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Design and Fabrication of Anti Reflection Coating by Pulsed Laser Deposition

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Abstract:

In this work design and fabricated antireflection coating with single layer is discussed. The fabrication of antireflection coating is achieved using pulsed laser deposition technique (PLD) which deposits MgF_2 *as a thin film layer coating.*

Result shows that wideband AR'C can fabricate when deposited thin film of MgF_2 *on glass at (1.2L) non-quarter optical thickness in annealing temperature. Also result appears that we have overcome the problem of control of thickness layer coating using (PLD) technique.*

Key words: Antireflection Coating, Pulsed Laser Deposition Technique

1. Introduction

Optical systems consist of a large part of a series of surfaces that are the boundaries between different materials. At these the directions of light obey the laws of reflection and refraction, and their shape is adjusted to direct the light in a desired manner. So the other properties of the surfaces, such as reflectance, transmittance, or phase change, are rarely satisfactory.

The optical thin-film coating is technologically very important to modem optics [1]. Which have numerous remarkable applications in many branches of science and technology, such as used in architecture, the automotive industry, energy conversion, computer and display devices, and communication energy [1]. One type of the most important coating is an antireflection coating [2].

Antireflection coating deposited on the surface is one of the most important methods for reducing the reflection loss [3]. In some applications antireflection coatings are required not only reflection has reduced but also transmittance has increased considerably [4]. In this work we design and fabrication AR'C with single layer by using PLD technique.

2. Basic theoretical

Designs AR'C depend on the Characteristic Matrix Theory to calculate reflection. To understand Characteristic Matrix Theory it is necessary to accept several statements. Where at the boundary the tangential of electric E and magnetic H components [5]

The characteristic matrix is:

$$\begin{pmatrix} B \\ C \end{pmatrix} = \begin{pmatrix} cos\delta & isin\delta/N_1 \\ iN_1 sin\delta & cos\delta \end{pmatrix} \begin{pmatrix} 1 \\ N_s \end{pmatrix} \quad (2\text{-}1)$$

When δ(phase thickness) $= \frac{2\pi nd}{\lambda_o}$

λ_o=design wave length

N_1= refractive index of material coating

N_s= refractive index of substrate

Therefore, we can write the reflectance (R), as follow [5]:

$$R = \left(\frac{N_0B-C}{N_0B+C}\right)\left(\frac{N_0B-C}{N_0B+C}\right)^* \qquad (2\text{-}2)$$

To get minim reflection depending to equation (2-2) refractive index will be

$$n_{1=}\sqrt{n_0n_s} \quad (2\text{- }3)$$

Where n_o and n_s are the refractive indices of the incident medium and substrate, respectively.

The electromagnetic radiation with shipments does not cause any loss of energy interaction, causing the case of re-radiation, the article appears transparent to this radiation, but that did delay the re-radiation will reduce the speed actors to light, and thus it is said then that the material has a refractive index (n)

$$n = \frac{c}{v} \quad (2\text{- }4)$$

The refractive index is a measure of polarizing material. Whenever it is great polarization delay is doing more and more the speed of light in a smaller article is the largest refractive index. [6]

The refractive index is associated with the reflectivity (R) and the Extinction coefficient (K) according to the following equation

$$n= \{(1+R)^2/ (1-R)^2-(K_o^2+1)\}^{1/2}+ (1+R)/ (1-R) \qquad (2\text{- }5)$$

The refractive index value can be calculated from the formula [7]:

$$n = \left(\frac{4R}{(R-1)^2} - K^2\right)^{1/2} + \frac{(R+1)}{(R-1)} \qquad (2\text{-}6)$$

The extinction coefficient K, which is related to the exponential decay of the wave as it passes through the medium, is defined as [8,9]:

$$K = \frac{\alpha\lambda}{4\pi}$$

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. [10]

