Preparation of wide optical spectrum and high antireflection MgF₂ thin film with SF₆ as reactive gas

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Abstract

In order to suppress F-deficiency, SF₆ was added into the working gas Ar₂ as the reaction gas to deposit MgF₂ thin film on quartz glass substrate with radio frequency (RF) magnetron sputtering, and the effects of working pressure on the chemical compositions, microstructure and property of MgF₂ thin film were investigated. The results show that with the working pressure increase from 1.0 to 2.5 Pa, the atomic ratio of F:Mg decreased continuously, and reached 2.02 at 2.0 Pa, very close to the ideal stoichiometric ratio of 2:1; the crystallinity of MgF₂ film improved first then decreased, and finally changed into amorphous state; the particles’ profile of MgF₂ film became clearer and their size increased significantly at first, but finally their profile became blurred. The refractive index of MgF₂ film decreased first and then increased, and got the lowest value at 2.0 Pa, 1.384, almost equal to that of MgF₂ bulk crystal. The transmittance of the coated glass within 300–1100 nm (hereinafter referred to as the transmittance of the thin film) increased first and then decreased. The transmittance of all films was higher than that of the bare glass substrate (93.2%), that is to say, all films had antireflection effect. The film transmittance reached 94.99% at 2.0 Pa, higher than that of the bare glass substrate by 1.79%, and higher than the simulated value calculated with G-Solver software by about 0.5%.

1. Introduction

One of the reasons for the solar cell conversion efficiency loss is that the photovoltaic glass has a reflection of nearly 10% to the incident sunlight. The most direct and convenient way to increase the solar cell’s conversion efficiency is to reduce its surface reflectivity and increase the absorption of sunlight. One of the most commonly used methods of antireflection is to coat a layer of antireflection film on the surface where solar cells absorb sunlight to reduce the light reflection. The antireflection film can be divided into single-layer, double-layer and multi-layer antireflection films, as well as multifunction films. The material selection of antireflection film not only depends on the band of the light to be antireflection, but also satisfies the requirements of other functions of antireflection film, such as protective film needs higher hardness, oxidation resistance and corrosion resistance etc. Zheng et al used the TiO₂ film with high refractive index not only to improve the visible light transmittance of the thermochromic VO₂ film, but also to protect the VO₂ film [1]. The crystal TiO₂ film with gradient oxygen defect can not only be used as the protective layer of photovoltaic devices, but also be used to allow carriers to transmit with low resistance to achieve high efficiency [2]. NiOx-based protective layer with oxygen defects also could enhance charge separation and transfer [3]. For space solar cells, the antireflection film needs a wide spectrum, such as 380–1100 nm, good chemical stability and resistance to cosmic ray irradiation. As the lowest refractive index material in nature, MgF₂ is one of the most competitive materials for the antireflection film of space solar cell glass cover because of its wide transmission spectrum, good chemical stability, radiation resistance and mechanical properties [4].

There are many methods to prepare MgF₂ thin films, including sol-gel, vacuum evaporation, and magnetron sputtering etc. Hannes et al prepared MgF₂ sol at low temperature, and deposited it on glass to get porous MgF₂
film, of which refractive index was 1.38, in good agreement with that of the MgF₂ bulk crystal [5]. Nock et al also prepared porous MgF₂ thin film with sol-gel method, which had the smallest reflectivity at 600 nm wavelength, 0.2% [6]. The biggest advantage of sol-gel method to prepare MgF₂ thin films is that it can effectively suppress F-deficiency defect. Its biggest disadvantage is that the film is porous, and its chemical stability, mechanical properties and radiation resistance need to be further improved. Andenet et al deposited MgF₂/BN film on the surfaces of GaAs and Si with vacuum thermal evaporation, which reduced the reflection loss to less than 5% over a wide window of the solar irradiance (1.1–3 eV) [7]. Cid et al deposited MgF₂/ZnS bilayer film on the surface of silicon solar cell with vacuum evaporation, and successfully prepared broadband antireflection film [8]. Jahanbakhsh et al deposited MgF₂ on the glass substrate with electron beam evaporation and they found that the measured spectrum of the sample was relatively consistent with the theory, and the film had the effect of increasing transmittance in the band of 400–1000 nm [9]. Gholampour et al deposited MgF₂/ZnS thin films on ZnS substrates by physical vapor deposition (PVD), the three-layer film of MgF₂/ZnS/MgF₂ increased the average transmittance of the double-side coated sample in the wavelength range of 8–12 μm by about 26% [10].

