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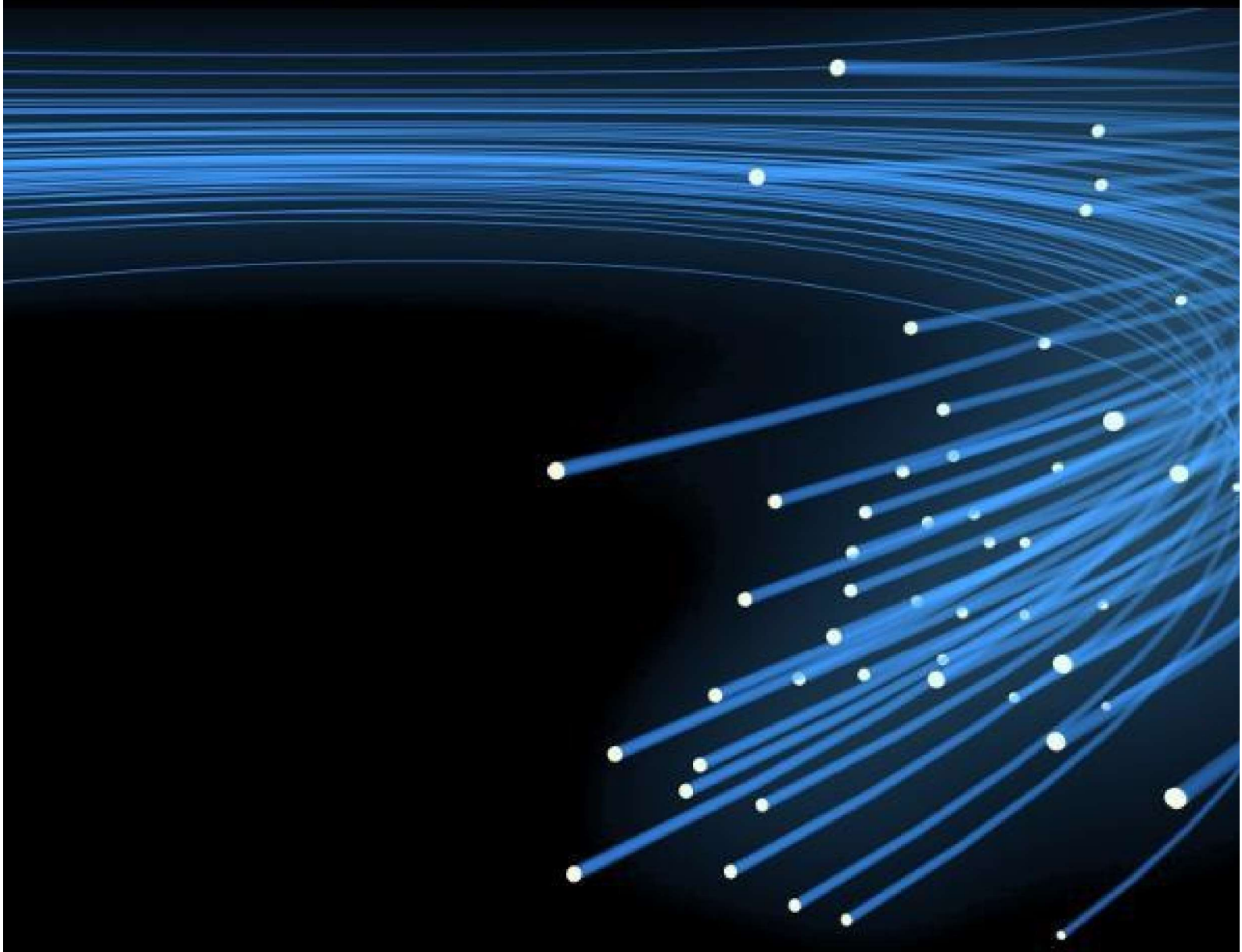

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Multi resonance perfect absorber based on graphene micro ribbons

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Abstract

Metamaterial-based perfect absorbers are used in many applications like photo-detectors, sensors, special light modulators, wireless communications and photovoltaic. The mechanism of absorption is based on the complete suppression of reflection and transmission of incident wave. Here we present a multi resonances perfect absorber made of Graphene micro-ribbons that each ribbons have different values of chemical potential witch brought us tunability, which by changing the value of chemical potential for each ribbon we can change the frequency of resonances independently and we can achieve to a tunable bandwidth. In the following the results for reflection and absorption from simulation are presented. Finally an equivalent circuit model is proposed for our structure and shown to very accurately predict the element absorption.