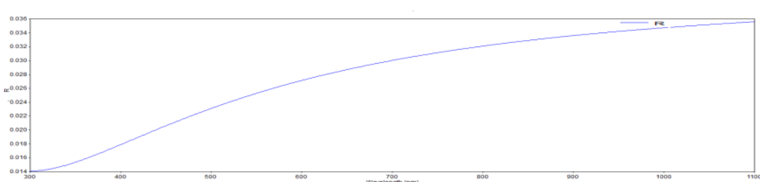
$$A + R + T = 1 \quad (2\text{- }7)$$

The design of a high quality AR coating is not an easy task to be done, since of the limitation in the optical materials diversity to be used in practice and the optimal thin film structure to be realized in order to obtain the lowest reflectivity. The optical AR coatings which designed in this work are valid for the spectral ranges 300-1100 nm [11]. This work design ARC depends an analytical method for non quarter optical thickness.

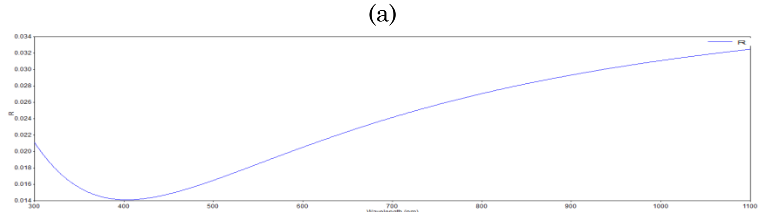
3. Experimental part

For study and design ARC single layer with non quarter optical thickness of layer coating we compute reflection with aid of equation (2-2), as shown in figure (3.1).

Figure (3.1) demonstrate the optical performance of deign ARC with non quarter optical thickness of layer coating ,using MgF_2 as material coating n_1= 1.38, glass (n_s) as substrate and air (n_o) incident medium the wavelength design λ_o=632.8nm. While the construction parameters of this design shows in table (3.1).



(a)



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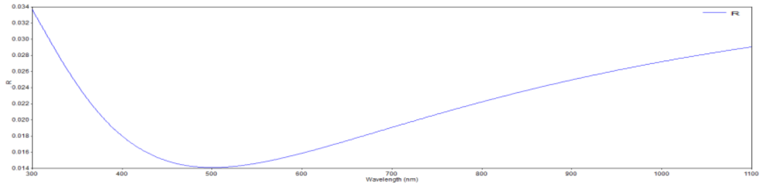

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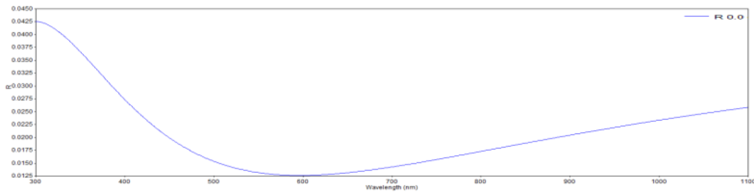

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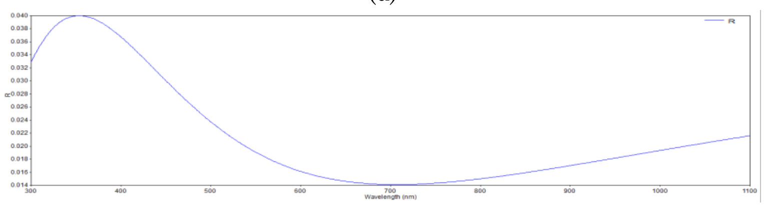

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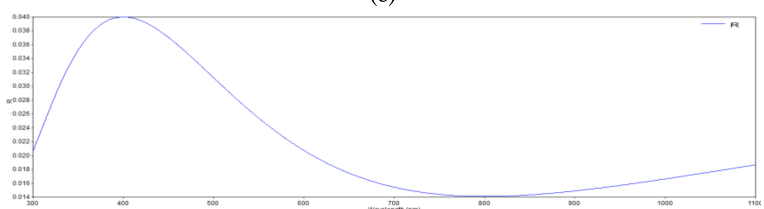