The principle of magnetron sputtering is to bombard the target with high energy ions. The target materials are sputtered to the substrate surface in the form of ions, atoms or molecules to form thin films. Compared with ordinary physical vapor deposition, such as vacuum thermal evaporation, magnetron sputtering has some advantages. First of all, it has considerable flexibility. It can deposit metal films with direct current (DC) power, medium frequency (MF) power or RF power. It can also deposit many kinds of ceramic films with metal targets by reactive sputtering, or with ceramic targets directly by RF power or MF frequency power. It can also deposit films with multiple targets co-sputtering to facilitate various doping. Secondly, due to the high kinetic energy of the splashed particles, they hit the substrate surface at a high speed and deposited into a film, so the adhesion between the film and the substrate is strong; for the same reason, the film is relatively dense. Thirdly, a few of the process parameters such as sputtering power, work pressure, and substrate temperature etc., can effectively affect the yield of the sputtered particles, so magnetron sputtering can obtain high preparation efficiency via these parameters’ adjusting. Therefore, magnetron sputtering has been widely used in the preparation of various inorganic functional films, and the equipment has become very cheap. Of course, it has been also used to prepare MgF₂ antireflection film. Lee et al prepared CeO₂/MgF₂ thin film with magnetron sputtering, of which reflectivity decreased to 1.87% in the wavelength range of 400–1100 nm, and the conversion efficiency of solar cells was improved successfully [11]. Stefan deposited metal Mg on glass substrate with direct current magnetron sputtering, where Ar₂, O₂ and CF₄ gas were introduced into the reaction chamber. And MgF₂ thin films were prepared, of which reflectivity at 760 nm decreased to 5.2%, and the average transmittance reached 93.4% when applied to solar energy equipment [12].

On the other hand, magnetron sputtering has its own disadvantages. One of the main disadvantages is that most of the target materials are sputtered out and deposited on the substrate surface in the form of ion rather than molecular during the sputtering of fluoride, oxides and other compounds, thus the film will have some chemical composition deviation. The main defect of MgF₂ thin films prepared by magnetron sputtering is the F-deficiency, it is very difficult for the atom ratio of F: Mg to reach the ideal stoichiometric ratio of 1:2. There are many factors that affect the film’s chemical stoichiometric ratio, including the quality of target material, the components and their ratio of working gas, the sputtering process parameters, such as the working pressure, the substrate temperature, and the sputtering power and so on. When the target, the substrate temperature and the sputtering power are determined, the working pressure, especially the partial pressure of reactive gas, has an important influence on the atomic ratio of compound film. Huang et al [13] prepared VO₂ films on quartz glass substrates with RF magnetron sputtering under various oxygen partial pressures, and found that the variation of oxygen partial pressure changed the film’s phase components, crystallinity, transmittance and sheet resistance. And the luminous transmittance of the film increased as high as 55.6%, while the solar modulation ability first increased to a maximum of 10.8% and then decreased as the oxygen partial pressure increased. Wamwangi et al [14] investigated the effect of oxygen flow rate on the structural and optical properties of zinc oxide thin films prepared by RF magnetron sputtering, and found that the oxygen flow rate affected the films’ crystallinity, thickness, optical reflectance spectrum and emission characteristics. Lee et al [15] deposited 30 nm-thick InZnSnO film transistors with RF magnetron sputtering with various oxygen partial pressures, and found that the oxygen partial pressure affected the overall electrical properties of the thin film transistors, which was associated with the change of interface trap density. Zheib etc [16] deposited vanadium carbide coatings with RF reactive magnetron sputtering at different nitrogen partial pressures. They found that the increase of nitrogen concentration from 0 to 27 at. % led to the decrease of carbon content from 48.50 to 30.50 at. % and the nitrogen partial pressure showed a significant influence on the friction coefficient of the film due to its density and residual stress factors.

Solar cell is one of the main power sources of various space equipments, such as satellite, space workstation, planet lander, etc. The working environment of space solar cell is very bad, where the temperature fluctuates greatly, there are a lot of cosmic rays, and high-energy particles’ impact [17]. Therefore, both the radiation
resistance and the light weight are the important characteristics of space solar cells different from those of the ground solar cells. Mars exploration is one of the important goals of human being’s space exploration. Due to the scattering of a great deal of dust suspended in the atmosphere on the Mars’ surface and the absorption of carbon dioxide gas in the atmosphere, the scattering degree of the infrared light (long wave) part of the solar spectrum is far greater than that of the blue light (short wave) part, so the solar spectrum has a certain degree of blue shift [18]. Accordingly, the design for the solar cell and its glass cover of Mars Lander also needs ‘blue shift’, such as adjusting the main absorption band of solar cell to 300–1100 nm.

