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Preparation single layer of (MgO) as antireflection coating using PLD technique

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Abstract

In this work preparation of antireflection coating with single layer of MgO using pulsed laser deposition (PLD) method which deposit on glass substrate with different thicknesses (90 and 100) nm annealed at temperature 500 K was done.
The optical and structural properties (X-ray diffraction) have been determined. The optical reflectance was computed with the aid of MATLAB over the visible and near infrared region. Results shows that the best result obtained for optical performance of AR'Cs at 700 shots with thickness 90 nm nanostructure single layer AR'Cs and low reflection at wavelength 550 nm.

Key words
Antireflection coating, PLD technique, MgO, optical properties.

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تحضير غشاء مضاد للانعكاس احادي الطبقة من اوكسيد المغنسيوم باستخدام تقانة الترسيب بالليزر النبضي

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الخلاصة

في هذا البحث تم تحضير طلاء مضاد للانعكاس احادي الطبقة لمادة اوكسيد المغنسيوم بطريقة الترسيب بالليزر النبضي. وعلى اساس من الزجاج وباسماك مختلفة 90-100 نانومتر وفي درجة حرارة التلدين (500) درجة كلفنية.
تم دراسة الخصائص البصرية والتركيبية للطلاء. الانعكاسية حسبت بواسطة برنامج MATLAB ضمن المنطقة المرئية والقريبة من الحمراء، النتائج اظهرت ان الحصول على افضل اداء بصري للطلاء المضاد للانعكاس عند سمك الغشاء 90 نانومتر وبعدد نبضات 700 نبضة وباقل انعكاسية و كان بطول موجي 550 نانومتر.

Introduction

Optical systems consist of a large part of a series of surfaces that are the boundaries between different materials. The optical coating is very important technologically to modem optics [1]. One type of the most important optical coating is an antireflection coating [2]. Antireflection coating work the opposite of a reflector. At the principal wavelength, it creates destructive interference for the multiple reflected waves, and constructive interference for the multiple transmitted waves[3] .This type of coating is commonly applied to the surfaces of optical components such as lenses, mirrors, and windows. When deposited on the surface of an interference filter, AR'C increases transmission and reduces the reflection [4].

MgO is a promising candidate for a variety of new applications, such as in lighting industry, optical systems, and laser technology, control technology, as well as creation thermal sensors. Furthermore the computed has been applied as a protective and antireflection layer [5, 6].

There are various methods for obtaining MgO films such as metal organic molecular beam epitaxy [7], vapor phase epitaxy [8], sol-gel syntheses, reactive sputtering [9], pulse laser deposition [10], and chemical vapor deposition [11].

Basic theoretical

1. characteristic matrix

The tangential of electric *E* and magnetic *H* components are shown in Fig. 1. The characteristic matrix for thin film single layer is [12].

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

where

$\begin{pmatrix} B \\ C \end{pmatrix}$ is defined as the characteristic matrix of the assembly.

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

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.

d =thickness of layer coating.

N_s= refractive index of substrate.

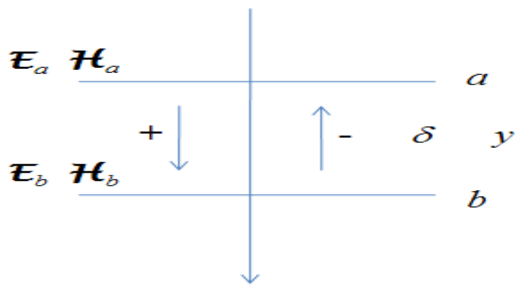


Fig.1: The components electric E and magnetic H waves.

Therefore, we can write the reflectance (R), the transmittance (T) and absorbance (A) in terms of B and C as follow [12].

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

$$T = \frac{4N_0\, R_e(N_s)}{(N_0B+C)(N_0B+C)^*} \quad (3)$$

$$A = \frac{4N_0\, R_e(BC^*-N_s)}{(N_0B+C)(N_0B+C)^*} \quad (4)$$

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 [13, 14]:

$$k = \frac{\alpha\lambda}{4\pi} \quad (5)$$

where (λ) is the wavelength of the incident radiation and (α) is the Absorption Coefficient.

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

(A) is the absorbance,(d) thickness of layer coating.

