Wideband Perfect THz Absorber using Graphene Metasurface

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Abstract

A wideband perfect thin absorber using graphene metasurface (MSF) at THz Band is investigated in this work. The graphene MSF structure is composed of a two-dimensional periodic array of graphene meta-atoms deposited on the silicon substrate terminated by a metal ground plane. The performance of the proposed MSF is numerically analyzed. An equivalent circuit model of the structure and its closed-form solution is introduced. The graphene MSF thin structure at 2.5 THz provides 100% of absorption with wide bandwidth, zero reflection and zero transmission at normal incidence in both transverse electric (TE) and transverse magnetic (TM) polarization. Under oblique incidence, the absorption is maintained at higher than 95%. Moreover, the graphene MSF structure has the advantage of frequency reconfiguration. The excellent absorption performance is maintained at all reconfigurable frequencies upon reconfiguration. The results reveal the effectiveness of the THz MSF with graphene meta-atoms, which can be promising for THz wireless environment.

Introduction

- MSF recently gained great attention due to its ability to control wave propagation from microwave to visible.

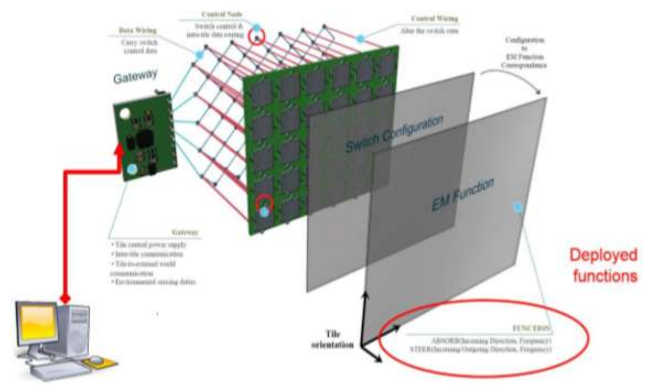


Fig. 1. Architectural overview of Programmable MSF tile

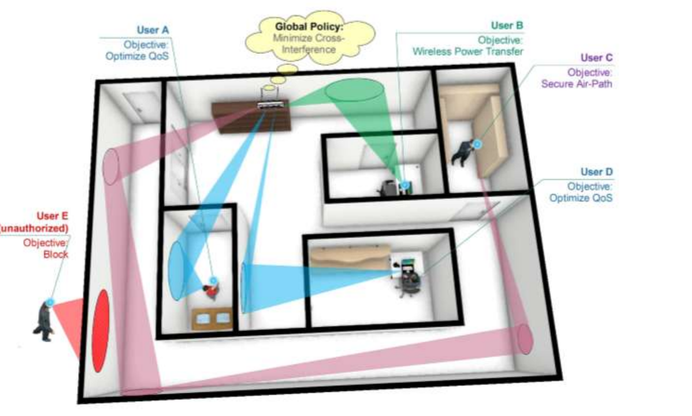
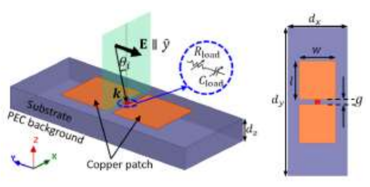


Fig. 2. Programmable Wireless Environment

- Hypersurface (HSF) designs is a high degree of MSF pattern customization and Allow for a high degree of tunability.
- HSF can be implemented two ways, such as (1) Switch-fabric approach based on a metallic-patch array, and (2) Graphene based approach exploiting its unique properties.



Switch-fabric approach

- Due to its unique properties at THz, graphene has become a promising candidate for the design of THz MSF absorber. Moreover, plasmon turnability in graphene enables graphene as a natural candidate for programmable THz MSF.

Design and Circuit Modelling of Graphene MSF

- A wideband perfect thin absorber using graphene metasurface at THz Band is designed and numerically analyzed.