Herein, SF6 was added into the working gas Ar2 as a reactive gas, and MgF2 thin films were deposited on quartz glass substrates via RF magnetron sputtering with high purity MgF2 as the target material. The effects of working pressure on the structure and optical property of MgF2 thin films within 300–1100 nm were investigated.

2. Experimental

2.1. Film preparation

The light transmission process in the system of Air-MgF2 thin film (refractive index 1.38)-Quartz glass substrate (refractive index 1.46, thickness 1.0 mm) was simulated with G-solver software, and the optimal thickness of MgF2 thin film was determined to be 70 nm, and the highest average transmittance within 300–1100 nm, or so called ‘the film transmittance’, could reached 94.51%.

MgF2 thin films were deposited on quartz glass substrates (99.9%, 50 × 25 × 1) with RF magnetron sputtering. The size of MgF2 target was Φ101.6 × 3 (99.99%, Nanchang Guocai Technology Co., Ltd, China). Before sputtering, the quartz glass substrates were cleaned with ultrasonic 15 min with decontamination powder, acetone, anhydrous ethanol and deionized water in turn, and then dried in a drying oven for standby. The working gas for sputtering was high-purity Ar2 (99.999%), SF6 (99.999%) with a flow ratio of 5% was added into Ar2 as the reaction gas, and the background vacuum degree was 6.0 × 10–4 Pa. The sputtering power was set to 185 W; the working pressure was set to 1.0 Pa, 1.5 Pa, 2.0 Pa, and 2.5 Pa, respectively; the target was pre sputtered for 10 min before deposition to clean the target surface, stabilize the working pressure and RF power.

2.2. Characterization

X-ray photoelectron spectroscopy (XPS, K-alpha, Thermo-fisher, USA) was used to qualitatively and quantitatively analyze the chemical compositions of the film. X-ray diffraction (XRD, D8 Discover, Bruker, Germany) was used to analyze the crystal structure of the film, and the scanning angle ranged 10 to 80°. The film surface morphology was observed with field emission scanning electron microscopy (FE-SEM, S4800, Hitachi, Japan). The film’s thickness and refractive index were determined with a spectrum ellipsometer (COSE-DVN-D-C, Syscos Instrument Technology (Shanghai) Co., Ltd, China). The film’s transmission spectrum within 300–1100 nm was reordered with an ultraviolet-visible near infrared spectrophotometer (UV–vis-NIR, UH4150, Hitachi, Japan).

3. Results and discussion

3.1. Effect of working pressure on F: Mg molar ratio of thin film

The XPS spectra of MgF2 films prepared at different working pressure are shown in figures 1(a) to (d), respectively.

According to the standard spectra, the peak corresponding to the binding energy of about 50 eV could be attributed to Mg2p, the peak corresponding to the binding energy of about 89 eV to Mg2s, the peak corresponding to the binding energy of about 1305 eV to Mg1s. The peak corresponding to the binding energy of about 685 eV could be attributed to F1s. Figures 1(e) and (f) were two local magnifications of figure 1(a), one for Mg1s peak around 1305 eV, the other for F1s around 685 eV. These two fine spectra show the binding energy, elements and their valence states more clearly. The peak corresponding to the binding energy of about 532 eV could attributed to O1s; the peak corresponding to the binding energy of about 99 eV to Si2p; the peak corresponding to the binding energy of 285 eV to Cls. Therefore, it can be determined that the film mainly contains F, Mg, C, Si, and O elements. Among them, C and O may come from the CO2 in the atmosphere adsorbed during the sample storage and transfer process; C may also from the adhered organic matter, which comes from the transparent plastic sample bag; O may also from O2 adsorbed on the sample surface from air. Si should come from the glass substrate.

The molar ratios of F: Mg in the samples prepared at different working pressures were determined via calculation to be 2.13 (1.0 Pa), 2.10 (1.5 Pa), 2.02 (2.0 Pa), and 1.91 (2.5 Pa), respectively, according to the intensity of Mg and F peaks in each figure and an appropriate sensitivity factor. It can be seen that with the
increase of working pressure, the molar ratio of F: Mg decreases continuously, and the value 2.02 of the sample prepared at 2.0 Pa is the closest to the ideal stoichiometric ratio of 2.0 among all the values. This is mainly because with the increase of working pressure, the ratio of F$^{-}$ ion in various ions and particles ionized from SF$_6$ gradually decreases, so the molar ratio of F: Mg in the film also decreased.