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 [15].

$$A + R + T = 1 \quad (7)$$

Experimental part

Fixed conditions for prepared MgO thin films include Q-switching Nd: YAG laser beam energy pulse (500 mJ), Pressure (8×10^{-2} mbar), pulse width (10ns), repetition frequency (6 Hz) and rotating of target (3/min), and the preparation conditions using variation number of shots (700 and 800).

The glass substrate was cleaning in the ultrasonic baths of acetone and alcohol, putting substrate on holder inside the chamber, putting a target in target holder, closing chamber and evacuating the air from inside the deposition chamber. The pressure reach $10^{-2} mbar$. Focusing Nd:YAG SHG Q-switching laser beam coming through a window is incident on the target surface making an angle of 45° with it.

MgO thin films exposed for annealing temperature at 500 K and for 3 hours to get the structural stability of these thin films.

The optical properties of the MgO thin films was determined by the UV-VIS spectrum (Optima Sp – 300 Plus), used to determined absorbance and transmittance.

The structural characterization determined by Rigaku Miniflex X- ray diffraction meter of 1.54 Å.

Results and discussion

1. Optical properties

The transmittance spectra of MgO films for different thicknesses (90 and 100) nm have been determined by UV-Visible transmission spectrum in the spectral range (400-1100) nm and annealed at temperature 500K are shown in Fig. 2.

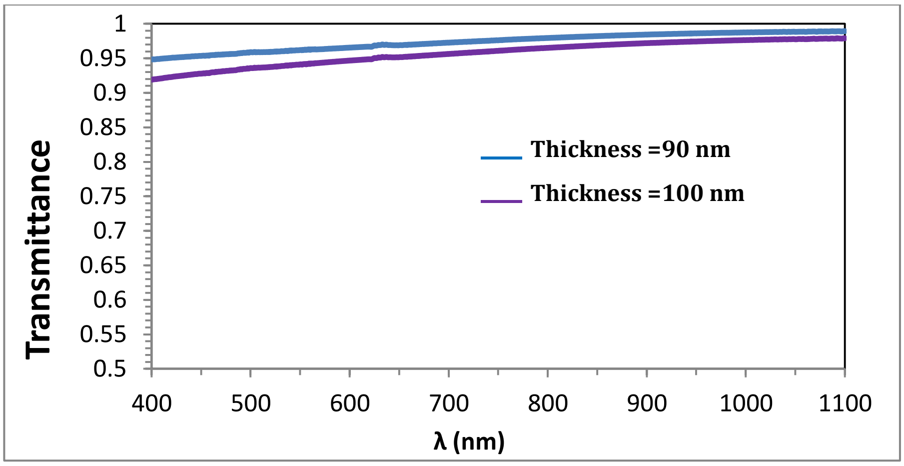


Fig. 2: Transmittance as a function of wavelength for MgO films for different thicknesses (90 and 100 nm).

The average transmittance in the spectra (400-1100nm) is about (91-97%). 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 90 nm thick, which decreased to 91% upon increasing the thickness to 100 nm. 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, and this leads to increase absorbance and decreasing transmittance.

The absorbance spectra of MgO thin film in the spectral range (400-1100) nm on glass substrate are shown in Fig. 3.

