Exploiting Graphene based Ultrathin Metasurface for Microwave Absorber

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Abstract: Metamaterials based absorbers have numerous applications which includes sensors, solar cells, thermophotovoltaics, wireless communications, emitters, etc. In this work, a graphene based metamaterial absorber is designed and demonstrated to cover broad range of microwave frequencies. The FR4 substrate is used to design this absorber. To achieve the broadband absorption a graphene sheet is placed to the top of absorber. The designed absorber covers the X and Ku bands in microwave regime of electromagnetic (EM) spectrum. Moreover, the polarization insensitivity and oblique incidence analysis is performed which shows that the designed structure is insensitive to polarization and incident angle of light.

Keywords- Graphene, metasurface, FR4, absorber, polarization insensitivity.

I. INTRODUCTION

Previously, absorbers gained attention due to its applications in military, communication system etc. [1]. Absorber are used to absorb unwanted signals that may harm the system performance. The absorber material is defined by electric permittivity (ε) and magnetic permeability (μ). Electric permittivity is the measure of effect of the material under the electric field. And the magnetic permeability is measure of effect of material under magnetic field. The loss tangent defined as how much wave is attenuated. So, larger the attenuations mean that more wave travels or absorbs through the material.

In addition, magnetic absorbers have high permeability and high magnetic loss. These absorbers have ability to compress the wavelength due to the high permeability. These absorbers can be used for cavity resonance and are available in the form of rigid epoxy. Dielectric absorber has no magnetic properties, the μ=1 for these absorbers. These absorbers are low-cost and low weight. Due to lack of magnetic properties, these are not used in cavity resonance applications. Some absorbers come in moldable form do not have both magnetic and dielectric absorber's properties.

Different types of absorbers being present in which some of them are free space absorbers; classified as reflectivity absorbers and insertion loss absorbers. The reflectivity absorbers reduce the level of the reflection with a metal back plan, whereas insertion loss absorbers reduces the signals that travel from one point to another point. Moreover, chirality based metasurfaces are presented to enhance the absorption based on novel techniques.

Absorbers used for closed surface are different from free space absorbers. Such absorbers are free from limitation of thickness of the material. In the cavity resonance absorber, the material used with high permittivity or permeability will cause the absorption of electromagnetic waves. Previously, lossy materials used for absorption but with the passage of time trend moves from lossy materials to metamaterials as the absorbers. Additionally, a lot of devices and algorithm introduced to design filters, amplifiers, photonic devices. A metamaterial-based absorber gained attention due to high absorption and the impedance matching with free space to overcome the reflections. This can be done by engineering the permittivity and permeability of metamaterials. The planar version of metamaterials termed as metasurfaces emerges due to high absorption of planar sheets or films that placed to the absorber material to keep the absorber thin.

Previously, for broadband absorption 3-unit cell of different design is being used. This design constitutes broadband absorption by placing 12 elements of unit cells on metasurface [2]. In the past research the FR4 graphene based absorber is being used with PEC back plan and PVC film is used on FR4 substrate. This absorber covered the band from 10.5-20.2 GHz band. For optically transparent wide band absorber 2 dielectric layer with patterned graphene is being used. This design gives 90% absorption from 6 to 15 GHz frequencies band.

In this work, graphene sheet is used to make highly efficient absorber. Graphene is 2D material and only extends in two dimensions while its third dimension is zero. Graphene has more electrical conductivity and strong dielectric loss that's why it is choose for microwave absorber.

II. DESIGNED METHDOLOGY

In design methodology, a FR4 substrate based absorber is being used with 2.2 dielectric constant (ε) and 0.02 loss tangent (ζ). On the substrate, polyvinyl chloride (PVC) film is added with 3.5 dielectric constant (ε). On the PVC film, 2 graphene rings and one patch is added to the absorber for high absorption. The sheet resistance of graphene is 1200 ohm/sq.

Absorber is backed with copper that causes transmission zero. Figure 1(a) and 1(b) shows the layered view and the top view of the proposed unit cell, respectively. The dimension of the proposed absorber are $P_x = P_y$ = 10mm, and w = 1mm. L_1 = 8mm, L_2 = 6mm. The thickness of copper metal t, FR4 substrate t_1 and PVC film t_2 is 0.035mm, 3mm and 0.017mm, respectively.