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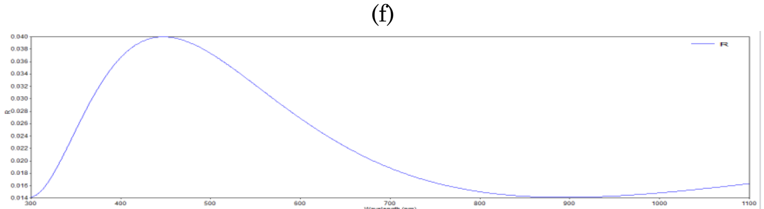

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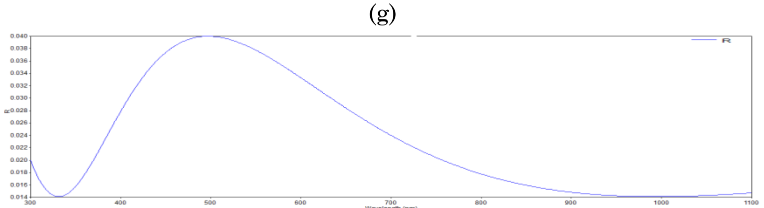


(h)

Figure (3.1) Design single layer ARC with non quarter optical thickness with construction: (a) Air/0.476 L/glass, (b) Air/0.636 L/glass, (c) Air/0.788 L/glass,

(d) Air/0.942 L/glass, (e) Air/1.11 L/glass, (f) Air/1.26 L/glass, (g) Air/1.41 L/glass, (h) Air/1.56 L/glass

Table (3.1) The construction parameters of design non quarter AR'C

Figure(4-2)	Construction design	Wave length of Minim reflection
(A)	Air/0.476 L/glass	300 nm
(B)	Air/0.636 L/glass	400 nm
(C)	Air/0.788 L/glass	500 nm
(D)	Air/0.942L/glass	600 nm
(E)	Air/1.11 L/glass	700 nm
(F)	Air/1.26 L/glass	800 nm
(G)	Air/1.41 L/glass	900 nm
(H)	Air/1.56 L/glass	1000 nm

Pulsed laser deposition (PLD) is a thin film deposition (specifically a physical vapor deposition, PVD) technique where a high-power pulsed laser beam is focused inside a vacuum chamber to strike a target of the material that is to be deposited. This material is vaporized from the target (in a plasma plume) which deposits it as a thin film on a substrate [12].

The films are prepared in room temperature and annealing temperature of (523K) at the preparation condition using number of shots of (150,250,350,450) and energy laser pulse 500 mJ, Pulse width 10ns, Repetition frequency 6 Hz Rotating of target 3/min, Room temperature26℃,pressure 8×10^{-2} mbar

There is a problem to control thickness of layer coating in pulsed laser deposition technique.

Overcome this problem we done experiment study depending on number of shot as showing in Figure (3.2) and Table (3.2) .This study helps us to guess the thickness of layer coating.

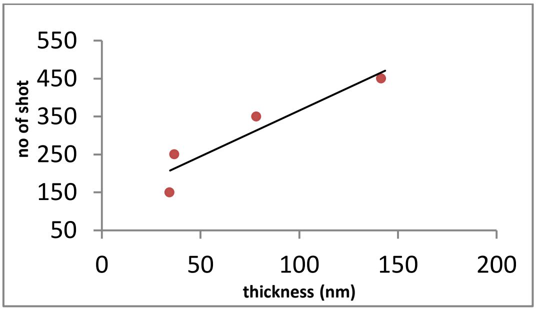


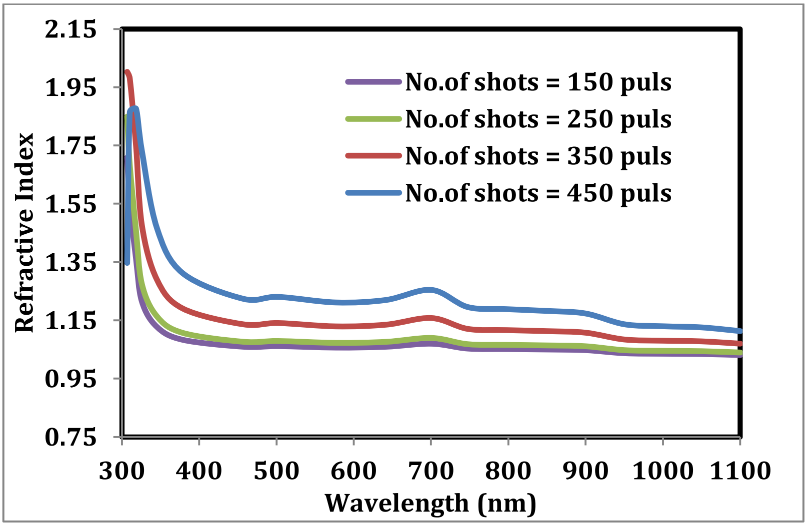
Figure (3.2) experiment relation between number of shoots and layer thickness

