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تحضير نوافذ بصرية لمنطقة الأشعة تحت الحمراء (3– 5) مايكرو متر باستخدام مادة أوكسيد الألمنيوم

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الخلاصة

تم في هذا البحث تحضير نوافذ بصرية تعمل ضمن الطول الموجي لمدى الأشعة تحت الحمراء باستعمال طلاء غير عاكس من مادة أوكسيد الألمنيوم (Al_2O_3) على قواعد من (ZnSe) بحيث يغطي النافذة الجوية (3–5) مايكرو متر. فباستعمال ثمان طبقات من أوكسيد الألمنيوم وعلى جانبي القاعدة كانت أعظم نفاذية بحدود 97% عند الطول الموجي 4.4 مايكرومتر.

Preparation of Optical Window in the Infrared Region (3-5) µm Using Al_2O_3 Material

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Abstract

In this work optical window for infrared region was prepared by using Aluminum Oxide (Al_2O_3)material as antireflection coating on ZnSe substrate which covers the atmospheric window 3-5µm. the maximum transition was 97% at a wavelength 0f 4.4µm.

Introduction

Antireflection phenomenon was first recognized by Raleigh and Fraunhofer in the 19^{th} century as a spontaneous process on atmospherically tarnished lenses (1). In 1934 Bauer (2) deduced that the reduction in reflectance is primarily due to interference phenomena. This phenomenon has been put in to good use in 1930 when the process of vacuum evaporation borrowed from the electronic industry, enabled the controlled industrial deposition to be introduced as what is subsequently called "antireflection coating (ARC)(3)".Nagendra and Mohan studied the antireflection coating phenomenon by the deposition of more than one of thin film layers in series(4). Grebenshchikov et al. (5) have published in 1946 the first book in antireflection coating of optical surfaces including the multilayer coating. ARC's enter new stage when characteristic matrix theory is submitted and discussed by Abeles (6) in 1950. Hrepin (7) and Epstein (8) put mathematical equations for designing optical filters. Also, Wellford (9) described a design of single layer ARC's with the aid of "Vector method". In all the optoelectronic devices and systems the optical windows can be considered as an optical filters for a specified spectral region. In order to minimize the losing power through reflection, it is useful to use the ARC technique for these windows (10). Novel design procedure of broad band multilayer ARC for optical and optoelectronic devices were deduced by (11).

The aim of this work is to manufacture infrared optical windows by using multilayer ARC's (Al_2O_3) deposited on ZnSe substrates.

Theory:

When light incident from media (n_o) with angle (Φ_o) on antireflection coating film (n_1) deposited on substrate of refractive index (n_s).

We obtain R_{max} (maximum reflectivity and R_{min} (minimum reflectivity) if (12): $n_s \geq n_1 \geq n_o$

$$R_{max} = \left[\frac{(n_s - n_o)}{(n_s + n_o)}\right]^2 \qquad when\, n_1 d_1 = \frac{\lambda}{2}, \lambda, \ldots\ldots \qquad [1]$$

$$R_{min} = \left[\frac{(n_1^2 - n_o n_s)}{(n_1^2 + n_o n_s)}\right]^2 \qquad when\ n_1 d_1 = \frac{\lambda}{4}, \frac{\lambda_3}{4}, \ldots\ldots \qquad [2]$$

Where:

$n_1 d_1$ is the optical thickness of the film

λ is wavelength of the incident light

$\delta = \left({}^{2\pi}/_{\lambda}\right) n_1 d_1 \cos \Phi$ Phase difference, d_1 is a film thickness

Thin film calculations (TF-CALC) program package was used to calculate the percentage of transmission and reflection of coating layers.

According to our calculations, the following design was used to get a high transmission on ZnSe substrate: (L_8HL_8)

L: is a layer with a low refractive index such as Al_2O_3

H: is a layer with a high refractive index such as ZnSe

From this design the maximum transmission was about 82.3% at the wavelength of 4.55μm for one face coating as shown in Fig. (1) And about 99.8% for both faces coating as shown in Fig. (2).

It is clear from these figures that, the importance of using antireflection coating on both sides of substrate is to get a high transmission and a minimum reflection.

