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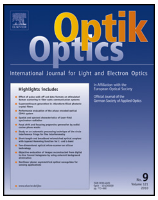

Original research article

Reflective solar blind filter based on dielectric multilayer

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ABSTRACT

We report on the design and fabrication of LaF_3/MgF_2 multilayer for use as a reflective solar blind filter. The deposited filter has the average reflectance of 36.5% in 240–280 nm, and it has the average reflectance of 1.8% in 281–760 nm. Reflectance suppression ratio between in-band and out-of-band is 20.3:1.

1. Introduction

Generally, in solar spectrum, 240–280 nm spectral region is called solar blind band. This is because that 240–280 nm lines in solar radiation are totally absorbed by the ozone layer when they go through Earth's atmosphere. This provides an advantage for detecting of solar blind radiation target on Earth surface because the background noise is very low. Detecting of solar blind radiation targets has been widely employed in fire warning [1], corona discharge recognition in electricity transfer [2], missile plume identification [3], chemical/biological sensing [4], convert communication [5].

Reflective SBF is a key optical component in detecting system of solar blind radiation target, and it can provide a high-intensity of output in 240–280 nm, meanwhile, suppression in 281–760 nm. Transmissive SBF has been successfully fabricated [6–11]. Safin et al. designed and fabricated SBF with the transmittance of about 20.0% [6]. Li and Chou prepared SBF with a 27.0% transmission peak consisting of a metal nano-grid by nanoimprint lithography [7]. Kim et al. provided a metal-dielectric multilayer SBF that is relatively insensitive to the incident angle [10]. Al/SiO_2 [9,10], Al/Al_2O_3 [8,10], Ag/SiO_2 [8] stacks were employed to fabricate transmissive SBF. As for reflective SBF, only Zhang et al. theoretically discussed the optimization of reflective MgF_2/Y_2O_3 SBF [12]. To our knowledge, until now, there is no literature about successful fabrication of reflective SBF. In this paper, we report on the design and fabrication of LaF_3/MgF_2 multilayer for use as a reflective SBF.

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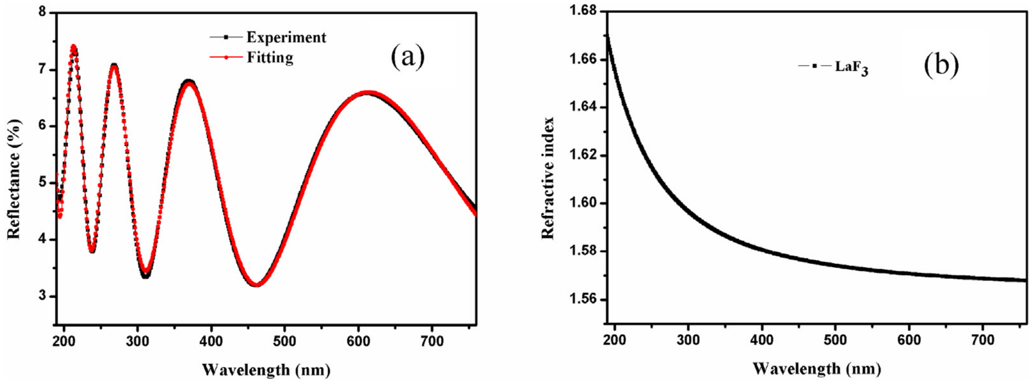

Fig. 1. (a) Fitting of measured reflectance data of a single-layer of LaF_3 with a thickness of 293 nm. (b) Wavelength dependence of the refractive index of LaF_3 films.

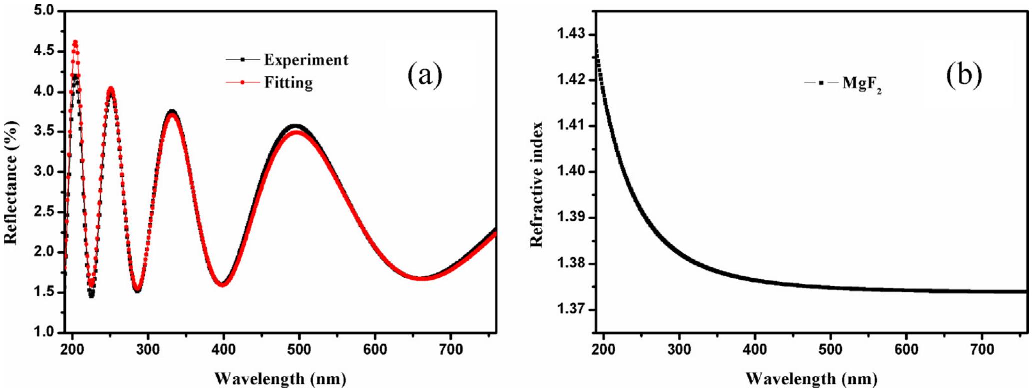

Fig. 2. (a) Fitting of measured reflectance data of a single-layer of MgF_2 with a thickness of 363 nm by model reflectance. (b) Wavelength dependence of the refractive index of MgF_2 films.

2. Design of reflective SBF

LaF_3 and MgF_2 are selected to be high- and low-index material, respectively. The optical constants of LaF_3 and MgF_2 were derived by us from characterization of reflectance for a single-layer by OptiLayer software [13]. Based on literature survey [14–16], it is found that it is reasonable that the refractive index is fitted using normal dispersion model, and the extinction coefficient is fitted using non-absorbing model in 190–760 nm. Normal dispersion model is also called as Cauchy model, and in this model, refractive index of the material is described as the one that decreases with the increasing of wavelength. Cauchy model is described by Eq. (1):

$$n(\lambda) = A_0 + A_1/\lambda^2 + A_2/\lambda^4 \tag{1}$$

where n is refractive index, A_0–A_2 are constants, and λ is wavelength. Non-absorbing model means that in this model, extinction coefficient of the material is zero.

The reflectance of the single layer of LaF_3 and MgF_2 was characterized by Lambda 1050 Spectrophotometer with a step of 1 nm in ambient atmosphere, and the incident angle is 6 °. Fig. 1(a) shows fitting of measured reflectance data of a single-layer of LaF_3 with a thickness of 293 nm, and the inhomogeneity is −2.0%; Fig. 1(b) shows wavelength dependence of the refractive index of LaF_3 films, and it is closed to that reported in Ref.14 (sample of EB, deviation of 1.2%) and 15 (deviation of 4.2%), which indicates our results are reliable. Fig. 2(a) shows fitting of measured reflectance data of a single-layer of MgF_2 with a thickness of 363 nm by model reflectance, and the inhomogeneity is −0.2%; Fig. 2(b) shows wavelength dependence of the refractive index of MgF_2 films, and it is very similar to that reported in Ref.15 (deviation of 0.7%) and 16 (sample of 250 °, deviation of 0.4%), which indicates that our results are reliable.

A traditional quarter-wave (QW) periodic multilayer and two non-periodic stacks optimized by two methods are designed. Optimized multilayer I is obtained utilizing Constrained Optimization in OptiLayer software, and Optimized multilayer II is obtained using Sensitivity-Directed Refinement in OptiLayer software. In Constrained Optimization, It is capable of setting constraints for individual layer thicknesses, and each layer can be specified whether the thickness of this layer can vary during optimization. The lower and upper thickness limits are set to be 10 nm and 100 nm, respectively, and all the layers vary during optimization I. In Sensitivity-Directed Refinement, based on the calculation of design sensitivity to