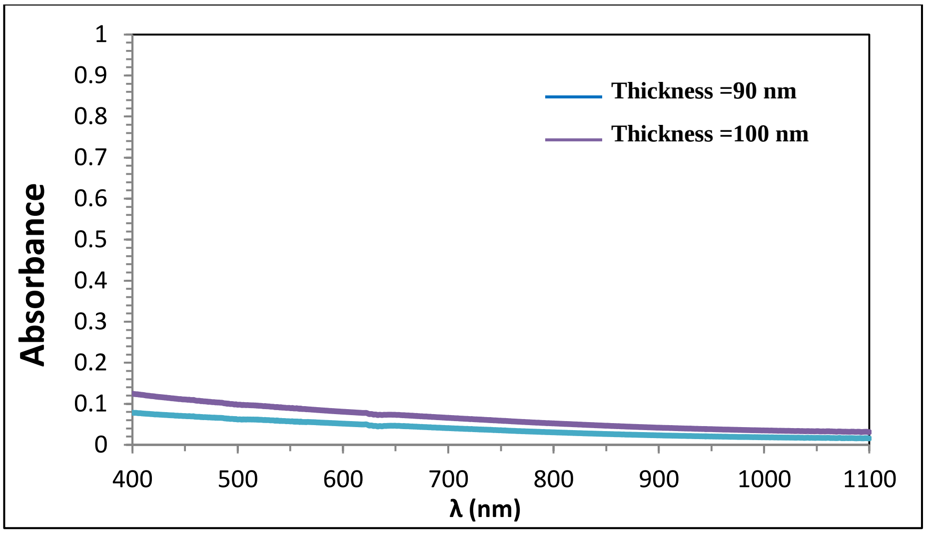


Fig. 3: Absorbance as a function of wavelength for MgO films of different thicknesses.

This figure shows the absorbance of MgO films increase with increase thicknesses of layer.

The absorption coefficient α is determined by using Eq. (6) the variation of the absorption coefficient of the MgO films is a function of wavelength as shown in Fig. 4. The absorption coefficient values are larger than (10^4 cm^{-1}) for all films. It can be noticed that α in general increases with increasing of thicknesses layers.

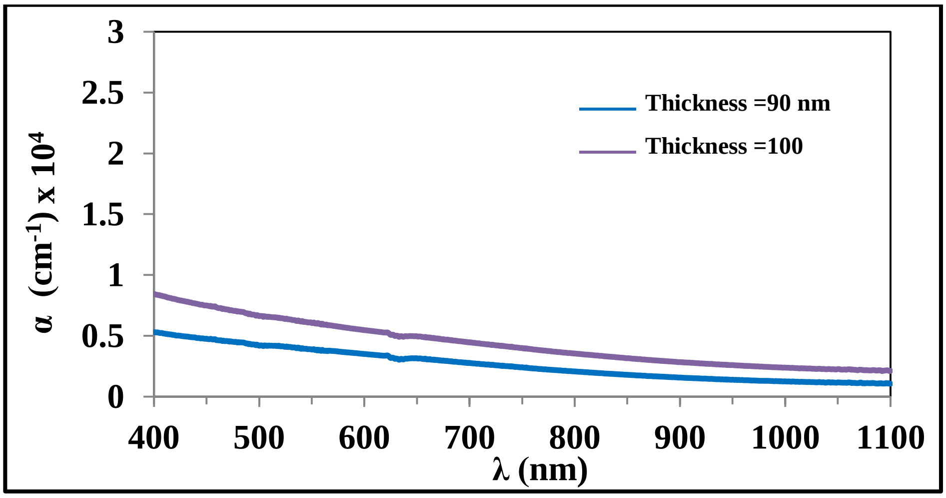


Fig.4: Absorption coefficient (α) as a function of wavelength for MgO films of different thicknesses.

The relation between refractive index and wavelength in the range (400–1100) nm, for different thickness (90 and 100) nm at annealing temperature (500 K) are shown in Fig.5. This figure shows dispersion phenomenon. This Figure also, shows the value of the refractive index various with wavelength have value between (1.17 and 1.53). More it can be observed in this Figure that the refractive index increases with increasing film thickness [16].

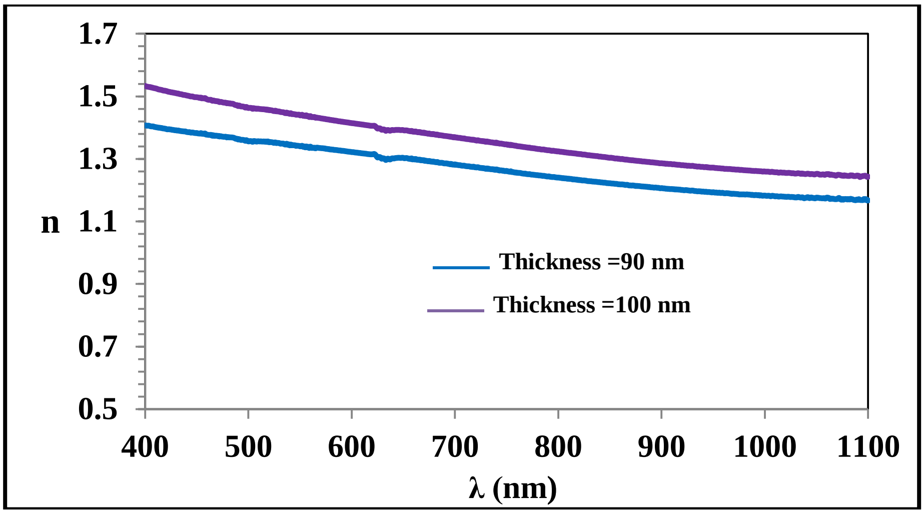


Fig.5: Refractive index as a function of wavelength for MgO films of different thicknesses.