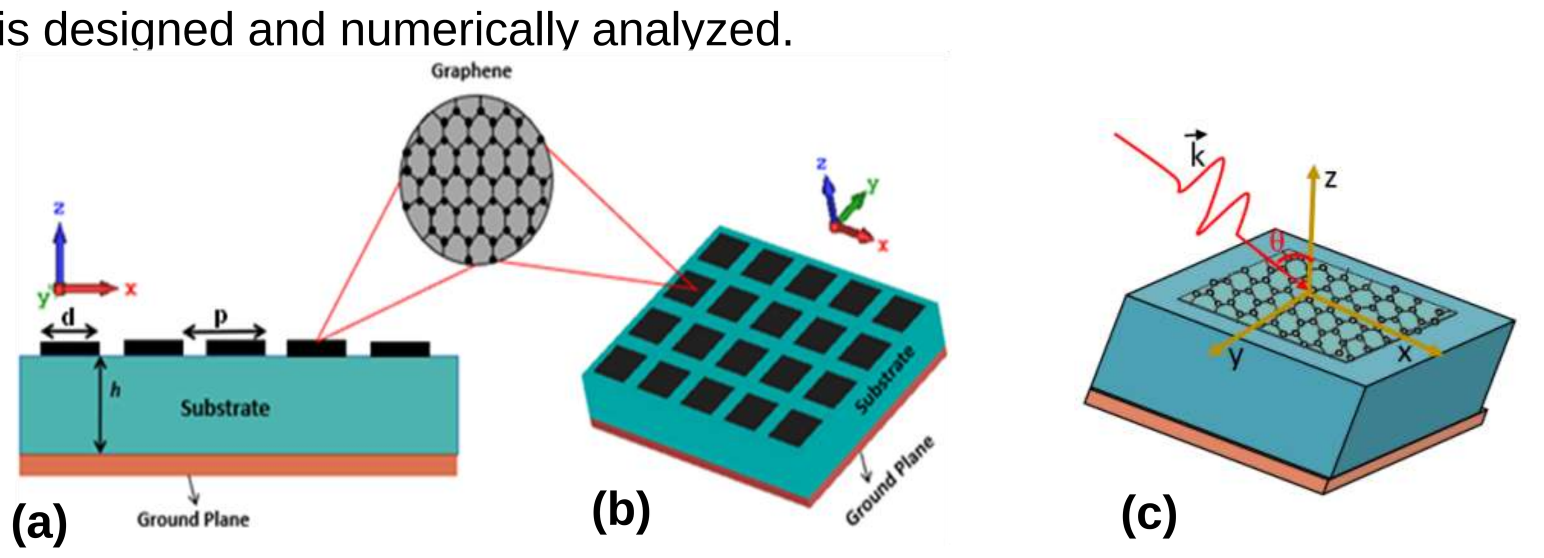


Fig. 3. Schematic of the graphene MSF (a) Cross-sectional view, (b) 3D view, and (c) its unit cell

- The graphene MSF structure is composed of a 2D periodic array of graphene elements deposited on silicon substrate terminated by a metal ground plane.
- The surface impedance of the graphene patch array and the input impedance of the metal-backed substrate can be expressed as

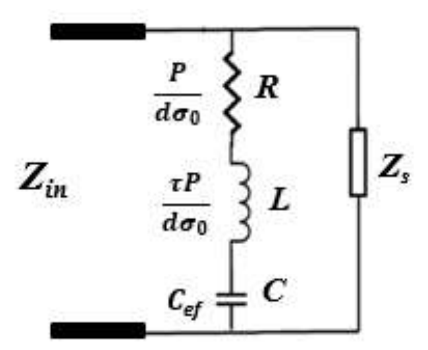


Fig. 4. Equivalent circuit of graphene MSF structure

$$Z_g = \frac{P}{d\sigma_0} + j\left[\frac{\omega\tau P}{d\sigma_0} - \frac{1}{\omega C_{ef}}\right] \quad \text{and} \quad Z_s = jz_c \tan(\beta h), \qquad \frac{1}{Z_{in}} = \frac{1}{Z_g} + \frac{1}{Z_s}$$

$$S_{11} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \qquad A = 1 - |S_{11}|^2$$

