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Graphene Metasurface for THz Wavefront Control

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1. Introduction

Terahertz (THz) technology is now becoming more important with the potential applications in biochemical sensing, security detection, and high-speed communication. However, because of lack of active materials for THz wave, wave control, e.g. intensity and phase distribution, is still challenging. Plasmonic metamaterial has opened up a new avenue to manipulate electromagnetic wave at will [1]. Unique wavefront control has been also demonstrated by a metasurface, which is a tailored surface structure, to introduce unusual phase discontinuity at the interface [2-5]. Here, we propose a novel plasmonic metasurface made of graphene ribbons to control the wavefront of THz wave.

2. Results and Discussions

Figure 1 shows a plasmonic metasurface consisting of a one-dimensional (1D) graphene ribbon array on a silver substrate with a 4-μm SiO_2 gap layer. Graphene ribbons exhibit plasmonic resonances to strongly scatter an incident THz wave with a finite phase shift [6]. Each graphene ribbon is carefully designed to introduce spatially non-uniform phase shift along the x axis. A supercell is then formed by the unit cells to accumulate a total 2π-phase shift in a period of Λ. The periodic phase distribution over the metasurface modifies the THz wavefront and reflected it at an angle of $\theta = \tan^{-1}(\lambda/\Lambda)$. By tuning the plasmonic properties of graphene ribbons via electrostatic gating, full control of THz wavefront can be achieved.

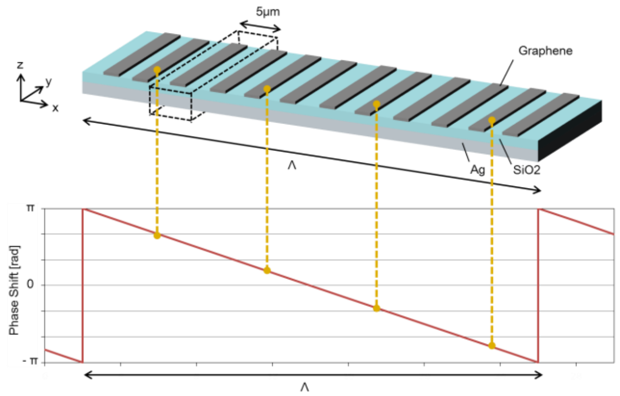

Fig. 1. Schematic of a graphene metasurface, consisting of a 1D graphene ribbon array on a Ag substrate with a 4-μm SiO_2 layer. Each graphene ribbon is designed to introduce spatially non-uniform phase shift along the x axis. A supercell is formed by the unit-cells to accumulate a total 2π-phase shift in a period of Λ. The periodic phase distribution over the metasurface controls the wavefront of THz wave, being reflected at an angle of $\theta = \tan^{-1}(\lambda/\Lambda)$.

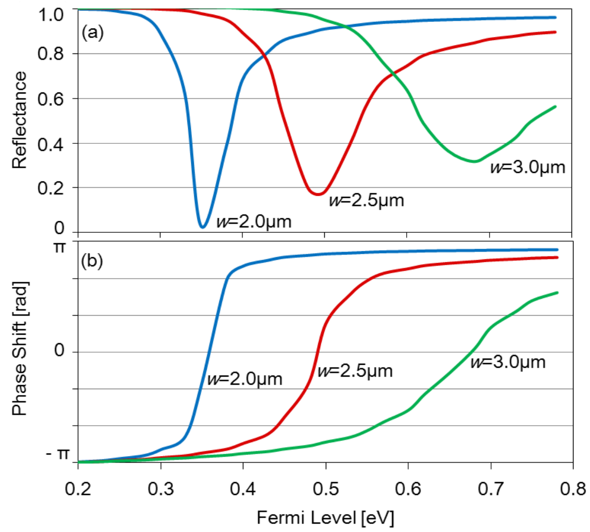

Fig. 2. Fermi-level dependence of (a) reflectance and (b) phase shift of the graphene ribbon with different ribbon width *w* at the operating frequency of 5 THz. The nearly 2π-phase shift is obtained at the resonance of each graphene ribbon.

To demonstrate our idea, a set of numerical simulations was carried out based on two-dimensional (2D) Finite-Difference Time-Domain (FDTD) method. Figure 2 shows the Fermi-level dependence of reflectance and phase shift of the graphene ribbons with different ribbon widths *w*. In the calculation, the operating frequency was set at 5 THz and the period of graphene ribbons was kept at 5 μm. The dielectric constant of SiO_2 was set at 3.8 and silver and graphene were described by the Drude model. Depending on the Fermi level and width of the graphene ribbon, typical plasmonic resonances ware clearly observed. In the case of w = 2.0 μm (blue curve), a deep dip of the reflectance and a large swing of phase shift were observed around the Fermi level of 2.5 eV. A nearly 2π-phase shift was obtained around the resonance, allowing for full control of the THz wavefront. In the presentation, the detail of THz wavefront control by the graphene metasurface will be also discussed.

Acknowledgements

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