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Research on ultra-wideband terahertz absorber with graphene loaded dielectric hemi-ellipsoid

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ABSTRACT

An ultra-wideband terahertz absorber is presented with dielectric hemi-ellipsoid on a monolayer graphene layer. The absorber has achieved an ultra-wideband absorption bandwidth from 2 THz to more than 10 THz with an average absorbance of 95.72%, the relative bandwidth reaches 133%. The excellent absorption properties owing to multiple discrete graphene plasmonic resonances(GPRS) and the continuous multimode Fabry-Perot (FP) resonances, the mechanism for the its ultra-wideband absorption are analyzed in details..

INTRODUCTION

Terahertz absorbers have various applications in terahertz imaging, thermal detectors, and communication. Among them, absorbers based on metamaterial and graphene have achieved great progress recently[1,2], including metal-loaded graphene absorbers, patterned graphene absorbers, and dielectric-loaded graphene absorbers. However, most of them operate at single or multiple bands. Even though a sequential multiband can be extended to broadband in certain absorbers, but its limited bandwidth and undesirable absorption ability still need to be resolved. The dielectric structures performed well in broadband absorption; however, a tradeoff between a wider absorption band and a worse absorption was suggested. Therefore, an absorber with an ultrawideband and good absorption is desirable.

RESULT

The scheme of the proposed absorber unit cell is shown in Fig.1.The periodic arrays of silicon hemi-ellipsoid(SHE) in the x-y plane are set on a monolayer graphene, which is supported by polydimethylsiloxane (PDMS) substrate and the bottom gold film.

