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A novel terahertz wave reflective polarizer for THz communication

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ABSTRACT

We design terahertz wave reflective polarizer that operates over a wide terahertz wavelength range and is based on a periodic bilayer structure. The structure is characterized by transfer matrix calculations. Results of simulations show that the mirror is highly reflecting for incidence angle $\theta \leq 60°$and TE as well as TM polarization in the wavelength range between 541.6 μm and 574.2 μm (i.e. frequency band between 522.5GHZ and 533.9 GHZ). As the incidence angle increases this reflection band blueshifts for both TM and TE polarizations.

1. Introduction

Terahertz (THz) frequency lies in between the microwave and infrared regions, and the wavelength range from 30 μm to 3000 μm (10 THz to 0.1 THz). The terahertz technology is a rapidly growing research issue in recent years and shows great potential applications in many scientific and technological fields, such as medical diagnosis, security screening, radio astronomy, atmospheric studies, short-range in-door communication, chemical, biological sensing, medical and biological imaging, and detection of explosives [1–5]. With the rapid development of terahertz radiation sources [6–8] and detectors [9,10], there is also a great demand for terahertz filters, polarizers, and attenuators [11–13]. However, quantitative studies on terahertz wave polarizer are still very limited. Therefore, it is valuable to investigate the design of a polarizer in the tetrahertz range.

In this letter, we present the numerical design and analysis of a reflective polarizer for the terahertz range made from a periodic bilayer birefringent polymer film. The novel terahertz wave polarizer has been designed and calculated through transfer matrix calculations. The proposed dielectric polarizer is highly reflecting for all incidence angles and TE as well as TM polarization. Moreover, we show that its performance accommodates reasonable fabrication tolerances.

2. Device configuration and analysis

The geometry of a high-efficiency terahertz wave reflective polarizer is shown in Fig. 1. The structure consisted of alternating high and low index layers. The incidence angles on each interface are related by Snell's law

$$n_a \sin\theta_a = n_H \sin\theta_H = n_L \sin\theta_L = n_b \sin\theta_b. \tag{1}$$

The phase thicknesses within the high and low refractive index layers are given by,

$$\delta_i = 2\pi \frac{\lambda}{\lambda_0} L_i C_i \quad i = 1, 2, \cdots, N \tag{2}$$

where λ is the operating free-space wavelength, $C_i = \sqrt{\frac{1-n_a^2 \sin^2\theta_a}{n_{i3}^2}}$ for TM polarization and $C_i = \sqrt{1-\frac{n_a^2 \sin^2\theta_a}{n_{i2}^2}}$ for TE polarization ($i = 1, 2, \cdots, N$). L_i is the layer optical lengths at normal-incidence, normalized by free-space wavelength λ_0, is defined as:

$$L_i \begin{cases} \frac{l_i n_{i1}}{\lambda_0} & (TM) \\ \frac{l_i n_{i2}}{\lambda_0} & (TM) \end{cases} \quad i = 1, 2, \cdots, N. \tag{3}$$

The alternating reflection coefficient ρ_T between the high/low interfaces obeys the following relation

$$\rho_{TM} = \frac{n_{H1} n_{H3} \sqrt{n_{L3}^2 - n_a^2 \sin^2\theta_a} - n_{L1} n_{L3} \sqrt{n_{H3}^2 - n_a^2 \sin^2\theta_a}}{n_{H1} n_{H3} \sqrt{n_{L3}^2 - n_a^2 \sin^2\theta_a} + n_{L1} n_{L3} \sqrt{n_{H3}^2 - n_a^2 \sin^2\theta_a}} \tag{4}$$

$$\rho_{TE} = \frac{\sqrt{n_{H2}^2 - n_a^2 \sin^2\theta_a} - \sqrt{n_{L2}^2 - n_a^2 \sin^2\theta_a}}{\sqrt{n_{H2}^2 - n_a^2 \sin^2\theta_a} + \sqrt{n_{L2}^2 - n_a^2 \sin^2\theta_a}} \tag{5}$$

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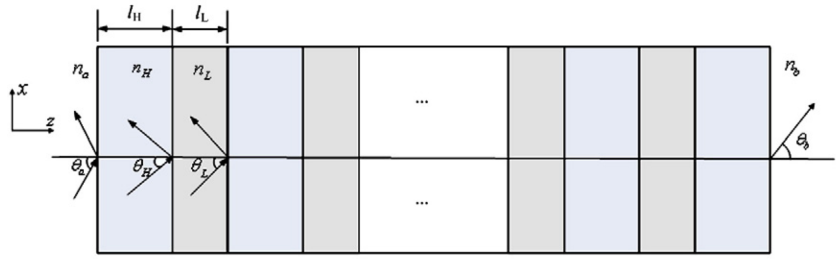

Fig. 1. Schematic diagram of the terahertz wave reflective polarizer formed by high and low index layers.

where ρ_{TM} is the TM reflection coefficient, ρ_{TE} is the TE reflection coefficient, n_{H1} is the refractive index of the high refractive index layer in the x direction, n_{H2} is the refractive index of the high refractive index layer in the y direction, n_{H3} is the refractive index of the high refractive index layer in the z direction, n_{L1} is the refractive index of the low refractive index layer in the x direction, n_{L2} is the refractive index of the low refractive index layer in the y direction, n_{L3} is the refractive index of the low refractive index layer in the z direction, n_a is the refractive index of the entry medium, and θ_a is the angle of incidence in the entry medium.

