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Enhancement of antireflection characteristic of resonant sinusoidal grating

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ABSTRACT

Broadband antireflective characteristic is frequently achieved by sinusoidal grating in the sub-wavelength domain. Also, in the resonance domain the enhancement of antireflection for broadband spectrum and wide-angle spectrum can be obtained. For external reflection grating, the total transmittance can reach to 99.9% when the aspect ratio is larger than 1.5 for both incident polarization states. For internal reflection grating, the antireflective property in relatively narrow broadband spectrum is revealed for TE polarization. But for TM polarization, broadband antireflection at appropriate grating period and groove depth is shown. It is found that the aspect ratio of grating is a significant parameter for improving antireflection performance.

1. Introduction

Recently, antireflective surface microstructure has attracted more and more attention based on its application in solar cells, highly efficient detectors, and so on [1,2]. Generally, its transmittance can be enhanced by a sub-wavelength microstructure. For sub-wavelength antireflection structures, only the reflected and transmitted zero-th orders are propagating, while the other higher diffraction orders are evanescent. In some applications, which only need highly efficient zero-th transmitted light [3,4], a sub-wavelength structure with feature size smaller than incident wavelength need to be researched. On the other hands, the feature of some applications, like detectors and solar cells, is absorbing as much radiation as possible, so the above restriction can be relaxed and higher transmitted orders are allowed [5]. Besides, when the scale of a surface structure is much larger than incident wavelength, the transmitted higher orders rather than only zero-th order play an important role in design of optical devices [6]. This larger feature size of structure can be called as the resonance domain [6].

It is well-known that the shape of grating has profound effect on antireflective performance. Dielectric transmission grating with rectangular groove was frequently investigated in theory and experiment [7]. But, theoretically, the diffraction efficiency of more than 97% in -1st transmitted order cannot be achieved due to the Fresnel reflection on interface between grating and air [8]. To further enhance total transmittance in wideband spectrum, the sinusoidal groove grating in the resonance domain is investigated in this paper.

2. Theory model of diffraction grating

Two kinds of schematic diagram of sinusoidal grating: external reflection grating with the light traveling from air to the grating, and internal reflection grating with light traveling from grating to air are shown in Fig. 1(a) and (b), respectively. In Fig.1, the period and the depth of grating are represented by Λ and h, and the refractive index of air, grating and substrate are denoted by n_0, n_g and n_s, respectively. The incident angle, the reflective angle, and the diffraction angle are represented by θ_i, θ_r and θ_t, respectively. The aspect ratio of grating is defined as h/Λ. A plane incident wave is regarded in calculation of diffraction efficiency of grating.

The diffraction characteristic of a grating can be determined by the classical grating equation as [5]

$$n_t \sin\theta_t - n_i \sin\theta_i = \frac{m\lambda}{\Lambda}, \quad (1)$$

where n_i is the index of refraction of incident medium, n_t is the transmitting medium's index of refraction, θ_i and θ_t are the incident angle and the diffraction angle of the mth order, respectively. When the grating period-to-wavelength ratio, $\frac{\Lambda}{\lambda}$, is [5]

$$\frac{\Lambda}{\lambda} < \frac{1}{\max[n_t, n_i] + n_i \sin\theta_{\max}} \quad (2)$$

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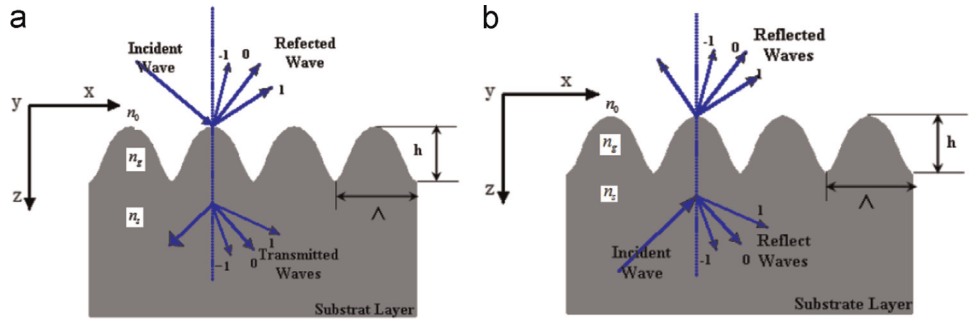

Fig. 1. Geometry of dielectric surface relief sinusoidal grating. (a) The external reflection grating and (b) the internal reflection grating.