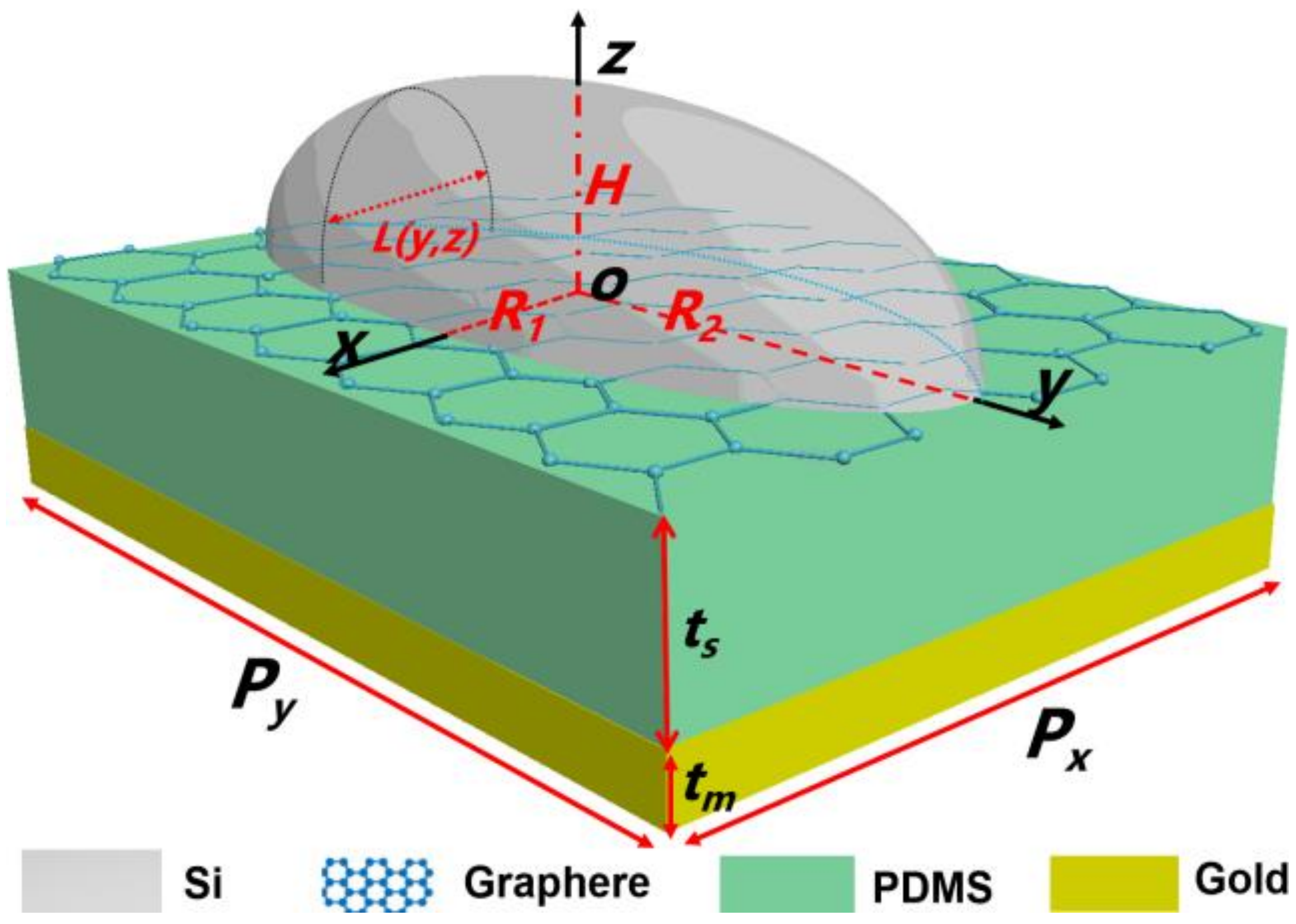

Fig. 1. Schematic of the unit cell of absorber with Px= 80µm, Py=24µm, R1 = 11µm and R2 = 38µm, H= 10µm, ts= 15µm, tm= 2µm.

The absorption curve in Fig.2. (a) shows that an average absorbance of 95.88% in an ultra-wide band between 2 THz to 10 THz is achieved, the relative bandwidth reaches 133%. Thedistribution of Ez on the xy-plane of z=100 nm are shown in Fig.2. (b)-(g), they are six representative absorption peak frequencies within the ultra-broad absorption band corresponding to the resonance frequencies of 2.05 THz, 2.95 THz, 4.10 THz, 5.70 THz, 7.10 THz and 8.95 THz separately. The order of the mode number N can be distinguished in Figs2. (b) - (d). For example, Fig. 2 (b) has one node in x direction, which corresponding the first order mode. As to the field pattern in Fig. 2 (c), two resonance modes can be found at different positions along y direction, which are the first and second order mode at the center and at both ends of the pattern, respectively. By comparing, the theoretical numerical results in Fig 3(a) also shows that there exist two modes at 2.95THz, they are represented as two points of intersection of the dotted line at frequency 2.95THz and the mode curves of N=1and N=2. Similarly, the field pattern in Fig. 2 (d) contains three modes, and so on. Nevertheless, at higher resonance frequencies, it is clear that the mode characteristics will become more complex and the electric field distribution patterns will become undistinguished due to the severe overlapping of different resonance modes, those are mixed-mode resonances as shown in Figs. 2 (e) - (g) .