Tuszewski et al investigated Ar$_2$/SF$_6$ plasma discharge with optical emission and mass spectrometry [19]. They found that when SF$_6$ gas was added into the working gas, it was mainly decomposed into lighter SF$_x$ ($x = 0$–2) and S$_2$F$_x$ ($x = 0$–1) neutral species, negatively charged F$^{-}$, and other positive ion species, such as S, S$_2$, SO, SF, SOF, S$_2$F, SF$_2$, SiF$_3$, SF$_3$, SOF$_3$, SF$_5$ etc. When the SF$_6$ gas partial pressure decreased or the sputtering power increased, the total percentage of positive ion species SF$_3$, SOF$_3$ and SF$_5$ decreased obviously, correspondingly the total percentage of positive ion species S, SO, SF, S$_2$, and SOF increased, which meant that a single SF$_6$ molecule could contribute more F$^{-}$ ions. In other words, when the partial pressure of SF$_6$ increases, the percentage of SF$_3$, SOF$_3$ and SF$_5$ etc ions with positive charge will gradually increase, while that of other particles with positive charge such as S, S$_2$, so and SF will decrease, correspondingly, the percentage of ionized F$^{-}$ ions will decrease. With the increase of working pressure, as the flow ratio of SF$_6$ remains unchanged, its partial pressure increases correspondingly, and the percentage of ionized F$^{-}$ ion decreases, so the molar ratio of F: Mg in the film also decreases. When the working pressure was 2.0 Pa, the amount and concentration of F$^{-}$ ions

Figure 1. Effect of working pressure on the XPS spectrum of MgF$_2$ film.
ionized in the vacuum chamber just made the combination of F\(^-\) ions and Mg\(^{2+}\) ions basically satisfy the ideal stoichiometric ratio of 2:1. When the working pressure increase further, the concentration of F\(^-\) ions ionized in the chamber was too low, resulting in the shortage of F\(^-\) ions in the film, and the molar ratio of F: Mg decreased to 1.91, away from the ideal stoichiometric ratio 2:1.

### 3.2. Effect of working pressure on micro structure of thin film

There is only one kind of crystal lattice structure for MgF\(_2\) crystal, tetragonal system, lattice constant of crystal cell is \(4.62 \times 4.62 \times 3.051 \times 90^\circ \times 90^\circ \times 90^\circ > \) (PDF #41-1443). Figure 2 shows the XRD patterns of MgF\(_2\) films prepared at different working pressures. It can be seen that firstly, only the characteristic diffraction peak of (220) crystal plane appears near 56° in the three diffraction patterns of the thin films prepared at 1.0 Pa, 1.5 Pa, and 2.0 Pa, respectively, the main characteristic diffraction peak of (110) crystal plane with the highest intensity and other characteristic diffraction peaks of (111), (210), and (211) crystal planes do not appear; while there is no diffraction peak in the diffraction pattern of the thin film prepared at 2.5 Pa. Secondly, when the working pressure increased from 1.0 Pa to 2.0 Pa, the characteristic diffraction peak of (220) crystal plane first became sharper then wider, and its intensity first increased greatly then decreased rapidly; when the working pressure reached 2.5 Pa, this diffraction peak disappeared. That is to say, with the increase of working pressure, the diffraction peak intensity first increases and then decreases.

The intensity, position angle and FWHM (Full width at half maximum) of the diffraction peak of (220) crystal plane of each crystallized film, as well as the molar ratio of F: Mg of each film, are listed in table 1.

| Sample | F: Mg ratio | \(\theta\) (°) | Intensity (a. u.) | FWHM | (220) interplanar spacing (nm) | Crystallite size (nm) |
|--------|-------------|----------------|------------------|-------|-------------------------------|---------------------|
| 1.0 Pa | 2.13 | 56.443 | 112 | 0.905 | 0.1629 | 10.7 |
| 1.5 Pa | 2.10 | 56.231 | 430 | 0.780 | 0.1628 | 19.0 |
| 2.0 Pa | 2.02 | 56.968 | 158 | 0.888 | 0.1615 | 10.4 |
| 2.5 Pa | 1.91 | Amorphous | — | — | — | — |

It is clear that the grain size first increases and then decreases rapidly with the increase of working pressure. In addition, the lattice constants were refined with Jade analysis software, and the (220) crystal plane spacing was calculated and listed in table 1. With the working pressure increase from 1.0 Pa to 1.5 Pa, the interplanar spacing of (220) crystal plane of the film decreases from 0.1629 nm to 0.1628 nm, and decreases further to 0.1615 nm as the working pressure reaches 2.0 Pa. These values of the interplanar spacing of (220) crystal plane are very close to 0.1633 nm of PDF card.