1. Introduction

Graphene is a monatomic layer of carbon atoms arranged in a honeycomb structure, which has unique properties, such as optical transparency, flexibility, high electron mobility and conductivity. The electrical conductivity of Graphene can be controlled using electrochemical potential via, for example, magnetic field, electric field bias or optical excitation [1]–[3].

Graphene is an alternative material for plasmonic applications [4]. Graphene exhibits much higher confinement of surface plasmon polaritons and supports relatively longer propagation [5], [6]. Therefore, Graphene can be used in many plasmonic applications such as modulators, filters, hyperlenses, absorbers and polarizers [7]-[10].

In this paper, we present a multi-resonance perfect absorber made of graphene micro-ribbons in terahertz regime. The key to achieve multi-resonance absorption is applying different value of electrochemical potential or gate voltage to each ribbons of Graphene. We can almost tune the frequency of the absorption independently by changing the gate voltage of each ribbon or by tuning the width of ribbons. Finally, we have proposed physical equivalent circuit based on transmission line model for our structure by using vector fitting method [11]. The values of circuit elements can be easily extracted from the reflection scattering parameter of the Graphene micro-ribbons at boundary between air and substrate. The accuracy of the proposed equivalent circuit is validated by comparing the obtained results with the well-known frequency-domain CST-MWS solver.

2. Structure of the perfect absorber

The structure of the proposed multi-resonance prefect absorber is shown in Fig. 1, it consist of a patterned graphene micro-ribbon in front and a ground plate made of Gold with a conductivity $\sigma = 4\times10^7$ S/m on the back that perfectly reflecting wave in terahertz regime and a dielectric with refractive index (n = 2.1) placed between them.

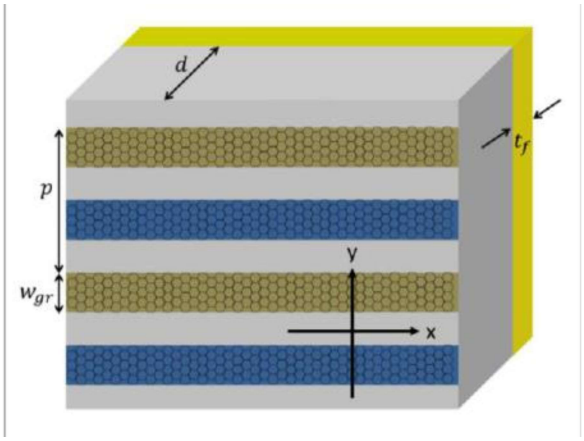
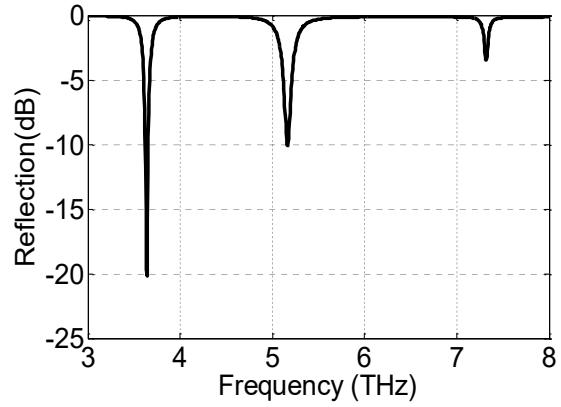


Figure 1: Schematic of the perfect absorber. The geometrical parameter of proposed absorber are p=2μm, w_{gr}=2 μm, d=4.7 μm, and t_f= 1μm. The blue micro ribbon made of graphene has μ_c=100 meV and the yellow one has μ_C=200 meV.

