Graphene Supercapacitor based Resistive Loops for Ultra Broadband Microwave Absorption

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***Abstract* – In this paper we present a new kind of equipment for ultra broadband microwave absorption, which consists of two graphene resistive loop (GRL) structures based on the graphene supercapacitors (GSCs), the different geometry sizes of the two GRLs provide two resonant frequencies. As a result, above 90% absorption ranging from 5 to 20GHz is obtained.**

***Index Terms* — Graphene, supercapacitor, microwave absorption.**

1. Introduction

The past decades have seen rapid advances in materials and structures for microwave absorption. Among them, resistively loaded high impedance surfaces (HISs) have been reported on intensively [1], which have prove great advantages including reducing the thickness, enhancing the width of incidence angles as well as bandwidth and so on.

Nowadays, graphene intriguing tunable properties arising from the interband and (or) intraband electron transitions demonstrate potential applications in next generation devices. To name a few, nanoresonators [2], metamaterials [3, 4] and wavefront control device [5].

More Recently, One can shift the Fermi level E_F of graphene significantly with a low applied voltage by the means of ion-gel top gate [6] and/or electrolyte medium [7, 8], which make a tremendous progress for engineering applications. Notably, in Ref. [8], a Salisbury screen structure that constructed by a electrolyte medium assisted tunable graphene resistive layer on the top and a $\lambda/4$ thick spacer that grounded with a PEC plane is investigated for X band radar absorption.

In this paper, inspired by the advantages of the resistively loaded HISs over Salisbury screen for electromagnetic absorption, we designed an improved analogue where the GRLs owing different resonance frequencies act as the Ohm sheets. Numerical simulations demonstrate that our proposed equipment can absorb 5~20 *GHz* electromagnetic waves with above 90% ratio. Moreover, our structure has a thickness of only 5.2 *mm*, which is ultra thin compared with the wavelength.

2. Tunable GRLs

(1) Graphene Property in Microwave Frequencies

The surface conductivity of graphene can be expressed as [5]

$$\sigma_g = \frac{-j2e^2 k_B T}{\pi\hbar^2\left(\omega - j\tau^{-1}\right)} log[2cosh(\frac{E_F}{2k_B T})], \quad (1)$$

where e is the electron charge, $k_B T$ is the thermal energy k_B and $\hbar$ are the Boltzmann constant and the reduced Plank constant (Dirac constant). τ and T represent the scattering rate and temperature. Here we set τ=0.2 *ps* and T =300 *K*.

Next, graphene surface impedance can be calculated using $Z_g = 1/\sigma_g = R_g + jX_g$, we can learn that in microwave frequency range, $\omega \ll \tau^{-1}$, on this condition, the imaginary part of Z_g (inductive reactance, X_g) can be ignored and graphene is regarded as a resistive sheet without dispersion property. Figure 1 shows that the real part of Z_g (resistance, R_g) decreases with E_F. For E_F =0 *eV* and ± 1 *eV*, $R_g \approx$ 1.2 $k\Omega/sq$ and 42.5 Ω/sq respectively.

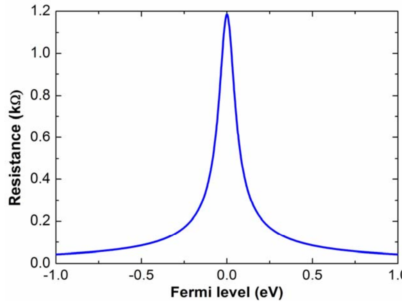

Fig. 1. The relationship between graphene surface resistance and the Fermi level in microwave frequencies

(2) GRLs using Electrolyte Medium Controlled GSCs

Fig. 2 gives a schematic representation of the GRL unit cell of based on GSC, the two-layer graphene (supported by the polyvinyl chloride substrate) is separated by electrolyte medium (diethylmethyl (2-methox-yethyl) ammonium bis (trifluoromethylsulfonyl) imide, [deme] [Tf2N]), where d (50 *um*) is the distance between the two-layer graphene, p indicates the period of the unit cell, w and a are the width and inner diameter of the GRL. When a bias voltage is applied, positive and negative ions will concentrate beside the graphene layers respectively, which act as a supercapacitor, generating a strong static electrical field, thus the graphene doping level can be significantly tuned.

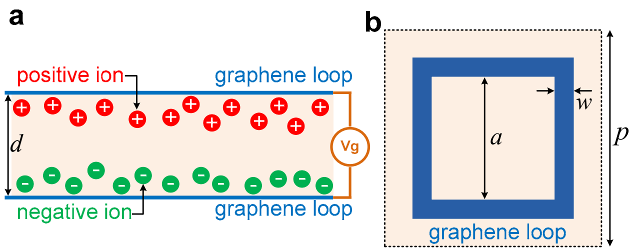

Fig. 2. Active GSC that contains two graphene loops separated by electrolyte medium.(a) size view and (b) top view

In this paper, we set the same p (11.2 mm) and w (1.2 mm) for the top GRL and bottom GRL respectively, but with different a (7.56 mm and 5.16 mm respectively).

3. Results and Discussions

The investigated absorber is sketched in Fig. 3, the top GRL is closely placed with the bottom one. The two layer GRLs and the PEC are separated with a spacer (foam with $\varepsilon = 1.05$) and the separation is indicated as s (5.2 mm). We consider the equipment is illuminated with a plane wave with incident angle θ . For simplicity, here we consider the reflection coefficient of the s (TE) wave, we set θ =0.

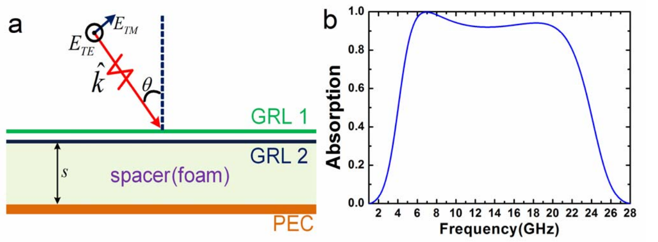

Fig. 3. (a) Proposed equipment for microwave absorption size view and (b) the simulation results of absorption.

Next, we employ CST Microwave Studio to obtain the absorption of the equipment, with the periodic condition in the plane direction of the GRLs. By adjusting the resistance of the graphene (about 60 Ω / sq), we can obtain a optimized absorption result, as shown in Fig. 3(b). It can be clearly seen that above 90% energy of the incident wave is absorbed from 5 to 20 GHz. The ultra broadband absorption can be interpreted as two coupled resonances arising from the GRLs that have different geometry sizes, which can be learn from the two absorption peaks in the cure of Fig. 3(b).

4. Conclusion

In summary, a new type of microwave absorber comprising tunable GRLs has been studied. Our proposed equipment shows good properties such as ultra broadband and ultra thin. Manufacture and measurement of this absorber will be investigated in future studies.

Acknowledgment

This work was supported in part by the National Natural Science Foundation of China (Grant Nos. 61271057), the Scientific Research Foundation of Graduate School of Southeast University, the Fundamental Research Funds for the Central Universities and the Innovation Program for Graduate Education of Jiangsu Province (Grant Nos. CXLX13_092).

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