3. Simulation results

We assume that the high and low alternating layers are birefringent, described by the triplet indices $n_H = [n_{H1}, n_{H2}, \text{and } n_{H3}]$ and $n_L = [n_{L1}, n_{L2}, \text{and } n_{L3}]$. The refractive indexes of the entry and exit media are n_a and n_b, respectively. By choosing biaxial high/low layers whose refractive indices are mismatched only in the x or the y direction, one can design a mirror structure that reflects only the TM or only the TE polarization. Here, we assumed that the combination of

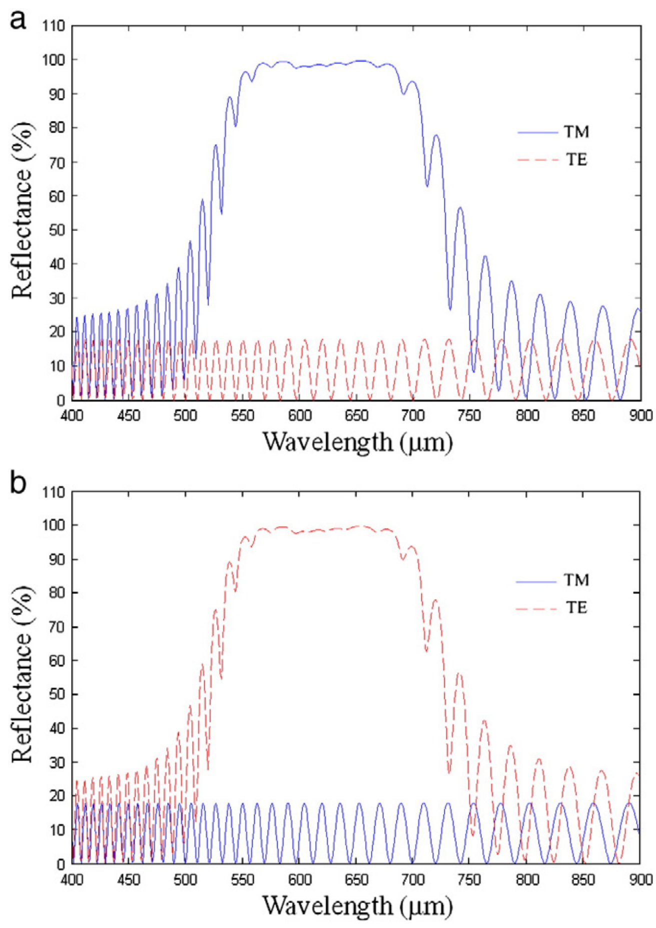

Fig. 2. TM and TE reflective polarizers (incidence angle $\theta = 0°$, $N = 40$). (a) TM polarizer (for the first case, $n_H = [1.86, 1.57, \text{and } 1.57]$ and $n_L = [1.57, 1.57, \text{and } 1.57]$). (b) TE polarizer (for the second case, $n_H = [1.57, 1.86, \text{and } 1.57]$ and $n_L = [1.57, 1.57, \text{and } 1.57]$).

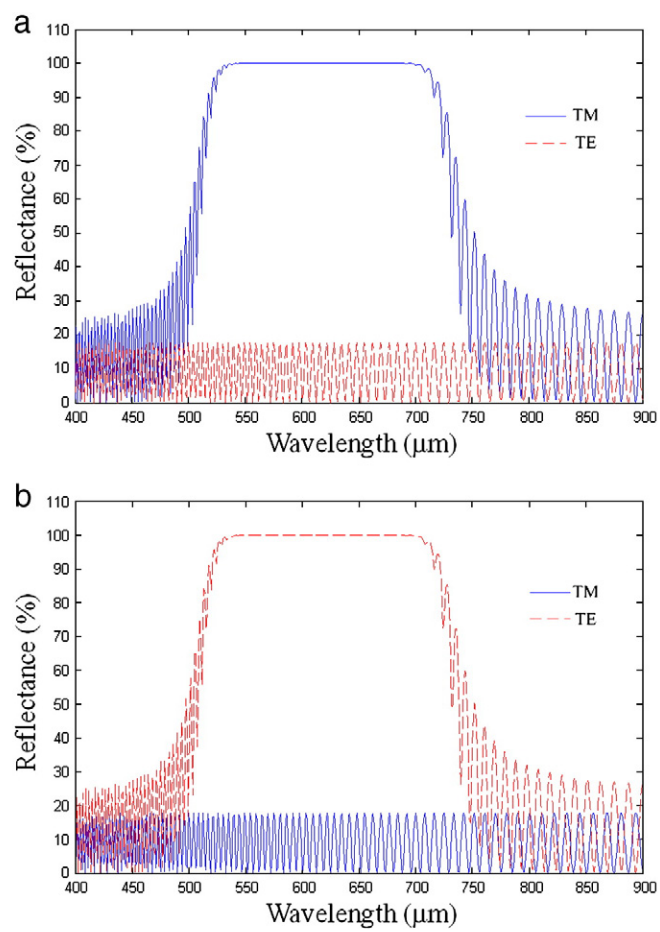

Fig. 3. TM and TE reflective polarizers (incidence angle $\theta = 0°$, $N = 100$). (a) TM polarizer (for the first case). (b) TE polarizer (for the second case).