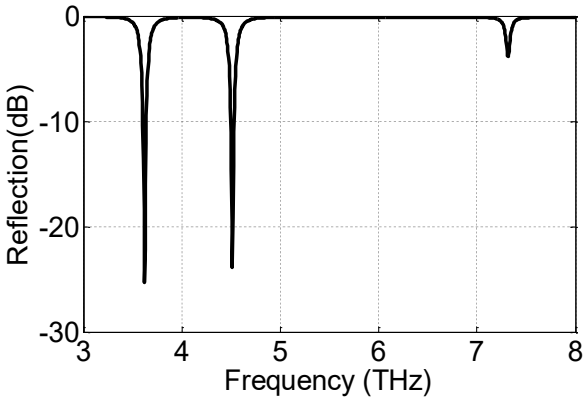
This proposed structure is periodic in (***y***) direction with periodicity p=2μm and infinitely extended in (***x***) direction. The permittivity of graphene is calculated from $\varepsilon_{GR}=\varepsilon_0+j\sigma_{GR}/\omega\Delta$ which Δ=1nm is the thickness of the graphene layer and σ_{GR} is the surface conductivity of graphene sheet that can be derived from Kubo formula [12] and write as:

$$\sigma_{GR} = \frac{ie^2}{2\pi\hbar^2} Ln\left[\frac{2|\mu_c| - (\omega + i2\Gamma)\hbar}{2|\mu_c| + (\omega + i2\Gamma)\hbar}\right] + \frac{ie^2 K_B T}{\pi\hbar^2(\omega + i2\Gamma)}\left[\frac{\mu_c}{K_B T} + 2Ln(e^{-\mu_c/K_B T} + 1)\right] \quad , \quad (1)$$

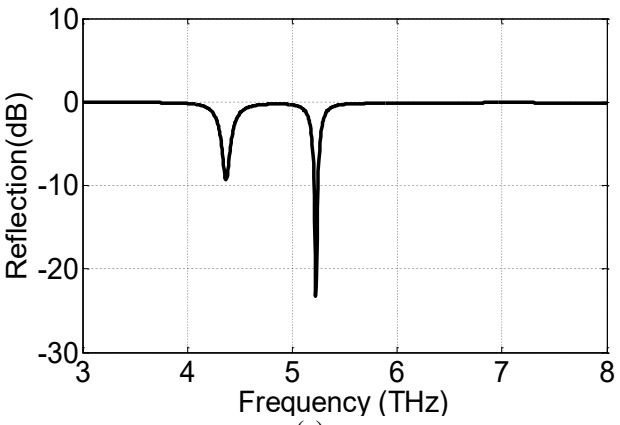
where e, $\hbar$ and K_B are universal constant related to the electron charge, Plank's and Boltzmann's constant, respectively. T is the temperature and is fixed to 300K. μ_C and 2Γ ($2\Gamma=\hbar/\tau$, τ is the electron-phonon relaxation time) are physical parameters of the Graphene sheet and account for chemical potential (or Fermi energy) and intrinsic losses, respectively. According to (1) by changing the value of chemical potential (μ_C) we can change the conductivity of graphene and use this fact for tune the frequency of absorption. The reflection of incident wave from simulation using CST-MWS [13] for the structure with two different chemical potential 100meV and 200*me*V are plotted in Fig. 2-(a). As it seems there is a first mode resonance in 3.64 THz related to ribbon with μ_C = 100meV and another one in 5.16 THz for μ_C = 200*me*V. By changing the value of chemical potential for each ribbon we can tune the frequency of absorption, for example we can reduce μ_C for the second ribbon and reduce the frequency of second absorption therefore as it decrease we can achieve to a bandwidth of absorption. The result for second ribbon with μ_C = 150meV and the first one without change are plotted in Fig. 2-(b), as it's obvious two peak of reflection are getting closer to each other and just the second resonance have been moved.



(a)



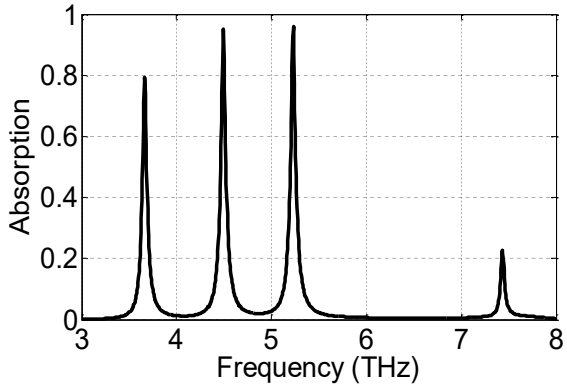
(b)



