Design of a Metamaterial Absorber in the Terahertz regime

Mahidol University
Wisdom of the Land

Natsima Sakda*, Rachapak Chitaree
*E-mail : natsima.sak@student.mahidol.edu

Motivation

Metamaterials (MMs) are the artificially engineered materials that can exhibit particular electromagnetic properties such as negative refractive index, left-hand behavior, extraordinary transmission, negative Doppler effect, etc. With this fascinating characteristics, applications of MMs into the terahertz regime (0.1-10 THz) are of great and increasing interest in the last few years. Several devices such as the perfect lens, invisibility cloaking, perfect absorber and transmission have been designed and fabricated for practical use in the THz band based system.

Theory of Metamaterial Absorbers

Most of Metamaterial Perfect Absorbers consist of 3 layers which are a periodically arranged metallic pattern layer, a dielectric layer and a continuous metallic layer. Each layer of MMPA has different functionality. **The first layer** matches the impedance between absorber and surrounding (air). Next, **the second layer** has the responsibility to give the space for the incident field to be stayed and absorbed. Finally, **the third layer** is needed to reflect back the field that cannot be absorbed in the middle layer to be absorbed again.

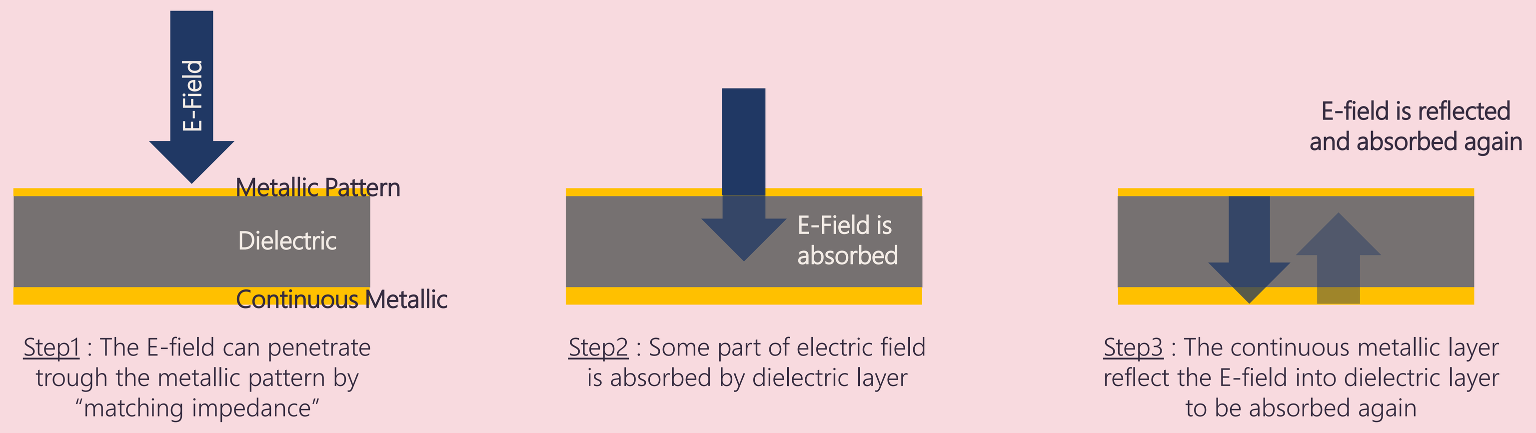

Figure 1 : The diagrams show how the electric field be absorbed at each layer.

Structure Design

The proposed metamaterial absorber was designed for multi-band absorption with omnidirectional property. The first layer is composed of the 4-subunit cell with 3 gap squares via counter-clockwise rotation.

