DESIGN OF TERAHERTZ BIO-ABSORBER USING PLUM FLOWER CURVES **

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A double peaks bio-absorber, which includes two metal layers and one dielectric layer, is proposed. The surface metal layer of the bio-absorber is a square array that consists of a plum shape metal cell that can produce double resonance absorption. By studying the surface current and electric field z-component, the double peak is shown to originate from the two distinct resonance modes of the plum flower curves induced by the incident electromagnetic wave. Due to the symmetrical structure, the proposed bio-absorber is not sensitive to the polarization direction of incident waves and can maintain high absorption rates in a wide, range of angles.

Keywords: *absorber, terahertz, absorption, peak.*

КОНСТРУКЦИЯ ТЕРАГЕРЦОВОГО БИО-ПОГЛОТИТЕЛЯ С ИСПОЛЬЗОВАНИЕМ СТРУКТУРЫ ТИПА ЦВЕТКА СЛИВЫ

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Разработан двухпиковый биопоглотитель, который включает в себя два металлических слоя и один диэлектрический слой. Поверхностный металлический слой биопоглотителя представляет собой квадратную решетку, состоящую из металлических ячеек в форме сливы, которая может давать двойное резонансное поглощение. Исследование поверхностного тока и z-компоненты электрического поля показало, что двойные пики возникают из двух различных резонансных мод структуры типа цветка сливы, индуцированных падающей электромагнитной волной. Благодаря симметричности структуры биопоглотитель не чувствителен к направлению поляризации падающих волн и может поддерживать высокую скорость поглощения в широком диапазоне углов.

Ключевые слова: *поглотитель, терагерцовый диапазон, поглощение, пик.*

Introduction. Since the concept of perfect bio-absorber was proposed by Landy et al. [1] in 2008, the resonance structure of bio-absorber has changed a lot in recent years; all kinds of structures, for example, electromagnetic induction coupling (ELC) [2–5] and frequency selective surface (FSS) [6–8], have been applied to design and fabricate perfect bio-absorbers. So far most of the literature reports on bio-absorbers involve putting much resonance structures together. However, such structures are bulky and difficult to fabricate. In this paper is proposed a novel double peak bio-absorber by using plum flower curves – the double peaks derived from the resonance model of plum flower curves. In this design, each unit cell of the bio-

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absorber has the same geometry, size, and orientation. Compared with the square resonators [9–11], the plum flower curves bio-absorber has a smaller size. Our simulation shows that the proposed bio-absorber is not sensitive to the polarization direction of incident waves and can maintain high absorption rates in a wide range of angles.

Structure design and characteristics analysis. The proposed bio-absorber is a three-layer structure, namely metal, medium, and metal. The two metal layers are gold whose conductivity is $\sigma = 4.09\times10^7$ S/m, and the medium layer is polyimide whose real dielectric constant and loss tangent are $\varepsilon_r = 3.5$ and $\tan\delta = 0.057$, respectively. In the bio-absorber cell $D = 2w$, whose structure is shown in Fig. 1, D is the total length of the metal, and w expresses the side length of the square ($D = 2\,w$).The bottom of the cell is a metal film, while the surface metal of the cell is composed of a square and four semicircles. The thickness of the two metal layers and medium layer are 0.2, 0.2, and 1.2 μm, respectively, while that of both of the circle sizes in the x and y direction is 20 μm.

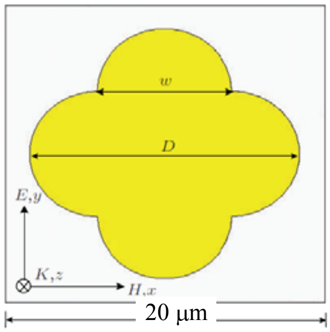

Fig. 1. The structure diagram of the bio-absorber.