Table (3.2) number of shot and layer thickness

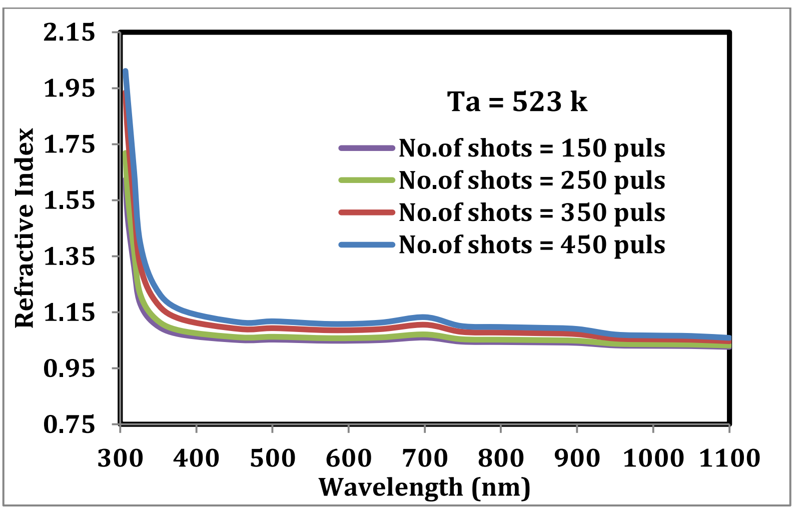
No. of Shots (pulse)	Thickness(nm)
150	34.5
250	36.91
350	78.38
450	141.6

The variation of the refractive index versus wavelength in the range 300–1100 nm, for different number of shots (150,250,350 and 450 shots) at R.T and annealing temperature (523 K), are shown in figures (3.3).

These figures view the dispersion phenomenon. The theoretical value of refractive index of MgF_2 equal 1.38 but cause of experimental conditions the value of the refractive index various with wavelength and become high stability over visible and near IR region have value in range (1.05-1.25) as appears in figure (3.3).