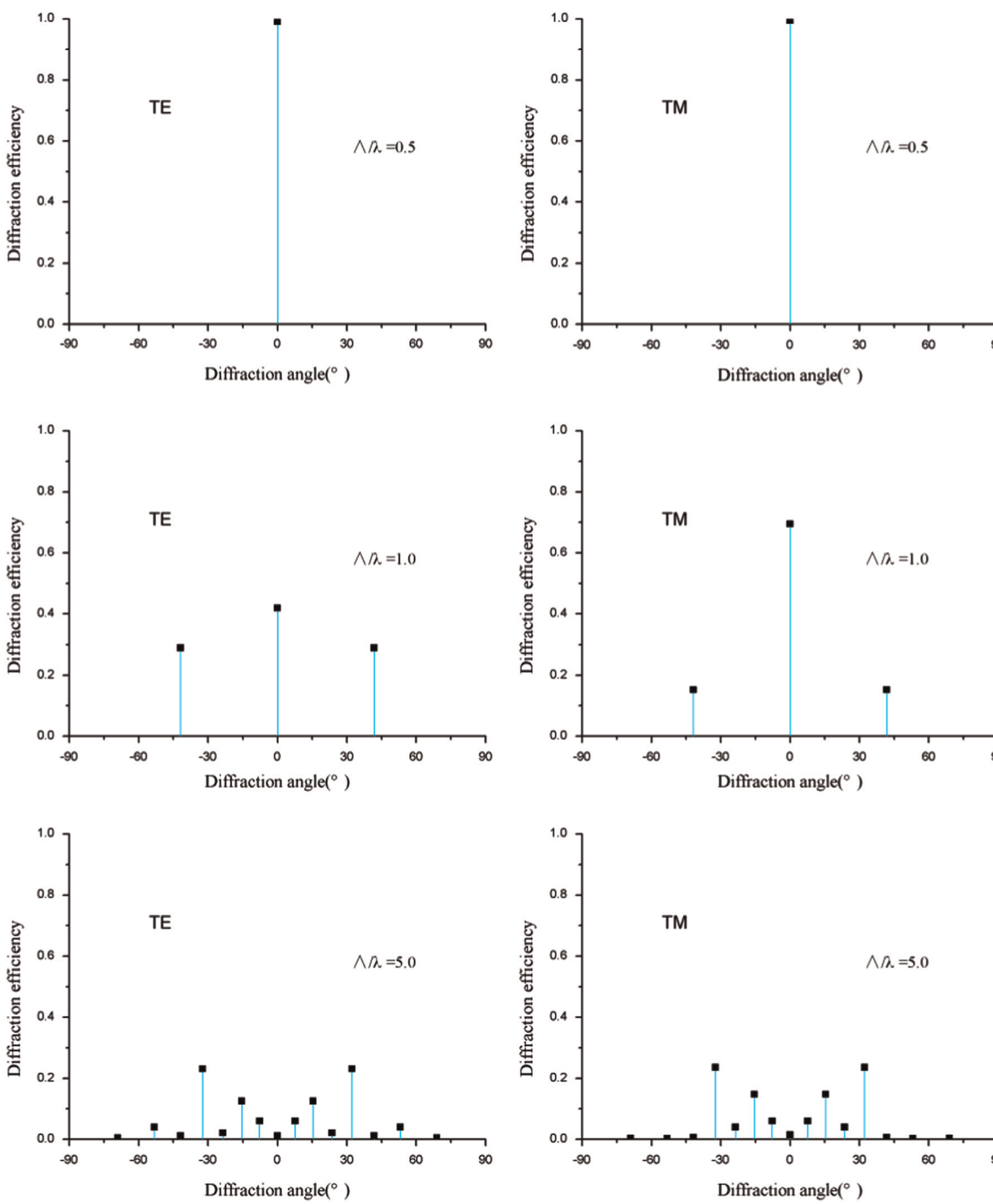

Fig. 2. Angular distribution of diffraction efficiencies for the external reflection sinusoidal grating with the illumination of TE and TM polarizations, respectively, at the normal incidence and the aspect ratio of 1.0.