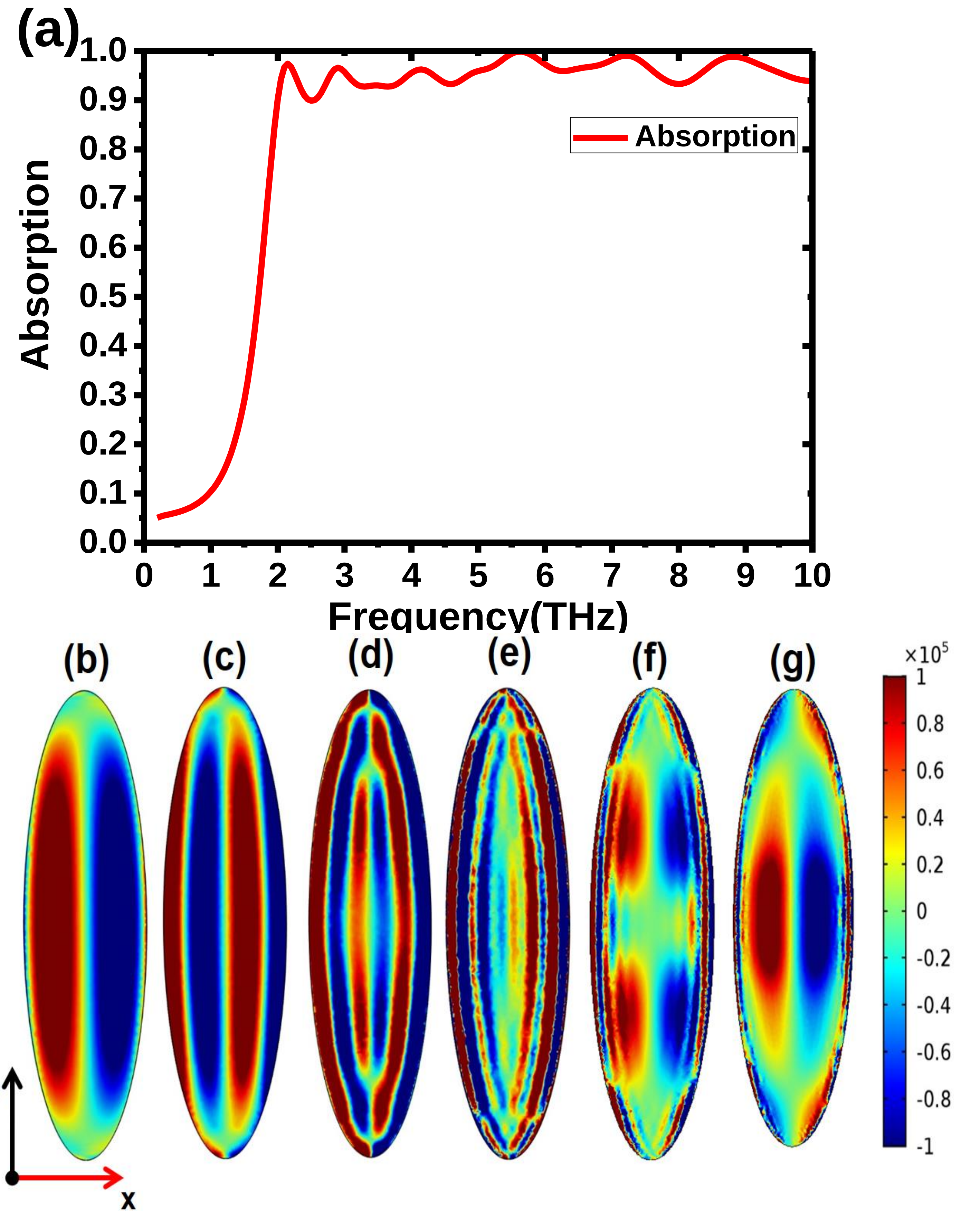

Fig. 2. (a) The absorption spectrum under normal incident wave with the electric field parallel to x-axis. The z component of the electric field 100 nm above the interface of graphene and SHE at resonance frequencies (b) 2.05 THz, (c) 2.95 THz, (d) 4.10 THz, (e) 5.70 THz, (f) 7.10 THz, (g)8.95 THz, respectively.

The effect of graphene on the absorption was investigated. Fig. 3 (a) shows the absorption spectrum for the absorber with and without graphene. It was discovered that the presence of graphene significantly affected the absorption property. The overall absorption spectrum performance worsened when the graphene was absent, particularly in the frequency region below 8 THz. In addition, the effect of the Fermi level of graphene on the absorption spectrum is shown in Fig. 3 (b), it can be seen that the absorption curves got flattened when the Fermi level was increased from 0.2 to 0.8 eV and an average absorption of 95.72% can be obtained. The Fermi level can be tuned by chemical doping or by applying a different gate voltage on graphene.