-a-

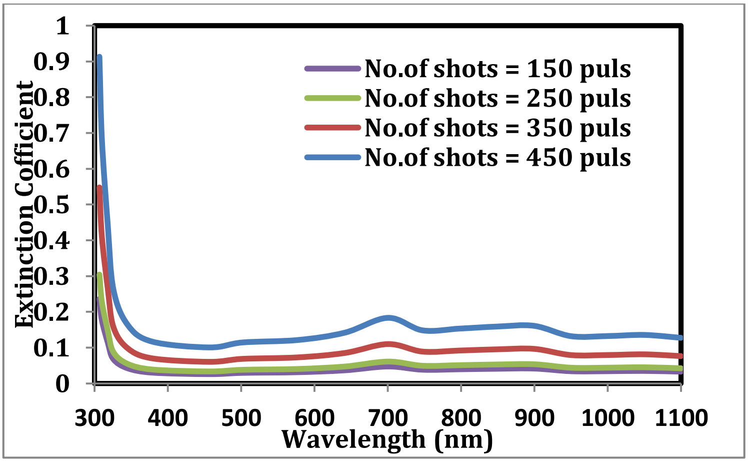


-b-

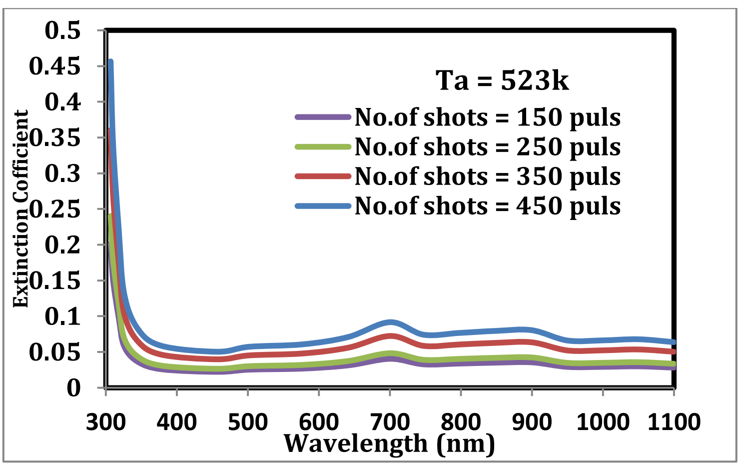
Figures (3.3): Refractive index as a function of wavelength for MgF_2 films -a- at R.T and –b- annealing temperature of different thicknesses.

We can notice from these figures the relation between refractive index decreases at annealing temperature Ta and increase with thickness layer coating.

The relation between the extinction coefficient and wavelength for MgF_2 films deposited at R.T and annealing temperature at different thickness are shown in Figures (3.4 a and b). We can observe from these figures that extinction coefficient decreases with annealing temperature and with increasing thickness.



-a-



-b-

Figures (3.4): Extinction coefficient as a function of wavelength for MgF_2 films -a- at R.T and –b- annealing temperature of different thicknesses.

The optical performance of AR'C at RT show in Figure (3.5) which appears reflection increase with increase thickness of layer coating and the samples of number shots (150,250,350) get fabricate AR'C for visible – near IR region.

While figure (3.6) appears the optical performance of antireflection coating at annealing temperature for shots (150,250,350,450).

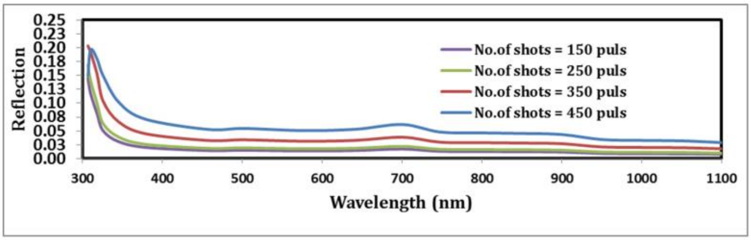


Figure (3.5) optical performance of AR'C for experiment result at R.T for different thicknesses.

At (T_a) the reflection decrease corresponding to RT and increase with increase thickness of layer coating .Also in annealing temperature we get fabricate AR'C in the visible - near IR region for shots (150,250,350,450).
Figure (3.5) and (3.6) appear fabricate wide band AR'C.

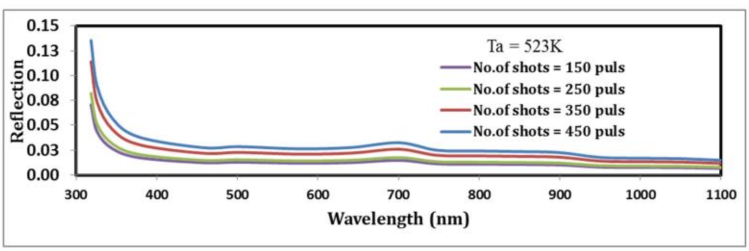


Figure (3.6) optical performance of AR'C for experiment result at T_a for different thicknesses

4. Conclusions

This work fabricates wide band antireflection over visible-near IR region. Result shows that non quarter of MgF_2 as thin film thickness less than 0.7L fabricate antireflection at R.T. At annealing temperatures optical thickness at 1.2L of MgF_2 thin film layer coating make fabrication antireflection coating.

Experimentally conclude when increase number of shots, the geometric thickness will be increase. Also the extinction coefficient and refractive index are decrease by annealing of MgF_2 film.

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