Absorption of the MSF is 100%, when $S_{11}=0$

Results and Discussion

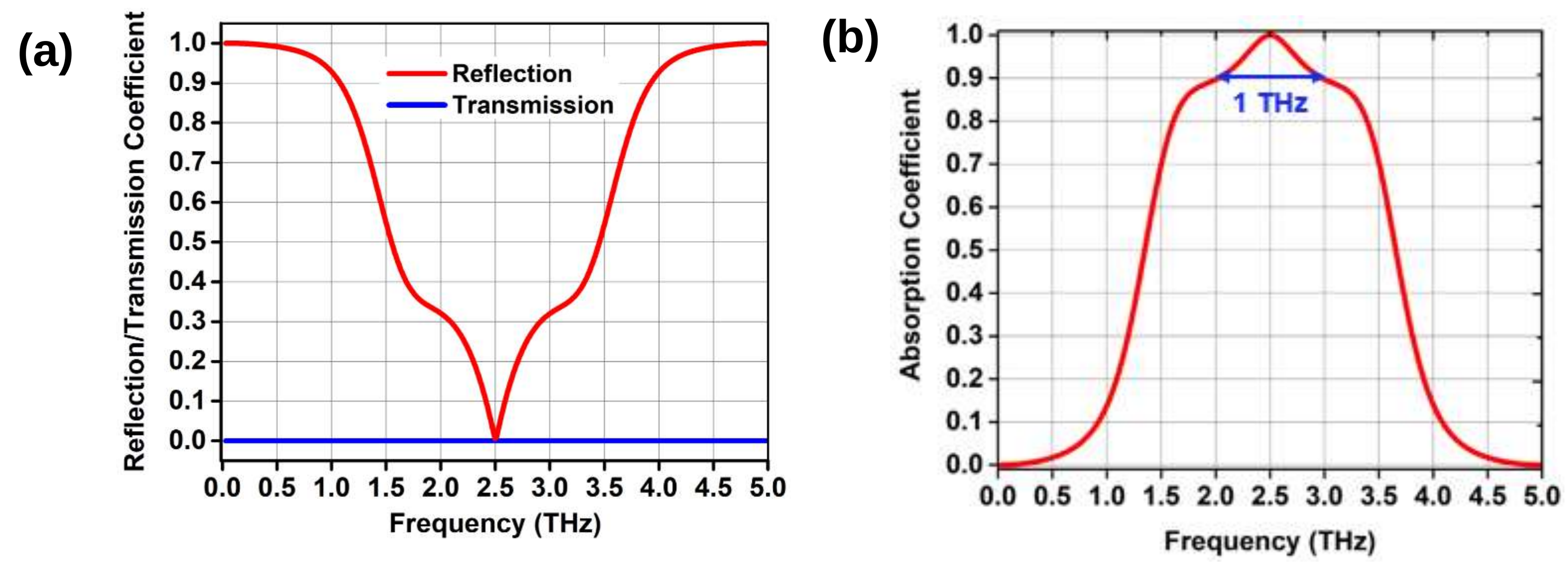


Fig. 5. (a) Reflection and Transmission spectra, and (b) Absorption spectra of graphene MSF

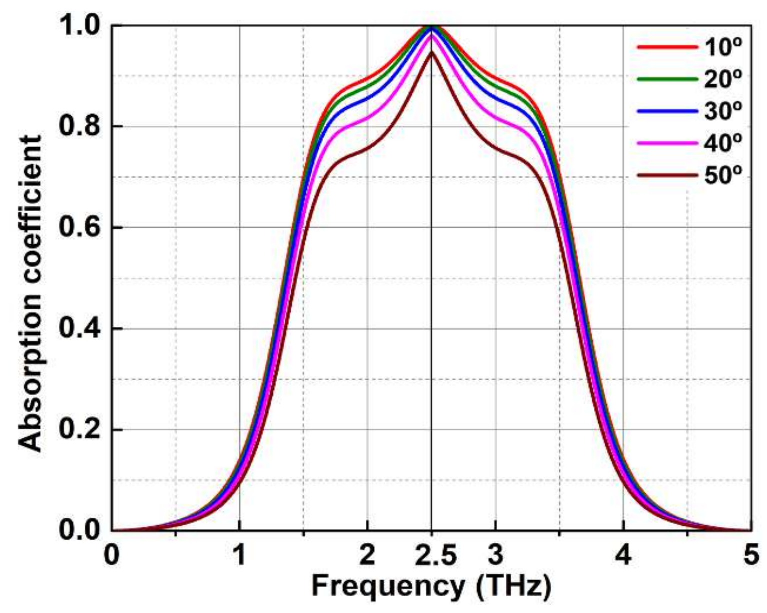
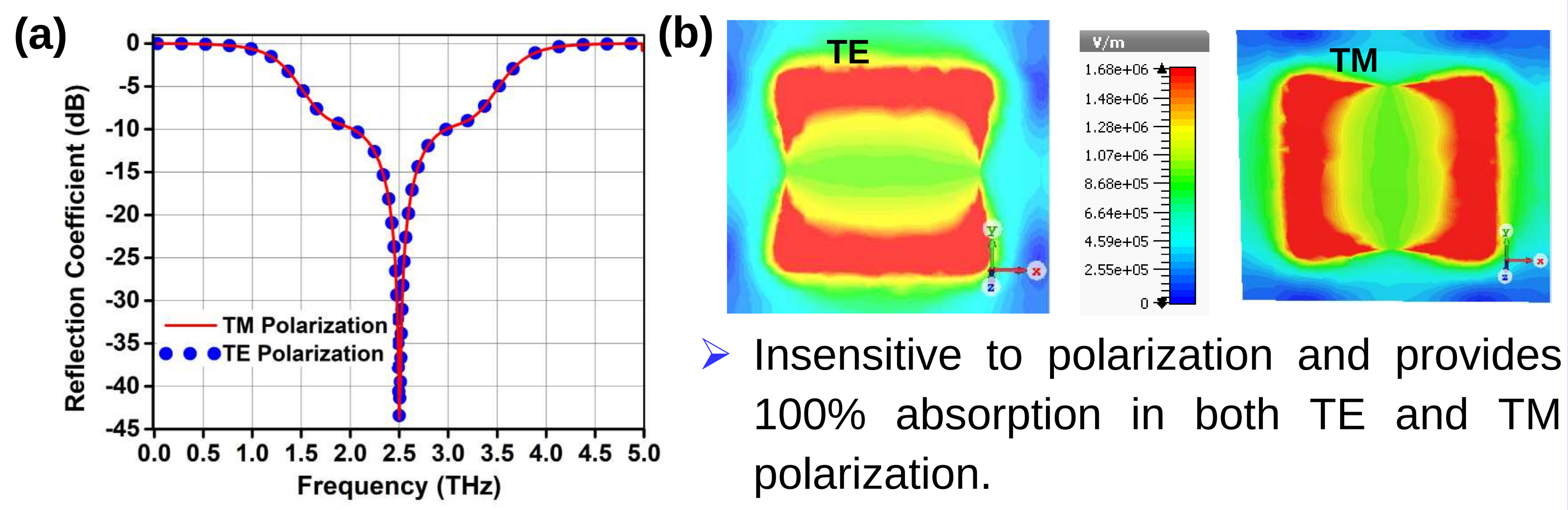