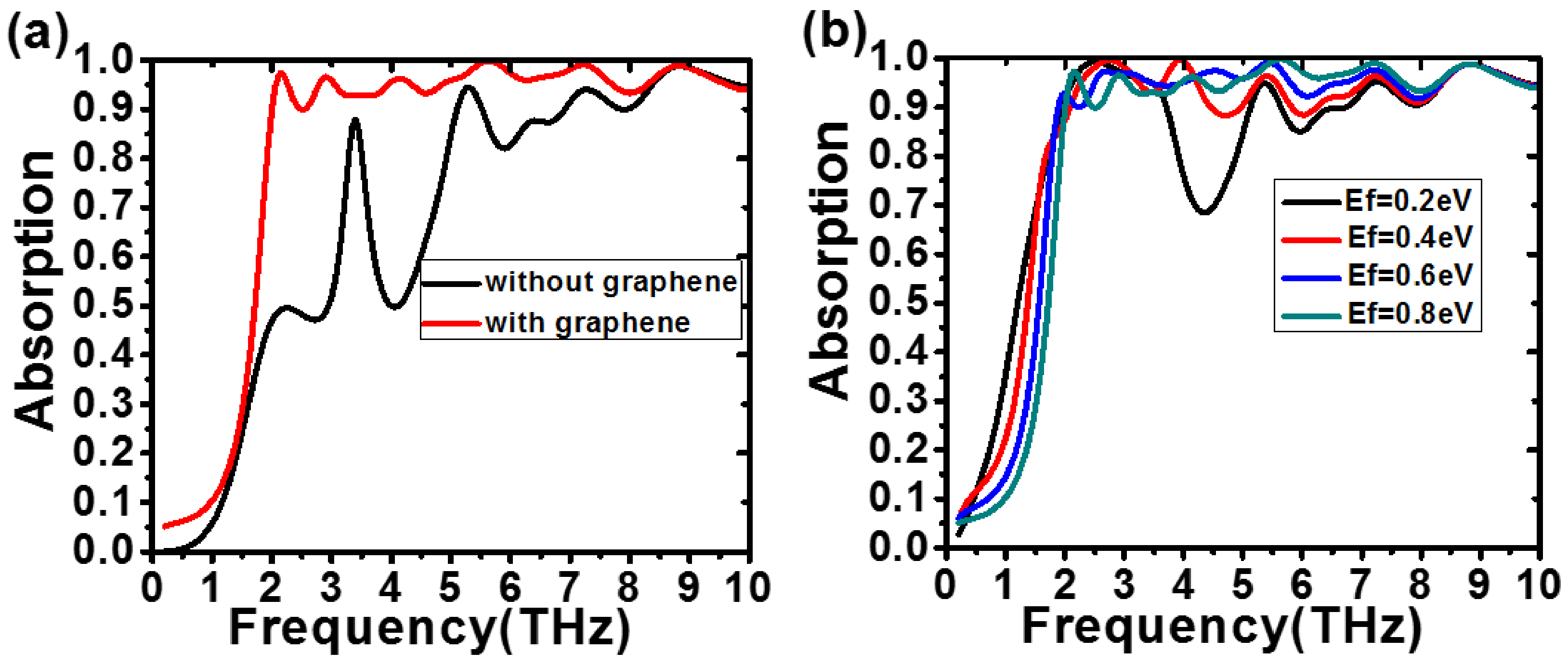

Fig. 3. Absorption of SHE absorber (a) with and without graphene; (b) Fermi level of graphene varying from 0.2 to 0.8 eV.

Summary

In summary, we have designed a high-performance, ultrawideband terahertz absorber with the structure of a dielectric hemi-ellipsoid loaded monolayer graphene. Ultrawideband absorption from 2 to more than 10 THz with a high average absorptivity of 95.72% and a relative bandwidth of 133% were achieved. Furthermore, it demonstrated excellent oblique incident angular tolerance and a stable absorption within 50° . Hence, its excellent absorption characteristics render it a promising candidate for applications in terahertz trapping, imaging, communication, and detection.

References

[1]. J. Yang et al., “Broadband terahertz absorber based on multi-band continuous plasmon resonances in geometrically gradient dielectric loaded graphene plasmon structure,” Sci. Rep., vol. 8, 2018, Art. no. 3239.

[2]. R. Singh, W. Cao, I. Al-Naib, L. Q. Cong, W. Withayachumnankul, and W. L. Zhang, Ultrasensitive terahertz sensing with high-Q Fano resonances in metasurfaces. Applied Physics Letters 105, 41–48 (2014).