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Influence of physical plasma etching treatment on optical and hydrophilic MgF_2 thin film

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ABSTRACT

In this study, MgF_2 thin film was prepared on glass substrate by thermal evaporation method. After that surface of the MgF_2 thin film was improved using physical plasma etching treatment by plasma enhanced chemical vapor deposition (PECVD) equipment. Structural properties and surface morphology and roughness of the thin films were evaluated by GIXRD, FESEM and AFM, respectively. Also optical properties were investigated throughout measurement of transmission spectra and refractive index in visible region by use of UV/vis spectrometer and ellipsometer, respectively. Water contact angles of the surfaces were measured by water contact analyzer. Results of the research indicated that transparency of the MgF_2 thin films remind without change and hydrophilic properties of the MgF_2 thin films turned to superhydrophilic properties after physical plasma etching treatment.

1. Introduction

Because of high transparency in wide range of wavelength (from about 0.12 μm in ultra-violet out to about 7 μm in mid-infrared), low refractive index, highly stable against humidity and mechanical abrasion, MgF_2 thin film is one of the most usable coatings for application as optical and electro optical devices such as photovoltaic cells, solar collectors, resonators used in high power laser devices and IR diodes [1–5]. But with regard to many of research MgF_2 surface has hydrophilic nature. So there are possibility for creation of water droplet and fog on the surface of MgF_2 thin film in rainy weather or humid condition. This is cause to decrease at transmission and optical performance of MgF_2 thin film. So, wettability of the MgF_2 thin film must be change to superhydrophilic. To solve of this problem, two types of processes exists that shift surface of hydrophilic materials to superhydrophilic. One of them is change in surfaces geometry and other is change chemically in the surfaces. In addition to creation of MgF_2 thin film with porosity by sol-gel method [6], there are several surface modification methods were proposed, including chemical treatment, physical and chemical plasma etching treatment, electrolytic oxidation, and coupling agents [7,8]. Among these methods, plasma etching treatment is one of the most promising processes due to its advantages such as surface modification without affecting on bulk properties [9]. Physical plasma etching is carried out with non-active gases such as Ar and chemical plasma etching is performed with active gases such as O_2 [7].

Thomas ae al, fujihara et al and many of other researcher [6,10–15] manufactured porous MgF_2 thin film by use of sol-gel method to improve optical properties but MgF_2 thin film product by this method has no suitable environmental durability. Saxena et al. fabricated single layer MgF_2 thin film by thermal evaporation method. He reported antireflection properties

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Table 1
Plasma etching parameters.

Gas type	Ar
Power (W)	100
Working pressure (Torr)	0.2
Time (min)	2
Temperature of process (°C)	25

of the thin film but without searching on wettability properties and surely just applicable in dry condition [2]. Maleki et al. applied noncontact and nondestructive method laser shock peening process to improvement of optical transmission and antireflection properties of MgF_2 thin film but such as pervious research, without working on wettability properties [5].

In the percent study, effect of physical plasma etching on wettability and optical properties of MgF_2 thin film coated on glass substrate by thermal evaporation technique is evaluated.

2. Experimental

2.1. Materials and methods

In this research, soda-lime glass slides with a dimension of $76 \times 26 \times 2\,mm^3$ were used as substrates. First coating of the MgF_2 thin films on glass substrate was carried out by thermal evaporation apparatus while deposition rate was selected equal to 1 nm/s and substrate temperature was set on 290 °C. It must note that magnesium fluoride tablet with purity of 99/99% utilized as primary material. Afterward plasma etching treatment was performed on the surface of the thin films by use of radio frequency plasma enhanced chemical vapor deposition apparatus. (RF-PECVD; 13.56 MHz, Plasma Fannavar Amin Co, Iran). Plasma etching parameters are summarized in Table 1.

2.2. Characterization

Structure of the MgF_2 thin film was examined via grazing incidence X-ray diffractometer (GIXRD; X'Pert Pro MPD). Cross-section image and surface morphology of the thin films, before and after plasma etching treatment, were observed using by Field Emission Scanning Electron Microscope (FESEM; TE-SCAN, MIRA3, USA). Atomic force microscope (AFM; DME, Dual Scope C-26, Germany) used for measurement of the thin film surface roughness, before and after plasma etching treatment at non-contact mode. RMS was obtained from average of three different points in the thin film surfaces. The transmittance and reflectance spectra of the thin films were obtained using a UV–vis spectrophotometer (PG instruments Ltd, T70) at normal incidence in the wavelength between 300 to 800 nm. Refractive index of the MgF_2 thin film coated on glass substrate in range of wavelength 300–800 nm was measured by means of ellipsometry (SENpro). In order to evaluation of the surface wettability, the water contact angles were measured by use of a digital microscope (Dino-lit, AM-8515T8-Edge) with droplet volume of 4 μl. The water contact angle was averaged from three measurements.

3. Results and discussion

GIXRD pattern of MgF_2 thin film has been shown in Fig. 1 GIXRD result showed that a broad peak with center of $2\Theta = 25°$ has been formed, indicated that MgF_2 thin film has amorphous structure. Of course as seen in the picture, existence of low intensity (110) diffraction peak at $2\Theta = 27°$ verify formation of modicum content crystalline MgF_2 thin film at the research deposition condition [16,17]. It is important to state that materials with amorphous structure due to lack of grain boundaries are appropriate for optical application and MgF_2 thin film crystallized as the substrate temperature increased above 300 °C [1,16].

Refractive index is one of the most important factors that influence on antireflection properties of the thin film [17]. Effect of refractive index in concerned with the thickness using Eq. (1):

$$nd = \lambda/4 \tag{1}$$

Where λ is expected wavelength (middle of visible region, 550 nm), d is physical thickness (thickness of thin films) and n is refractive index of thin films.

Thus optimum thickness for maximum transmission at special wavelength was calculated with Eq. (1). In fact, optical thickness of the thin film (nd) must be equal to an odd number of quarter wavelengths [2]. The spectral dependence of the refractive index for MgF_2 thin film is presented in Fig. 2. According to ellipsometry spectra, refractive index of the MgF_2 thin film at 550 nm is 1.385. Therefore with regard to Eq. (1), deposition of the MgF_2 thin film with thickness of 99.3 is necessary to maximized transmission.

Fig. 3 Shows transmission spectra of bare glass substrate and glass substrate coated with MgF_2 thin film, before and after physical plasma etching treatment. As seen in Fig. 3, because of low refractive index, deposition of MgF_2 thin film increased transmission from 91.4% to 94.3% at 550 nm. It is in good agreement with previous studies [13,18]. Also from results observed