Fig. 6. Absorption spectra of graphene MSF under oblique incidence

- The graphene MSF at 2.5 THz provides zero reflection and zero transmission, 100% of absorption with wide bandwidth of 1 THz under normal incidence.
- The absorption for oblique incidences from 0° to 50° is more than 95%.



- Insensitive to polarization and provides 100% absorption in both TE and TM polarization.

Fig. 7. (a) Reflection spectra and (b) Electric field distribution in TE and TM polarization

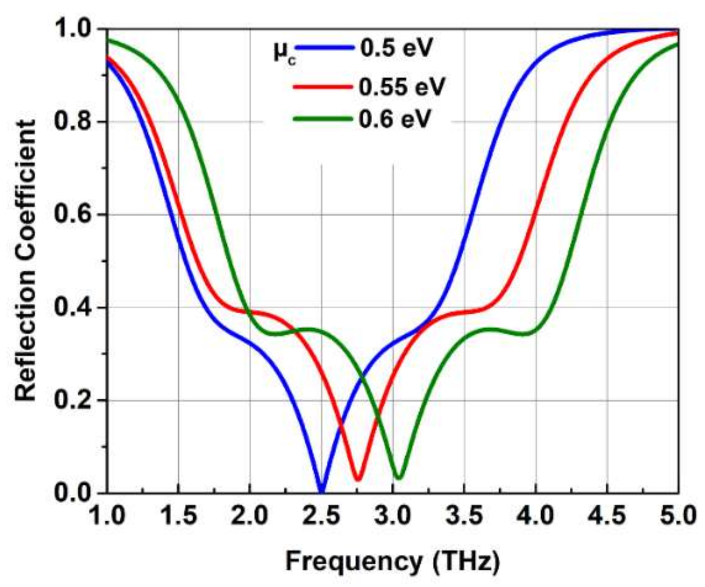


Fig. 8. Frequency reconfiguration of graphene THz MSF surface

- The central frequency tuned from 2.5 THz to 3.1 THz as chemical potential μ_c increases from 0.5 eV to 0.6 eV.
- The excellent absorption performance is maintained at reconfigurable frequencies.

Conclusion

We investigated a simple structured THz metasurface using graphene meta-atoms. An equivalent circuit model of the structure and its closed-form solution is introduced. The graphene MSF thin structure provides 100% of absorption with wide band width, zero reflection and zero transmission at 2.5 THz. In addition, the structure has advantage of polarization insensitive, frequency reconfiguration and larger insensitive oblique incidence. The results reveal the effectiveness of the THz metasurface with graphene meta-atoms, which can be promising for THz wireless environment.

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