The extinction coefficient (k) is calculated by using Eq. (5). The variation extinction coefficient as a function of wavelength for MgO thin films with different thicknesses (90 and 100) nm are shown in Fig. 6.

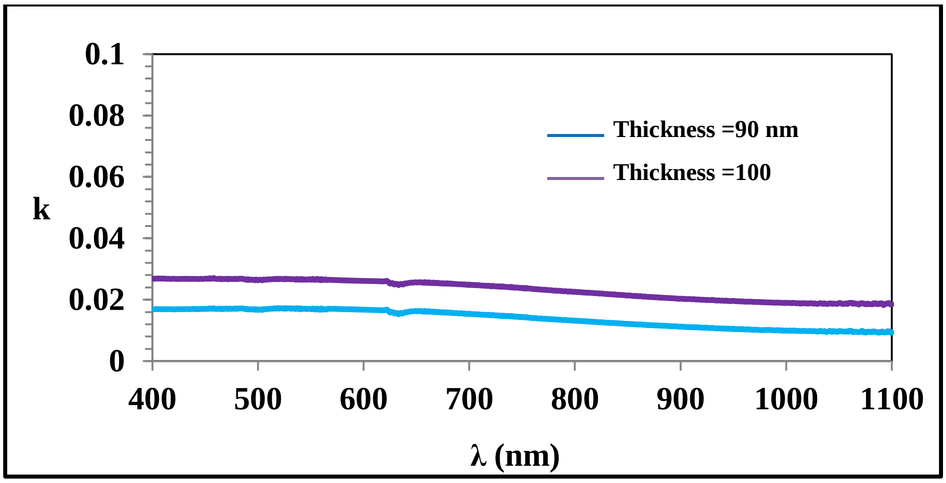
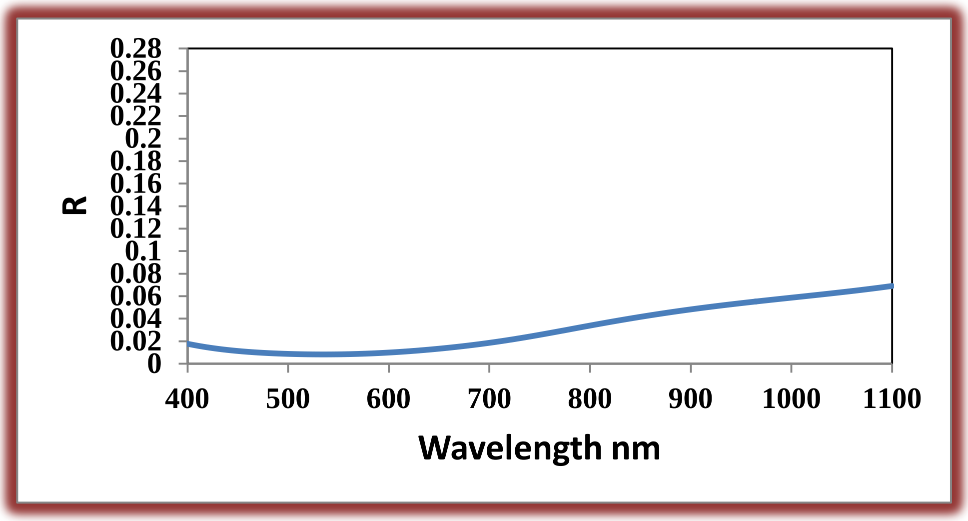


Fig.6: Extinction coefficient as a function of wavelength for MgO films with different thicknesses.