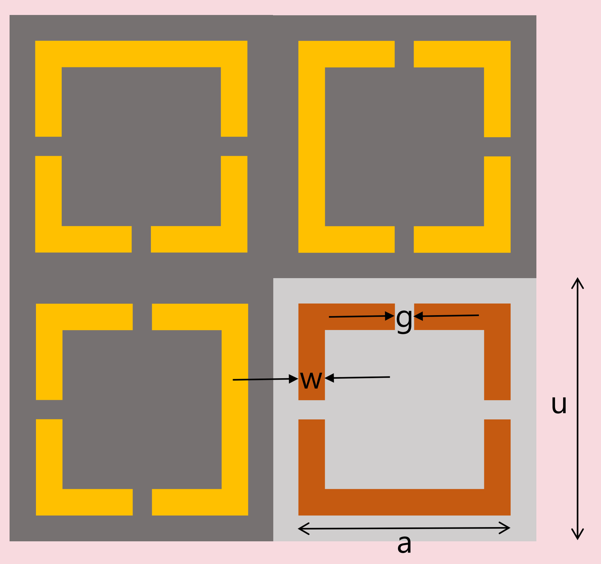

Figure 2 : Top View of the unit cell structure (shaded color for dimension only)

Figure 3 : Side View of the unit cell structure

The periodically arranged metallic pattern layer consist of 4 square-shaped ring resonator, each one having 3 gaps. The metallic pattern is made of gold having the conductivity 4.09×10^7 S/m and thickness t=0.4 μm. The top view dimensions are u=70 μm, a=55 μm, w=6.5 μm and g = 5 μm. Next, the dielectric layer is made of polyimide having the dielectric constant 3(1+i0.06) and thickness as h=7 μm. The bottom layer is continuous metallic having thickness as b=2 μm.

Simulation Results

By using the finite-difference frequency-domain (FDFD), the simulation results shown that the proposed structure provides 4 absorption peaks at 1.05, 2.09, 3.50 and 3.74 THz with corresponding absorbance of 59.3, 99.1, 98.0 and 99.7, respectively.

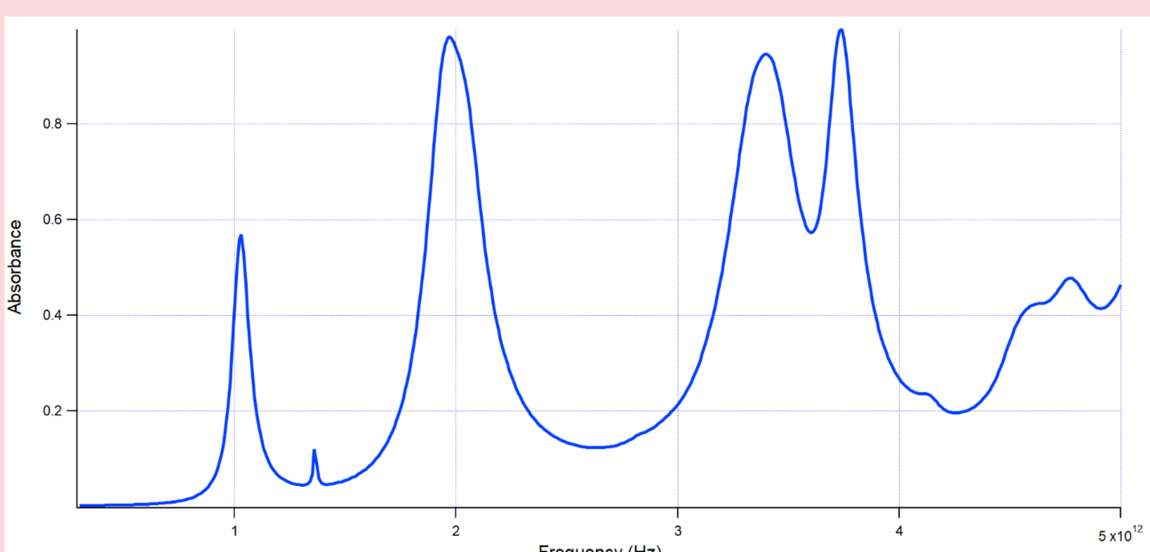

Figure 4 : The absorbance of proposed metamaterial structure in terahertz regime

4 figures below show the electric field distribution in the proposed structure at the absorbance frequency.

