Omnidirectional mirror for terahertz wave

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Abstract. We design an omnidirectional dielectric mirror that operates over a wide terahertz wavelength range and is based on a periodic bilayer (tellurium and polystyrene) structure. The structure is characterized by using transfer matrix calculations. Results of simulation show that the presented dielectric mirror is highly reflecting for all incidence angles and TE as well as TM polarization in the frequency band between 0.451 THz and 0.821 THz (wavelength range 365.5 µm–665.5 µm), when the incidence angle is less than 45°. Tolerance analysis reveals a large tolerance to fabrication errors.

1. Introduction
With the realization of THz generator and detector, electromagnetic terahertz frequency range (0.1 THz–10 THz) attracted significant attention and has been extensively investigated [1-3]. Terahertz applications include imaging techniques for quality control of industrial goods, medical diagnosis, security screening, radio astronomy, atmospheric studies, short-range indoor communication, chemical, biological sensing, and security checks of people, mail, or luggage. For all these applications efficient, inexpensive, and compact terahertz sources and detectors need to be developed. In addition, passive functional devices such as beam splitter, switches, filters, and terahertz wave mirrors are required. Mirrors which are highly reflective for all incidence angles are called omnidirectional mirrors. Some approaches to achieving terahertz wave mirrors have been reported in the literature. However, quantitative studies on terahertz wave omnidirectional mirrors are still very limited. Therefore, it is valuable to investigate the design of omnidirectional mirrors in the terahertz range.

In this letter, we present the numerical design and analysis of an omnidirectional dielectric mirror for the terahertz range made from periodic bilayer tellurium and polystyrene structure. The novel terahertz wave omnidirectional dielectric mirror has been designed and calculated through transfer matrix calculations. Simulation results show that the omnidirectional dielectric mirror has a highly reflecting for all incidence angles, TE as well as TM polarization and wide bandwidth. Moreover, we show that its performance accommodates reasonable fabrication tolerances.

2. Device design and analysis
Here, we use thin slices of tellurium and polystyrene to build an omnidirectional terahertz mirror. The structure consisted of thirty alternating layers of tellurium and polystyrene on a teflon substrate. The sketch of the high-efficiency terahertz wave omnidirectional dielectric mirror is shown in figure 1.
3. Simulation results

Here, the physical length of both tellurium and polystyrene is \( l = l_g = \lambda_0/4 \). The number of periodic bilayers is \( N = 30 \). The refractive index of tellurium and polystyrene are \( n_H = 4.6 \) and \( n_L = 1.6 \), respectively. The simulation is performed with the parameters given above. The incidence angles \( \theta \) is equal to \( 0^\circ \), \( 30^\circ \), and \( 45^\circ \), respectively. The spectral response of this structure for both TE and TM-polarized incident terahertz wave is shown in Fig. 2 as calculated by the transfer matrix calculations. Figures 2 show the terahertz reflection spectra through the structure for TE and TM polarizations. As the incidence angle increases this reflection band blueshifts for both TE and TM polarizations. For both polarizations a frequency band can be found for which the mirror is highly reflecting for all angles. According to analysis as above, when the incidence angle is less than \( 45^\circ \), TE and TM-polarized terahertz wave modes are reflected with 100% for a wide wavelength range 365.5\( \mu m \) and 665.5\( \mu m \).
In addition, we examined the performance of the omnidirectional dielectric mirror as a function of potential fabrication errors that affect dielectric layer length. Simulation results (see Fig. 3) for a variation in dielectric layer length from 135µm to 115µm (20µm range for the design dielectric layer length) show that both TE and TM modes reflectivity bandwidth has little change.

![Fig. 2 TE and TM reflection spectrum of the proposed mirror structure for incidence angle θ=45°](image)

(a)

(b)

Fig. 2 TE and TM reflection spectrum of the proposed mirror structure for incidence angle θ=45° (a) dielectric layer length of 115µm, (b) dielectric layer length of 135µm

4. Conclusion
We theoretically demonstrated an omnidirectional mirror for the terahertz range made from polystyrene and thin slices of tellurium. This offers the opportunity to achieve a high-efficiency omnidirectional dielectric mirror to reflect TE and TM polarized modes. For frequencies between 0.451THz and 0.821THz, the structure is highly reflecting for all incidence angles and TE as well as TM polarization. The present mirror is mechanically flexible and could be used for in-door terahertz wave communication systems. The proposed terahertz wave omnidirectional mirror has reasonable tolerances to fabrication errors.

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