Experiment

The type and surface features of the substrate have a great influence on the properties of the deposition films into the substrate.

In this work ZnSe substrate were used, the polishing machine and grinding for these substrates were performed by using a polishing machine type TF-250 from (TEANWARTZ CO., Germany), and using diamond pastes with different smooth degrees (0.25, 1, 3, 9)μm for each smooth degree has a special polishing cloth. Then, these substrates were chemically cleaned as follows:

1- Using chemical solutions such as methanol then insert it in the ultrasonic device for 15 min.
2- ZnSe were immersed in 2.5% HF then rinsed with demonized water and immersed in methanol, substrates where then dried with special smoothing papers.

The Al_2O_3 with purity 99.999% was deposited on both sides of ZnSe substrates by using thermal evaporation machine type (Varian). The film thickness was measured by crystal monitoring which work with mechanical shutter to stop the deposition process when we reach the desired thickness. The thickness for each Al_2O_3 layer was 195nm.

The transmission for these ZnSe substrates without coating were measured by using Fourier Transform Infrared (FT-IR) spectrophotometer as shown in Fig. (3). the maximum transmission was 72%. After that, these ZnSe substrates and high purity Al_2O_3 material were placed in a vacuum coating machine having electron gun and operating voltage 6KV under vacuum of 10^{-5} mbar.

Results

1- The maximum transmission was about 82% for ZnSe window after coating with eight layers of Al_2O_3 ARC's for one face of substrate (thickness of each layer = 195 nm) as shown in Fig.(4).
2- The transmission became 97% for these ZnSe substrates after coating with eight layers of Al_2O_3 ARC's on both faces of the substrate as shown in Fig.(5).

Conclusion

From the previous results it is possible to fabricate optical window with maximum transmission of 97% by using eight layers of Al_2O_3 ARC's on both faces of ZnSe substrate. These results are in agreement with the theoretical results deduced from (TF-CALC) program package.

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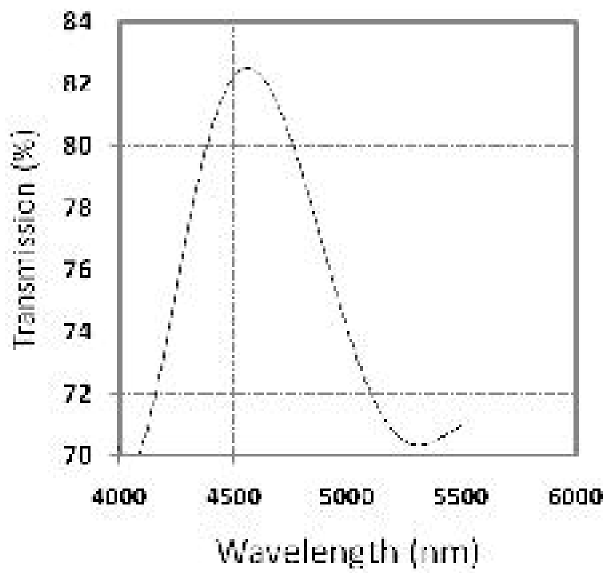

Fig. (1) the relation between transmittance and wavelength for ZnSe with coating on one side