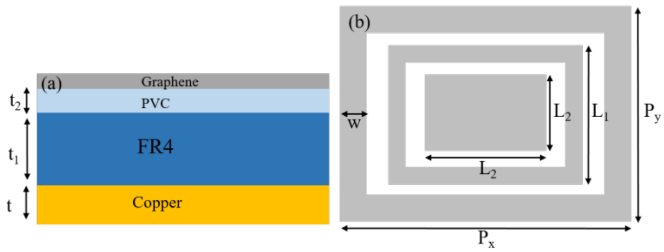

Figure 1. Unit cell of the absorber (a) Layered view, (b) Top view

III. Results

It is obvious that the absorption of any absorber will be high when reflections and transmissions are minimum. Both reflection and transmission are related with the design frequencies. The absorption is calculated by using the formulation as given in Eq. (1).

$$A(\omega) = 1 - R(\omega) - T(\omega) \quad (1)$$

where $T(\omega)$ is the transmission, $R(\omega)$ is the reflection and $A(\omega)$ is the absorption of the absorber. $T(\omega)$ will be zero due to back metal plane reflector. Therefore, the absorption is only calculated by $R(\omega)$ and can be written as in Eq. (2).

$$A(\omega) = 1 - R(\omega) \quad (2)$$

In actual, $R(\omega)$ is calculated by $|S_{11}|^2$ which is the reflection parameter for the designed absorber. So, the absorption in Eq. (2) becomes:

$$A(\omega) = 1 - |S_{11}|^2 \quad (3)$$

S_{11} is calculated using Finite Difference Time Domain (FDTD) method. For the simulation periodic boundary condition applied to x-y plane whereas open boundary condition applied to z plan.

The absorption for the designed absorber is depicted in Figure 2. The absorber shows absorption more than 50% from 8 to 19 GHz. The absorber should be insensitive to polarization angle to achieve the maximum efficiency. The polarization insensitivity analysis for the designed absorber is demonstrated in Figure 3. The results shows that the polarization angle (φ) 0° to 90º, the absorption is same so the proposed absorber is insensitive to polarization.

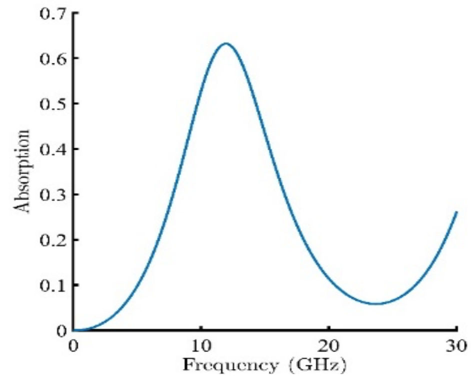

Figure 2. Absorption for the designed absorber

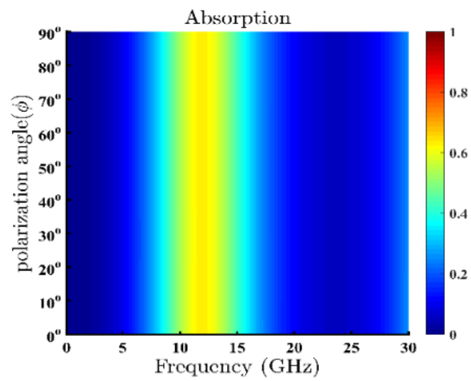

Figure 3. Polarization insensitivity analysis for the designed absorber

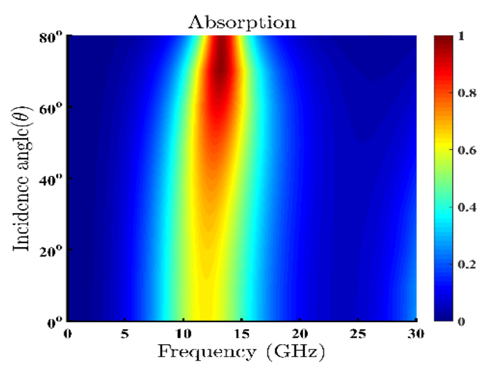

Figure 4. TE wave incidence angle analysis for the designed absorber

The incident angle of light can affect the efficiency of the absorber. The incident angle analysis for the TE wave illuminated the proposed absorber is depicted in Figure 4. The incident angle of light from 0 ° to 80º shows the maximum absorption at the aforementioned frequency range

IV. Conclusion

The proposed absorber with FR4 substrate covers the X (8 to 12 GHz) and Ku (12 to 18 GHz) frequency bands with maximum absorption. The proposed absorber design is insensitive to polarization angle from 0º to 90º. Meanwhile, the absorber is insensitive to incident angle up to 80º and 35º for TE and TM polarized wave. Graphene film is placed on top of the absorber to achieve the maximum efficiency. Compared to the state of the art metasurfaces in which different unit cells placed for broadband absorption, this designed absorber only used one substrate and a single unit cell. In addition, multilayers also used to achieve broadband absorption. This work paved the way towards potential application in communication and sensing under X and Ku frequency band.

References

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