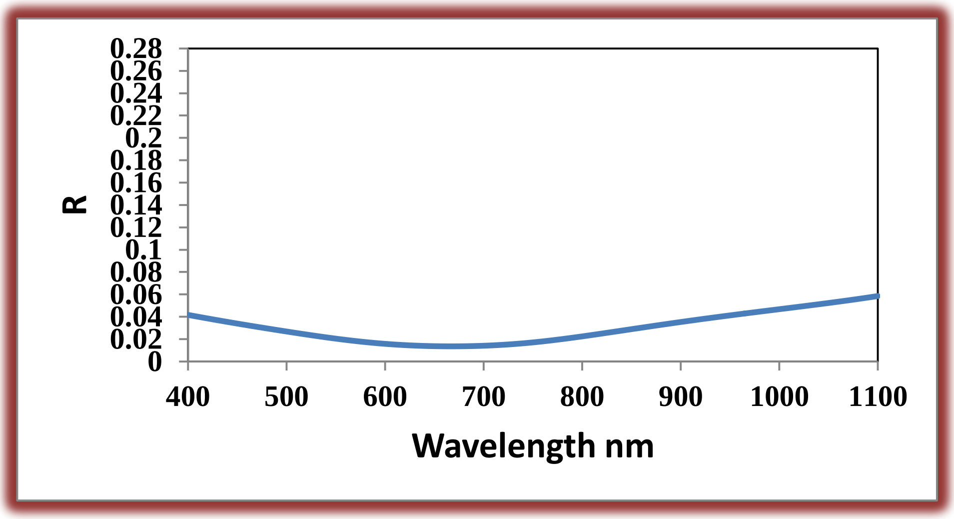
From this figure it can be noticed that the extinction coefficient (k) takes the similar behavior of the corresponding absorption coefficient. It can also be noticed that the extinction coefficient increases with increasing thicknesses layers [17].

2. Fabricating and comparing between experiment and theoretical optical performances of AR'C.

The optical performance of AR'C is computed with the aid of Eq. (2) and MATLAB over the wavelength range (400-1100 nm) with thicknesses films (90 and 100) nm and accredited on optical constants (n, k) of films as shown in Fig. 7.



(a)



(b)

Fig.7: Optical performance of AR'C for experiment result for thicknesses (a:90 nm, b:100 nm).

This Figure shows fabricated AR'C for visible – near IR region at shots number (700 and 800) and thickness (90, 100) nm respectively.

Fig. 7(a) shows optical performance of AR'C with low reflection at design wavelength (550 nm) at 700 shots and 90nm. While Fig. 7(b) shows to AR'C with low reflection at wavelength 668 nm.

The comparison of optical performances between experiment and theoretical results for sample of shots number 700 at 90 nm thickness are shown in Fig. 8. This Figure shows convergence between experiment and theoretical results in two region visible and near IR.

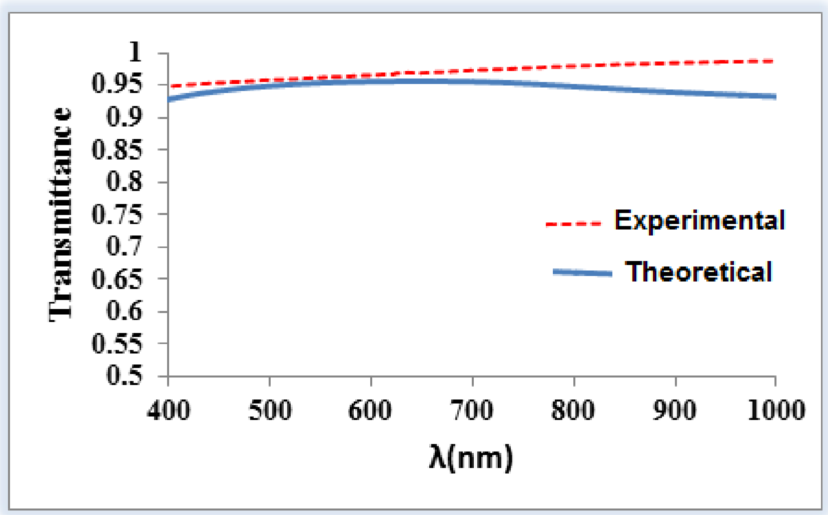


Fig.8: comparison of optical performances for AR'C between experiment result (…….) and theoretical results (——) at (90 nm) thickness.