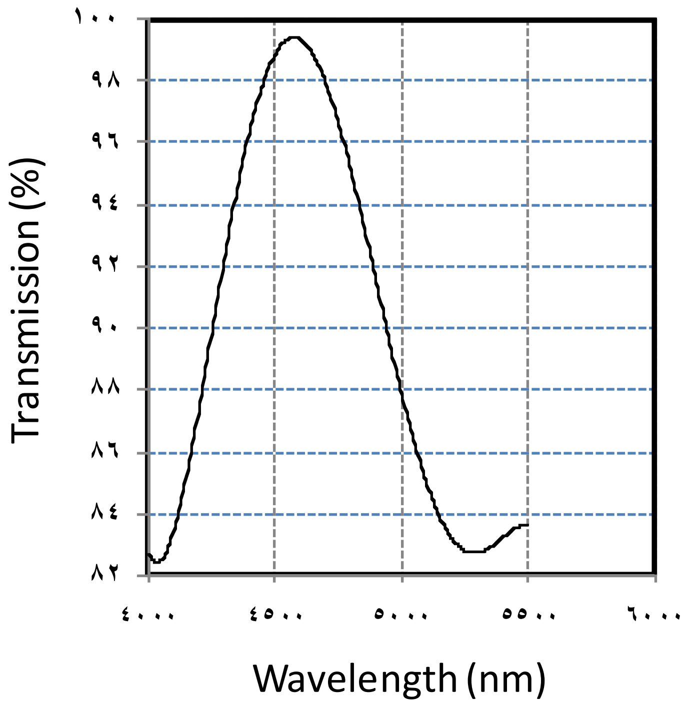

Fig. (2) the relation between transmittitance and wavelength for ZnSe with coating on both sides

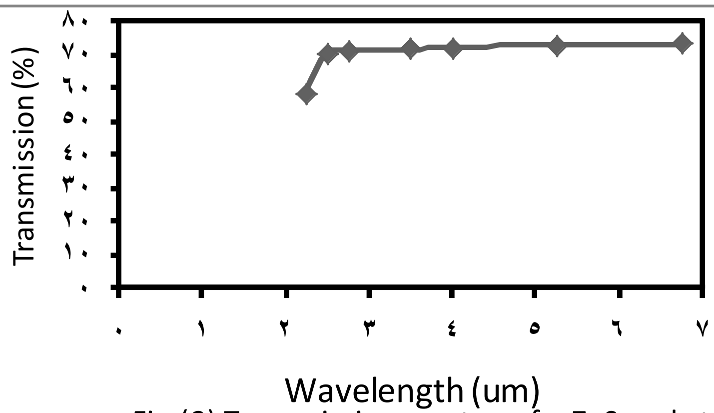

Fig.(3) Transmission spectrum for ZnSe substrate

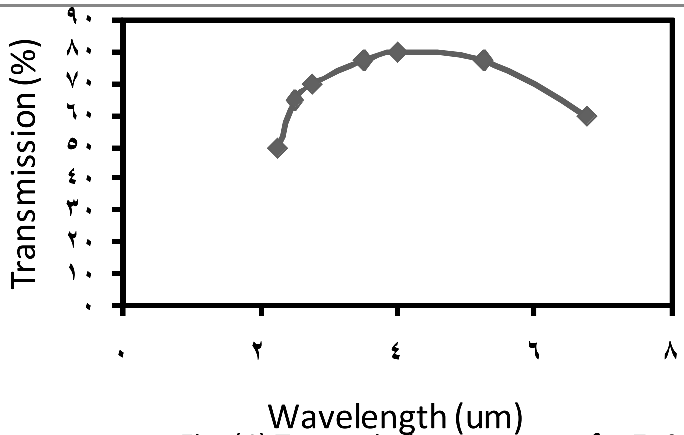

Fig. (4) Transmission spectrum for ZnSe substrate with antireflection coating (Al_2O_3)on one side

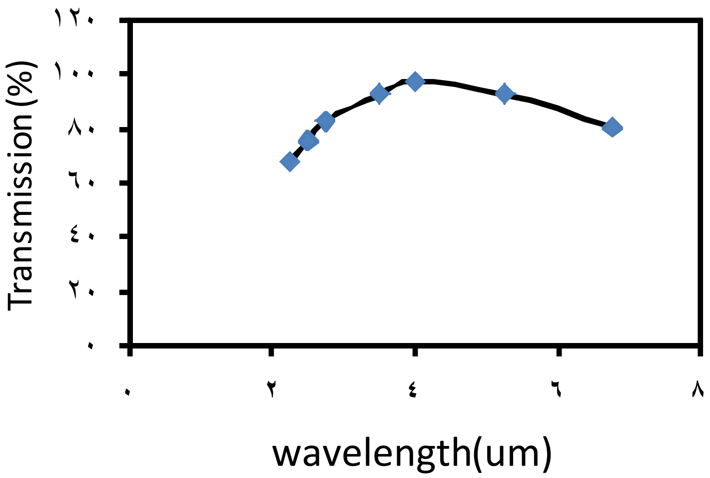

Fig. (5) Transmission spectrum for ZnSe substrate with antireflection coating (Al_2O_3) on both side