![Figure 2. Effect of working pressure on XRD pattern of MgF\(_2\) thin film.](image)
The absence of characteristic diffraction peaks of (110), (111) and (211) crystal planes may be due to the preferred orientation of the sputtered particles during deposition and crystallization. Compared with (110), (111), (210), and (211) crystal planes, the interspacing between (220) crystal planes is smaller (PDF No. 41–413), and the 〈220〉 crystal orientation is in the direction of non-dense arrangement of atoms, so it is easier for particles to adhere along the 〈220〉 crystal orientation. When the working pressure is low, the crystallinity of the film is low. The first reason is that the molar ratio of F: Mg is 2.13, which is larger than the ideal chemical ratio of 2:1. Secondly, the output and energy of the sputtered particles, the deposition rate of the film are relatively large, and the time for the sputtered particles to combine and react with each other is not enough. With the increase of working pressure, the output and energy of the sputtered particles and the deposition rate of the film reduced, and the combination and reaction time between the particles become sufficient, thus the molar ratio of F: Mg also approaches to the ideal chemical ratio of 2:1, so the crystallinity of the film obviously improved. When the working pressure increases to 2.5 Pa, firstly, the molar ratio of F: Mg is significantly lower than the ideal chemical ratio of 2:1; secondly, the probability of collision between the sputtered particles and gas molecules will be greatly increased, the energy of particles will be significantly reduced, and the diffusion ability of particles and the binding ability between particles will be reduced when they are deposited to the substrate surface, so there will be a great deal of vacancies and interstitial toms etc defects in the film, the crystallinity decreases significantly and even becomes amorphous.

### 3.3. Effect of working pressure on the surface morphology of thin film

The surface micro morphologies of MgF$_2$ films prepared at different working pressure are shown in figure 3.

![Figure 3. Effect of working pressure on the surface micro morphology of MgF$_2$ film (a) 1.0 Pa; (b) 1.5 Pa; (c) 2.0 Pa; (d) 2.5 Pa.](image)

It is clear that the working pressure has a significant effect on the surface morphology of MgF$_2$ film. First of all, all the film surfaces are very compact. Comparing figure 3(a) with figure 3(b), it can be seen that when the working pressure increases from 1.0 Pa to 1.5 Pa, the profile of particles on the film surface becomes clearer, and particle size increases significantly. When the working pressure increases from 1.5 Pa to 2.0 Pa, the particle size increases little, however, a nearly continuous white network is formed among particles, as shown in figure 3(c). When the working pressure continues to increase to 2.5 Pa, the particles can only be outlined by the white network, although the white network has been blurred and the size of the particles has increased significantly, as shown in figure 3(d). The change of the surface micro morphology of the film corresponds to the change of the crystallinity of the film. However, the particle size shown in figure 3 is much larger than the crystallite size listed in table 1; this is because that a single particle is composed of multiple grains that aggregated together.

### 3.4. Effect of working pressure on optical property of thin film

Figure 4 shows the refractive index spectra of MgF$_2$ films prepared at different working pressure. It can be seen from figure 4 that, as the incident wavelength increases from 300 nm to 1100 nm, the refractive index of the film decreases gradually. Secondly, with the increase of working pressure, the refractive index of the film decreases...
At first and then increases; when the working pressure is 2.0 Pa, the refractive index of the film is the lowest. Table 2 shows the thickness of each film, and its refractive index range of 300–1100 nm, as well as its refractive index at 550 nm. It can be seen that, with the increase of working pressure, the refractive index of the film at 550 nm decreases from 1.409 to 1.384 after 1.395, very close to the refractive index of the bulk MgF2 crystal, 1.38, and then rises to 1.459.