3. X-ray diffraction (XRD) for MgO thin films

XRD study was carried out in order to get an idea about the structure of MgO thin film prepared by PLD techniques. The X-ray diffraction measurement was carried out on MgO thin films deposits at number of shot equal to (700 shot of 90 nm thickness).

Fig.9 and Table 1 explain the structure of annealed film which found to be polycrystalline structure for sample with the dominant orientation in the (200) direction and weak peak at (111) and (220). Result of XRD is compared with standard (96-901-3272). It can be observed that significant in crystalline is cleared. The X-ray diffraction data of thin film coincides with that of the known polycrystalline cubic MgO peak.

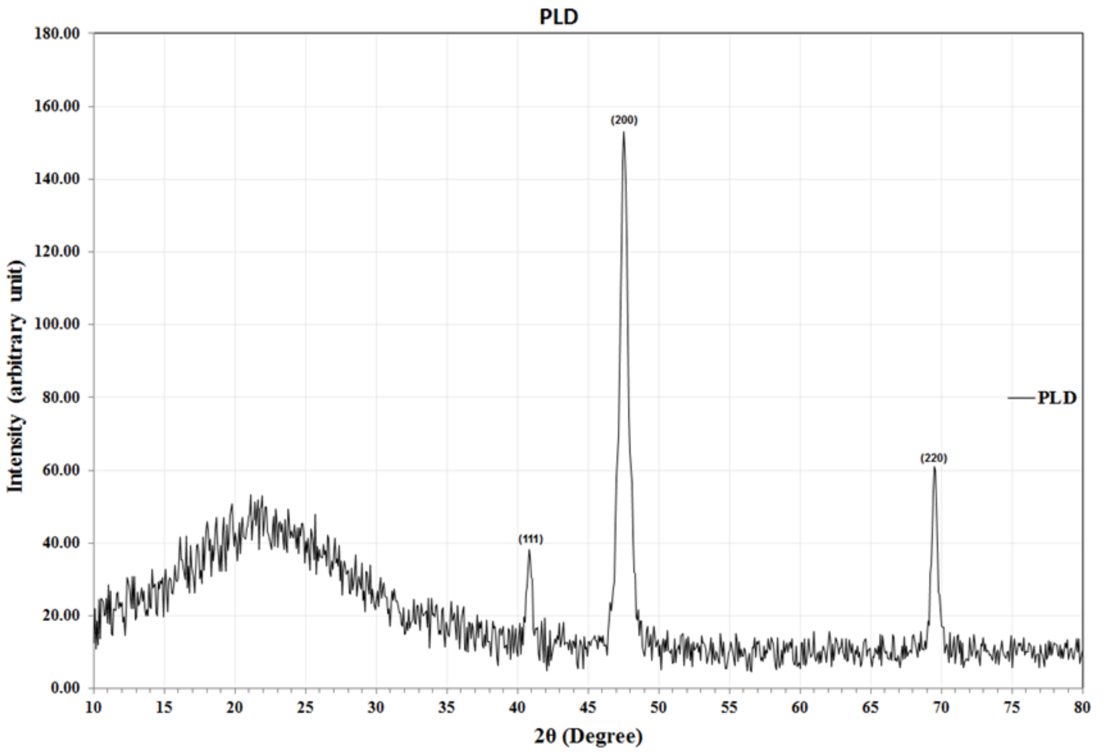


Fig .9: X-ray diffraction for MgO thin film.

Table 1: X-ray diffraction for MgO thin film.

2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	C.S (nm)	hkl	d_{hkl} Std.(Å)
40.8870	0.3100	2.2054	27.4	(111)	2.2061
47.5580	0.4210	1.9104	20.6	(200)	1.9105
69.5430	0.5130	1.3507	18.9	(220)	1.3509

Conclusions

There is a fabricated AR'C at annealing temperature (500K) and Number of shots (700 and 800). The optical performance of AR'C with low reflection at design wavelength (550 nm) of 700 shot and wavelength (668 nm) at 800 shot and the XRD results give the polycrystalline of cubic structure at annealing temperatures and the preferred orientations are (111) (200) (220) for MgO films.

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