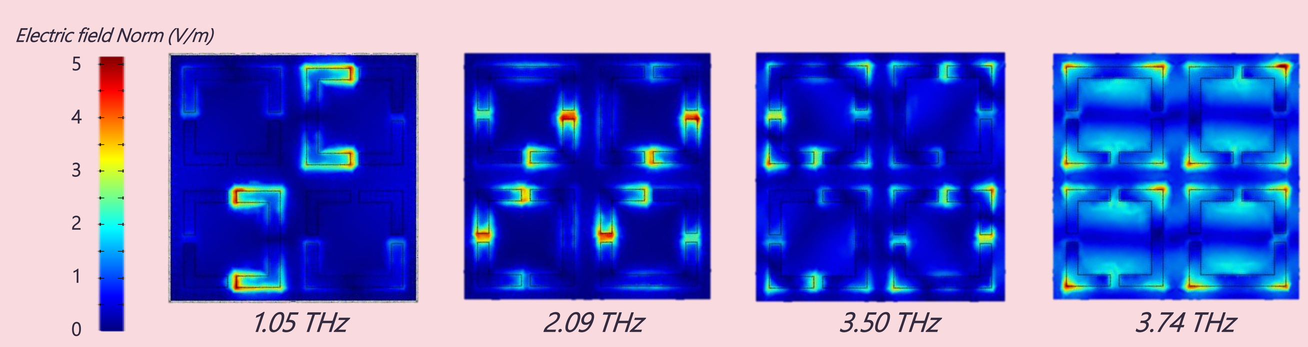

Figure 5 : The Electric filed distribution of 4 absorption peaks at 1.05, 2.09, 3.50 and 3.74 THz

Simulation Results (cont.)

The azimuthal angle of the incident field was considered for all 4 absorbance frequencies. The simulation shows that absorbance frequencies are insensitive to the azimuthal angle. Moreover, the geometry parameters were also considered. The metamaterial length (a) and the gap width (g) were the parameters that affect the absorbance frequency on term of both absorption peaks and absorbance, as shown,

