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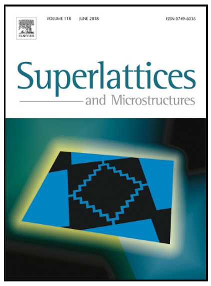

Multi-mode Tunable Absorber Based on Graphene Metamaterial

Ning Hu, Peiguo Liu, Li-an Bian, Qihui Zhou, Chenxi Liu, Jihong Zhang, Hanqing Liu

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Multi-mode Tunable Absorber Based on Graphene Metamaterial

Ning Hu, Peiguo Liu, Li-an Bian*, Qihui Zhou, Chenxi Liu, Jihong Zhang, Hanqing Liu

College of Electronic Science and Engineering,

National University of Defense Technology,

410073 Changsha, China

*E-mail address: dk061bianlian@126.com

Abstract: In this paper, a novel design of metamaterial absorber (MA) with multi modes and tunability characteristics in terahertz (THz) range is presented. The MA consists of patterned gold-graphene on the top layer, graphene sheet and gold ground separated by SiO_2. The chemical potential of patterned graphene and graphene sheet can be tuned independently. Thus, the regulation flexibility of MA is greatly enhanced. For demonstration, the proposed MA is investigated using circuit analogy method and the distributions of the electric field are also discussed in detail to explore underlying mechanism. Numerical calculations are stimulated in a commercial full-wave solver and indicate that the proposed MA possesses excellent absorption properties. There are three perfect absorption ($\geq 99.2\%$) modes at 2.4 THz, 4.2 THz and 7.2 THz respectively. Under the regulation of chemical potential, the proposed MA could serve as single-frequency or dual-frequency absorber without change of physical structure. When working as single-frequency absorber, the MA could be regulated between different modes during a large frequency range and the absorption peaks could also be regulated within the same mode during a relative smaller frequency range. Furthermore, the MA has two absorption peaks at 2.4 THz and 7.2 THz ($\geq 95\%$) simultaneously as dual-frequency absorber. The proposed MA shows promising application potentials due to the flexible modulation and functions and this work provides a new perspective for the design of tunable THz absorbers based on graphene.

Keywords: Graphene; metamaterial; multi-mode absorption; perfect absorption; THz

1. Introduction

Metamaterial, an artificially engineered periodic nanostructure with many exotic electromagnetic properties, has emerged as a promising mean to manipulate EM waves [1] and many novel electromagnetic components based on metamaterial have aroused extensive interests [2-5]. Among these applications, metamaterial absorber (MA) is of great importance due to its potential applications for thermal emission, imaging and sensing [6-8]. Perfect absorption was firstly proposed by Landy in 2008 [9]. The basic principle of perfect absorption is to control the electromagnetic resonance and achieve the match between the MA and free space to reduce the reflectivity of incident EM waves and using the dielectric loss and ohmic loss of the absorber to achieve EM waves absorption. Though perfect absorption in THz whose frequency ranges from 0.1 THz to 10 THz has shown promising application values [10-12], nature materials are hard to realize it, which makes THz MA become a hot pot of THz and MA research. After Tao designed the first narrow-band THz absorber [13], various of THz MA structures are proposed from single-band to multi-band and broadband [14-17]. However, these MAs can only work at fixed frequencies and their potential in practical use is limited. Furthermore, tunable MAs are also designed. For instance, J. Zhao et al. use varactor diodes to realize tunable MA [18] and electrostatically actuated MEMS are applied in Ref. [19]. Besides, laser [20, 21], temperature [22], voltage modulation [23] are also applied in the design of MA. However, except for voltage modulation MAs, the conventional tunable methods require specific conditions that are hard to achieve or the structures are too complicated.

Graphene, as a two-dimensional (2D) carbon material, has attracted intensive concerns since in 2004, a team led by Geim proposed a more efficient way to produce it based on exfoliation procedures [24]. Graphene possesses ultra-high electronic mobility, highly confined plasmonic propagation and extremely low loss [25]. More importantly, the conductivity and permittivity of graphene can be continuously and visibly changed by tuning the chemical potential, which is regulated by chemical doping or bias voltage [26]. The extraordinary properties of graphene make it a good candidate for the design of tunable devices [27, 28] and it was theoretically shown that the combination of graphene and anisotropic metamaterial could realize various unique electromagnetic properties [29-32]. In recent years, graphene-based metamaterial absorbers have won the favor of the researchers and kinds of structures have been proposed. For example, graphene nanodisk [33], micro-ribbons [34, 35], all these structures