TERAHERTZ METAMATERIAL ABSORBER BASED ON GRAPHENE PLASMONS

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Electromagnetic wave-matter interactions are considered fundamental to a wide range of modern photonic and electronic technologies, with particular significance attributed to the terahertz (THz) frequency regime [1] for applications including sensing, imaging, and wireless communication [2]. Within this spectral region, graphene [3] has been identified as a promising plasmonic platform due to its two-dimensional (2D) structure, electrically tunable carrier concentration, and capability to support surface plasmon polaritons (SPPs) exhibiting extreme subwavelength confinement and relatively low damping. A graphene metamaterial absorber (MMA) exhibiting near-unity, electrostatically tunable THz absorption was designed through finite element method (FEM) simulation. Graphene was represented using a surface conductivity formulation derived from the Kubo formalism. For highly doped graphene at THz frequencies, the conductivity is approximated by a Drude-like expression [4]:

$$\sigma_g = \frac{e^2 E_F}{\pi \hbar^2} \frac{i}{\omega + i/\tau} \tag{1}$$

where, ω, τ, $\hbar$, and E_F are defined as the angular frequency of the incident radiation, carrier relaxation time, reduced Planck constant, and Fermi energy, respectively.

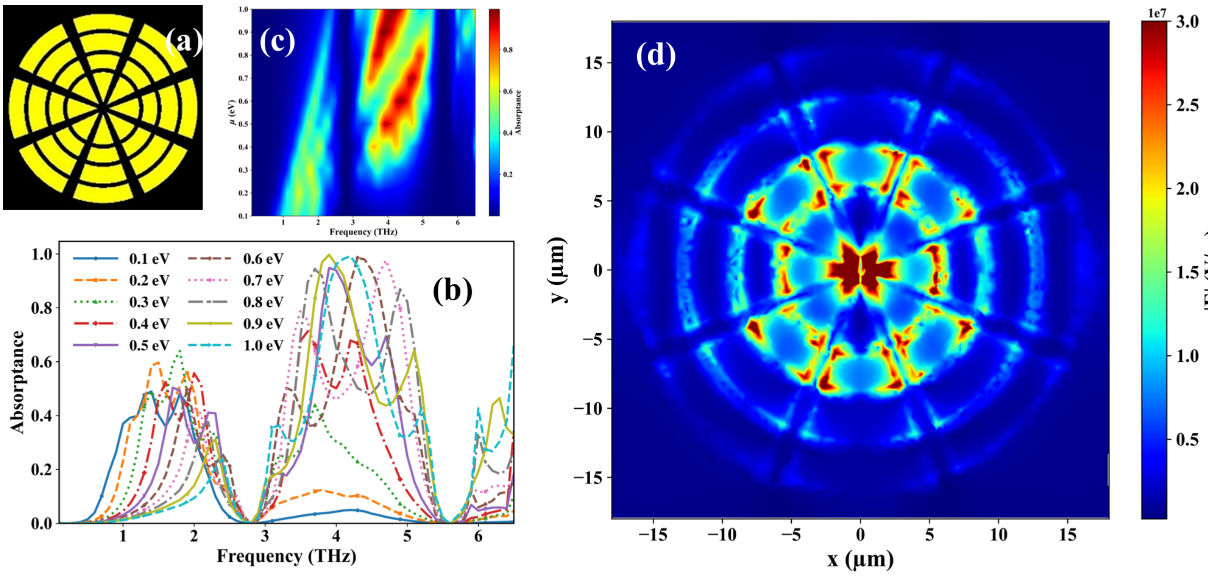

Fig. 1. Graphene-based metamaterial absorber: (a) 2D schematic of the structure; (b) chemical potential dependent absorption spectra; (c) absorption heatmap; and (d) electric field distribution at the resonance frequency (3.9 THz) for $\mu = 0.9\,\text{eV}$.

The absorption response of the graphene-based MMA was evaluated for chemical potentials $\mu = 0.1\text{–}1.0\,\text{eV}$. As illuatrated in Fig. 1(b), a pronounced blue shift of the dominant absorption resonance is induced with increasing μ, accompanied by a substantial enhancement of absorption, by which efficient electrostatic tunability is demonstrated.

The μ–frequency absorption heatmap presented in Fig. 1(c) provides a global representation of this behavior, wherein dispersive absorption bands are observed to shift monotonically toward higher frequencies as μ increases. The electric field distribution at resonance (Fig. 1(d)) is characterized by strong confinement within the graphene pattern, through which efficient plasmonic absorption is verified. Collectively, robust electrically tunable near-perfect absorption is demonstrated, and the suitability of the proposed structure for actively reconfigurable THz absorbers is established.

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