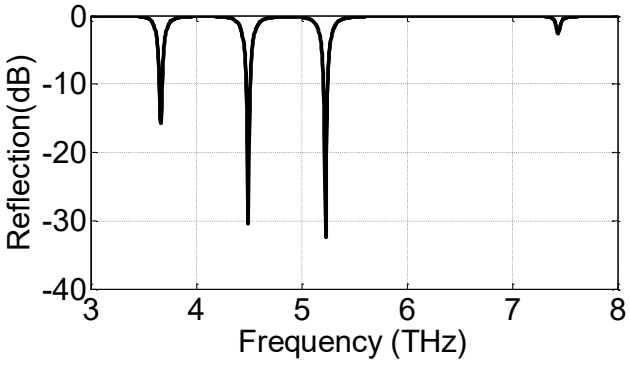
(c)

Figure 2: The reflection scattering parameter of the proposed structure shown in Fig. 1, (a) for μ_C=100,200*me*V, (b) for μ_C = 100,150*me*V, and (c) for μ_C=150, 200*me*V.

Now assume that we fixed μ_C for the second ribbon on 200 *me*V and change μ_C for the first ribbon from 100 *me*V to 150 *me*V and we see that the second resonance are fixed and the first resonance are getting closer to the second one Fig. 2-(c).



(a)



(b)

Figure 3: (a) Absorption of the proposed structure in Fig. 1, (b) Reflection scattering parameter.

Consequently we achieve to a dual frequency of absorption which are independently tunable, also by raising the number of ribbon with different value of chemical potential we can

Table 2: The values of circuit elements.

Circuit Elements	Values
C_r[F], R_r[Ω]	**1.0491e-17**, 9.1759e+04
C_{p1}[F], R_{p1}[Ω], **L_{p1}[H]**, b_1	**5.2453e-18**, 3.4004e+05, **2.4651e-10**, 5.3445e+28
C_{p2}[F], R_{p2}[Ω], **L_{p2}[H]**, b_2	**5.2453e-18**, 5.8226e+05, **9.1205e-11**, 3.1211e+28

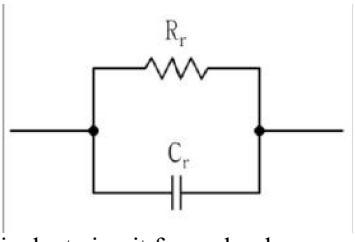


Figure 6: Equivalent circuit for real pole.

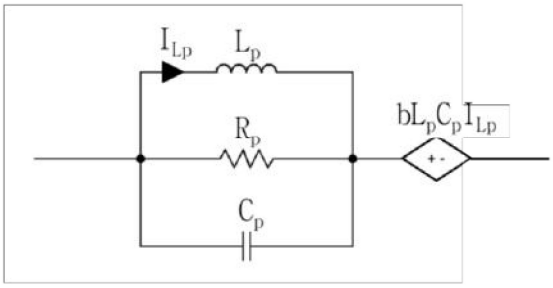


Figure 7: Equivalent circuit for complex poles pair.

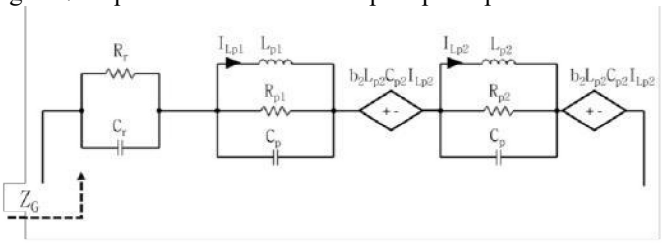


Figure 8: Equivalent circuit for Z_G

4. Conclusions

In this paper we present a multi-resonance perfect absorber that each resonance can be tuned independently by changing the value of chemical potential μ_C and also by tuning the width of graphene ribbon we can relocate the frequency of absorption. Therefore we can achieve a bandwidth of absorption. In the following for the first time we purposed an algorithm to find an equivalent circuit for our structure. To this end first we calculated impedance of patterned graphene by using the results of CST-MW and then by applying vector fitting method which brought us residues and poles we can obtain a transfer function, after that we used a method for synthesis of an equivalent circuit model of transfer function and simply calculate the value of circuit's element.

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