Figure 5 shows the transmission spectra within 300–1100 nm of the glass substrate coated MgF2 films at different working pressure (hereinafter referred to as the film transmission spectrum) and the transmission spectrum of the bare glass substrate. It can be seen from the figure that, first of all, the transmittance of the films and that of the bare glass substrate basically increase with the increase of wavelength except for the film prepared at 2.0 Pa, of which transmittance begins to decrease very slowly since about 560 nm. For the second, all the film spectra intersect with the bare glass substrate spectrum. The transmittance spectrum of the film prepared at 1.0 Pa or 2.5 Pa intersects with that of the bare glass substrate at about 480 nm, while the transmittance spectrum of the film prepared at 1.5 Pa or 2.0 Pa intersects with that of the glass substrate at about 410 nm. The wavelength of the junction first decreases and then increases with the increase of working pressure. That is to say, the junction first moves to the left and then to the right. At the right of the junction, the transmittance of film is higher than that of the substrate; at the left of the junction, the transmittance of film is lower than that of the substrate. According to the visual inspection, the integrated transmittance of each film should be higher than that of the bare glass substrate. And the junction of the film prepared at 2.0 Pa is on the left-most, and its transmittance on the right side of the junction is much higher than that of the bare glass substrate, therefore, the transmittance of the film may be the highest.

To integrate all transmittance spectra, the specific transmittance values are also listed in Table 2. It can be seen that with the increase of working pressure from 1.0 Pa to 2.5 Pa, the transmittance of the thin film first increased

| Working pressure (W) | Thickness (nm) | Refractive index within 300–1100 nm | Refractive index at 550 nm | Transmittance (%) within 300–1100 nm |
|---------------------|----------------|---------------------------------|--------------------------|-------------------------------------|
| 1.0 Pa              | 65.0           | 1.433 ~ 1.402                   | 1.409                    | 94.249                              |
| 1.5 Pa              | 65.3           | 1.419 ~ 1.388                   | 1.395                    | 94.306                              |
| 2.0 Pa              | 67.0           | 1.408 ~ 1.377                   | 1.384                    | 94.990                              |
| 2.5 Pa              | 63.24          | 1.483 ~ 1.452                   | 1.459                    | 93.528                              |
| Glass               | 0              |                                | 1.46                     | 93.20                               |

Figure 4. Effect of working pressure on refractive index spectrum of MgF2 thin film.

Table 2. Thickness, refractive index and integral transmittance of MgF2 film.
from 94.249% to 94.99%, and then decreased to 93.528%. It can be said that the transmittance of all the thin films is higher than that of the bare glass substrate, 93.2%, i.e., all the thin films have realized the antireflection function.

Figure 6 is based on the data in Table 2, shows more intuitively that the transmittance within 300–1100 nm of the film has a good corresponding relationship with its refractive index at 550 nm, that is, the transmittance increases with the decrease of the refractive index, and vice versa. As stated in the experimental section, the optimal thickness of MgF₂ film is 70 nm, and the highest integral transmittance calculated with G-solver software is 94.51%. However, the experimental results show that the transmittance of film prepared at 2.0 Pa is 94.99%, which is higher about 0.5% than the simulated value calculated by G-Solver software, 94.51%.

4. Summary and conclusions

In order to suppress the F-deficient defect in MgF₂ thin film, SF₆ was added into the working gas Ar₂ as the reaction gas, MgF₂ thin film was prepared on quartz glass substrate with RF magnetron sputtering. The chemical composition of the film was quantitatively analyzed with XPS, the microstructure of the film was analyzed with XRD, and the surface micro morphology of the film was observed with SEM, the transmittance of MgF₂ film and that of the glass substrate were measured with UV–vis-NIR spectrometer, and the thickness and refractive index.
of the film were measured by Spectro ellipsometer. The effects of working pressure on the structure and property of MgF₂ film were investigated. The main conclusions are as follows:

1. With the increase of working pressure from 1.0 Pa to 2.5 Pa, the atomic ratio of F: Mg continuously decreases, and reaches 2.02 at 2.0 Pa, very close to the ideal stoichiometric ratio of 2:1.
2. The crystallinity of MgF₂ film improves first, and then decreases, and finally changes into amorphous state with the increase of working pressure; when the working pressure is 1.5 Pa, the crystallinity is the highest. The particles’ profile on MgF₂ film surface becomes clearer at first, finally becomes blurred; the particle size increases significantly.
3. The refractive index of MgF₂ film decreases first and then increases with the increase of working pressure. The film’s refractive index at 550 nm gets the lowest value 1.384 at 2.0 Pa.
4. All the thin films’ transmittance within 300–1100 nm is higher than that of the bare glass substrate, i.e., all of them are of antireflection function. The transmittance of the film reaches 94.99% when the working pressure is 2.0 Pa, which make the transmittance of the bare glass substrate increase by 1.79%, and is higher about 0.5% than the simulated value calculated by G-Solver software.

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