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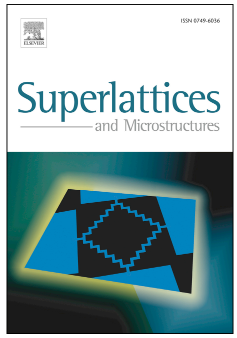

Near-unity absorption in a graphene-embedded defective photonic crystals array

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Near-unity absorption in a graphene-embedded defective photonic crystals array

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Abstract: Near-unity absorption is achieved theoretically at the terahertz frequencies by the graphene-based absorber under the condition of approaching critical coupling. The designed structure is composed of a defective photonic crystal array equal to the multilayer subwavelength grating, which possesses simultaneously the properties of photonic crystal and subwavelength grating so that both FP resonance and Fano resonance are excited. To simulate the structure accurately, rigorous coupled-wave analysis is employed. It is found that the dip can be introduced into the high absorption spectrum by the coupling of two resonances, which is realized by tuning the chemical potential of graphene, the geometry and equivalent thickness of grating as well as the angle of incident wave. The unusual absorption spectra are believed to be useful in the detection and modulation of terahertz waves.

Keywords: Graphene absorber; near-unity absorption; photonic crystals array; FP resonance; Fano resonance; critical coupling

1. Introduction

Absorbers are key components in the signal detecting, biosensing along with photoelectric modulating. Recently, graphene-based absorption structures are reported a lot[1-5]. Due to the unique electric and optical characteristics of the two-dimensional material, the absorbers with graphene present better performances than before without graphene, such as smart electric tunability[6], higher quality factor[7] or broader bandwidth[8].

Among these absorbers, the ones with the near-unity absorption is favored in many realistic scenarios. For example, they in sensors can improve the devices' sensitivity relying on the large modulation depth[9]. For the near-unity requirement, a free-standing monolayer graphene is helpless, since it cannot break through the limitation of 50%[10]. To improve the dilemma, various strategies are adopted to strengthen the field intensity at the graphene's position. We only focus two resonance effects here, since under these effects the chosen graphene needs not be patterned so that there are not extra loss channels from atomic scale roughness of the edges[11]. Firstly, FP resonance as a common way can be realized easily by a defective photonic crystal (PC). When the graphene nanolayer is embedded into the defect, expected absorption is achieved[12-13]. Secondly, Fano resonance as a strange a bit way can be obtained by the subwavelength grating, which originates from the interaction between a narrow discrete state and a wide continuum state[14]. Through this effect, the reflection and transmission in far field are transformed rapidly, which has been used to design the optical switch[15] and filter[16]. In the near field, the intensity of electric field is surged. When the graphene is placed in the vicinity of the grating backed by a perfect mirror, the near-unity absorption is observed by virtue of the constructive interference[17-19]. For the FP resonance, the absorption spectrum is symmetric and broad relatively. For the Fano resonance, the absorption spectrum is just Lorentzian-like but narrow extremely. As known, if two different resonances are coupled, some peculiar lineshapes may occur. For example in Ref.[20], by coupling a broad spectrum provided by the metal grating with a narrow one provided by the graphene grating, the Fano-type resonance spectrum is exhibited by the hybrid graphene-metal grating. Then, if the FP resonance and Fano resonance are excited simultaneously and further coupled between each other, an unknown absorption spectrum would arise, which may result in innovative functions.

In this paper, we arrange the photonic crystals with graphene-incorporated defects as a multilayer subwavelength grating to realize the near-unity absorption in the range of terahertz (THz). On one hand, the FP resonance and Fano resonance in this structure will exist at the same time, whose coupling is implemented by adjusting the characteristic parameters of graphene and grating. On the other hand, the absorption level is determined by comparing the size between the external leakage rate and the intrinsic loss rate. Finally, the two near-unity absorption peaks are obtained as well as the unusual coupled spectra lineshapes are discovered based on our graphene absorber.