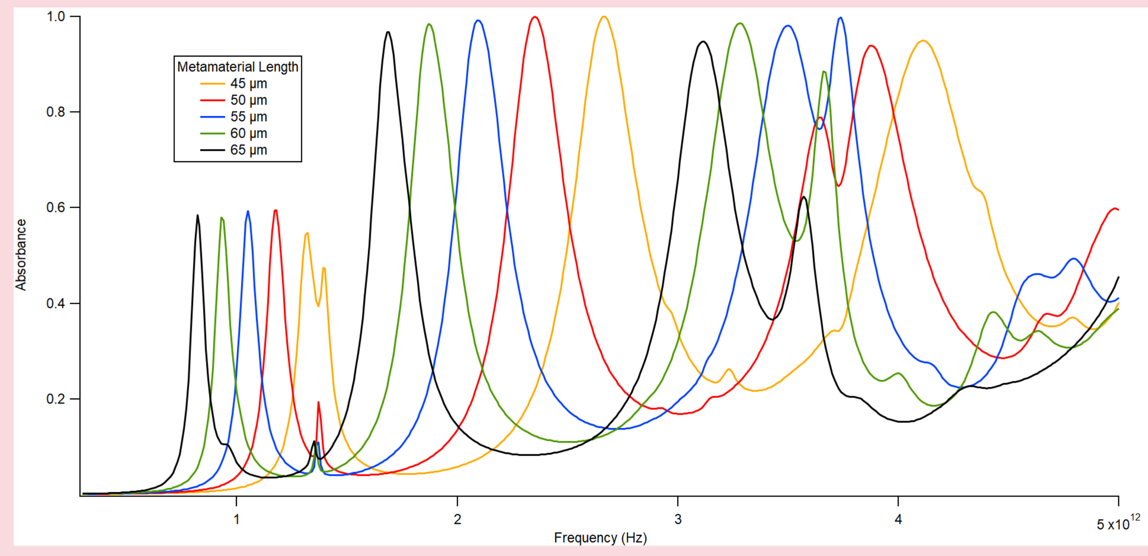

Figure 6 : The effect of metamaterial length to the absorbance frequency

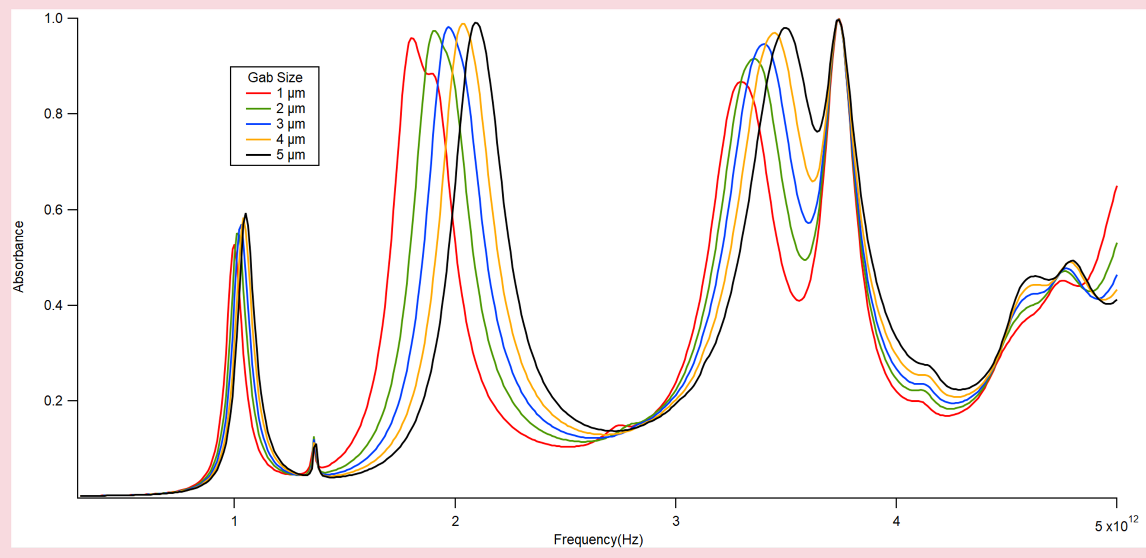

Figure 7 : The effect of metamaterial gab size to the absorbance frequency

The metamaterial length affects the absorption characteristics by , inversely proportional, shifting the frequency position for 1st and 2nd peak but more complicated affect in the 3rd and 4th peak in terms of peak frequency and absorbance. And the gap width affect the absorption by slightly proportional shift the frequency position for 1st, 2nd, and 3rd but doesn't affect for the 4th peak.

Conclusion

From the proposed absorber structure, with 3 layers, 4 peaks of absorbance at 1.05, 2.09, 3.50 and 3.74 THz insensitive to azimuthal angle of an incident electric field can be obtained. Moreover, the geometry parameters, length and gap size of the metamaterial absorber, also affected the absorption characteristics in term of peak frequency and absorbance.

Future work

Prior to put the designed structure into practice, the omnidirectional property of the metamaterial absorber has be examined.

Acknowledgements

I would like to express my gratitude The Science Achievement Scholarship of Thailand scholarship for a financial support. And Thailand Center of Excellence in Physics, for permission to use a simulation software.

References

Rhee, J. Y., et al. "Metamaterial-based perfect absorbers." *Journal of Electromagnetic Waves and Applications* 28.13 (2014): 1541-1580.

Appasani, Bhargav, et al. "A Simple Multi-band Metamaterial Absorber with Combined Polarization Sensitive and Polarization Insensitive Characteristics for Terahertz Applications." *Plasmonics* (2018): 1-6.

Withayachumnankul, Withawat, and Derek Abbott. "Metamaterials in the terahertz regime." IEEE Photonics Journal 1.2 (2009): 99-118

AORG
Applied Optics Research Group
Department of Physics, Faculty of Science, Mahidol University