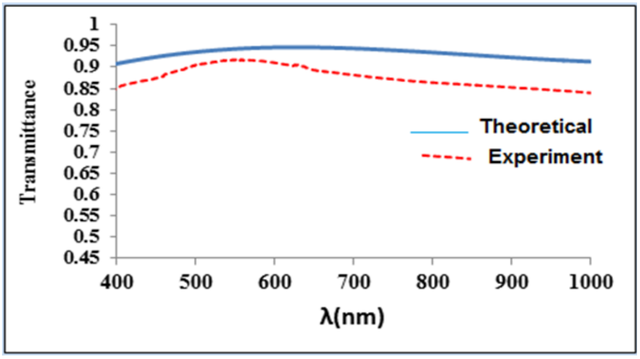


Figure 9: Comparison of Optical Performances for AR'C Between Experimental and Theoretical of 100 nm thickness

Surface Topography Structure (AFM)

The surface topography determined for MgO film at thickness 100nm, this film has been prepared for best optical performance ARC's, as shown in Figure 10.

This MgO film presentation a smooth surface with average Roughness 18.4 nm, root main square (RMS) 21.8 nm, and grain size 97.82 nm.

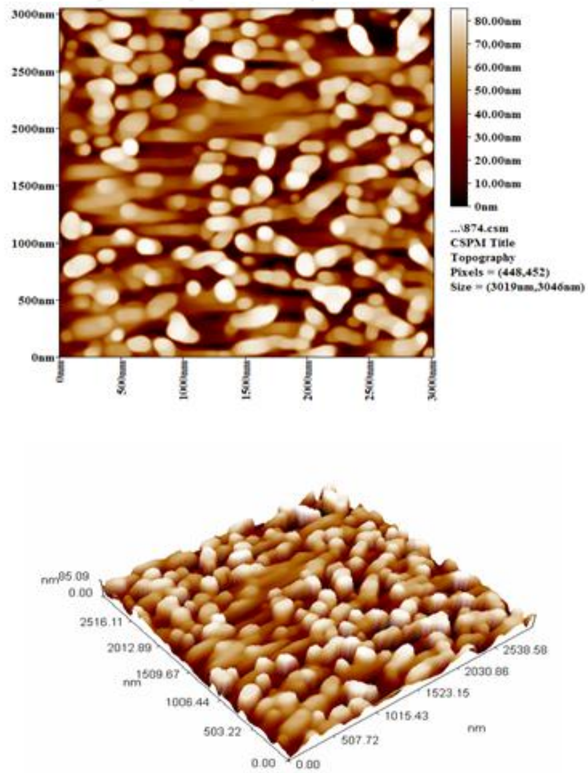


Figure 10: Image AFM of Thickness 100nm

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5. Conclusions

- There is a linear relation between deposition time and the thickness of layer coating.
- There is fabricated AR'C for visible – near IR region for all samples of deposition time, except deposition time 120 min.
- There is fabricated wideband optical performance AR'C with single layer, at deposition time 60 min, for optical thickness in1.25L and thickness layer (100nm).It is challenging to get his optical performance with single layer and this result help overcome the problems of manufacture specialized optical performance AR'Cs.
- The MgO thin films are found to be good transmittance in (visible and near IR) region.

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