In this paper, the performance of the bio-absorber is simulated by CST Microwave Studio 2011 with the time domain finite integral method. To facilitate the analysis, the directions of x and y are taken as periodic boundary conditions, while the direction of z is regarded as the open boundary condition. When the THz wave vertical is incident on the surface, the absorption A of the bio-absorber can be obtained by using $A = 1 - |S_{11}|^2 - |S_{21}|^2$, where S_{11} and S_{21} are the reflection coefficient and transmission coefficient. Due to the THz wave walking in the metal just around 70 nm distance, the transmission coefficient $S_{21} = 0$ and absorption $A = 1 - |S_{11}|^2$.

In order to get the maximum absorption rate, the reflectivity must be reduced according to the theory of impedance matching – the equivalent impedance of the bio-absorber changes with change in the bio-absorber's structure parameters. When the equivalent impedance equals the free space impedance, the reflectivity

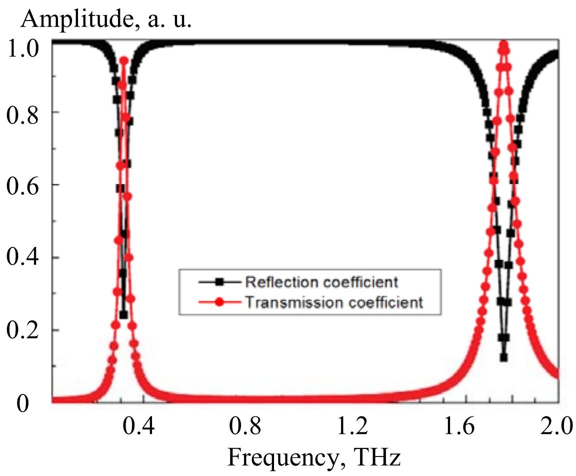

Fig. 2. The reflection and transmission curve of the proposed bio-absorber.

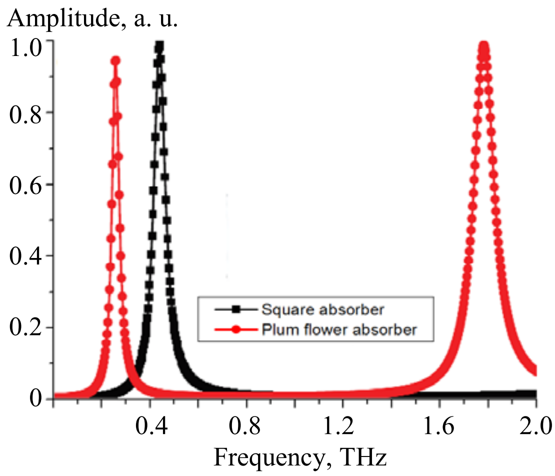

Fig. 3. The contrast figure between a square bio-absorber and the proposed bio-absorber.

is minimum and the absorption is maximum. Through the simulation analysis, the absorption and reflectivity of bio-absorber are shown in Fig. 2, where there are double peaks at 0.3 and 1.75 THz, and absorption of the first peak and second peak is 94.2 and 98.5%.

Figure 3 shows the absorption peak diagram of square and plum flower bio-absorbers that have the same size and array cycle. It can be seen that the plum flower bio-absorber has two absorption peaks. Such phenomenon is the result of the space filling in plum flower structure: in a certain area, the line length of the plum flower will be increased, with the order growing endlessly.

Absorption principle and experimental simulation. In order to study the absorption principle of the proposed bio-absorber, the surface current and *Z* component of the electric field are calculated and analyzed in this paper. A field monitor is set at 4.32 THz, while the surface current and *z* component are shown in Fig. 4. Figures 4a,b show that the reverse parallel current is formed on surface metal and substrate metal, and the reverse current can produce strong electromagnetic response, thus forming a resonance in the *z* direction. The distribution of the electromagnetic field is shown in Fig. 4c,d. It can be seen that the charges are gathered in surface metal and substrate metal layer along the *y* direction. Meanwhile, the upper and lower metal layer have the opposite charges at the same time, which show that there is electric dipole resonance caused by the electric field in the *y* direction. The strong electromagnetic resonance causes the electromagnetic energy to be consumed by the bio-absorber.

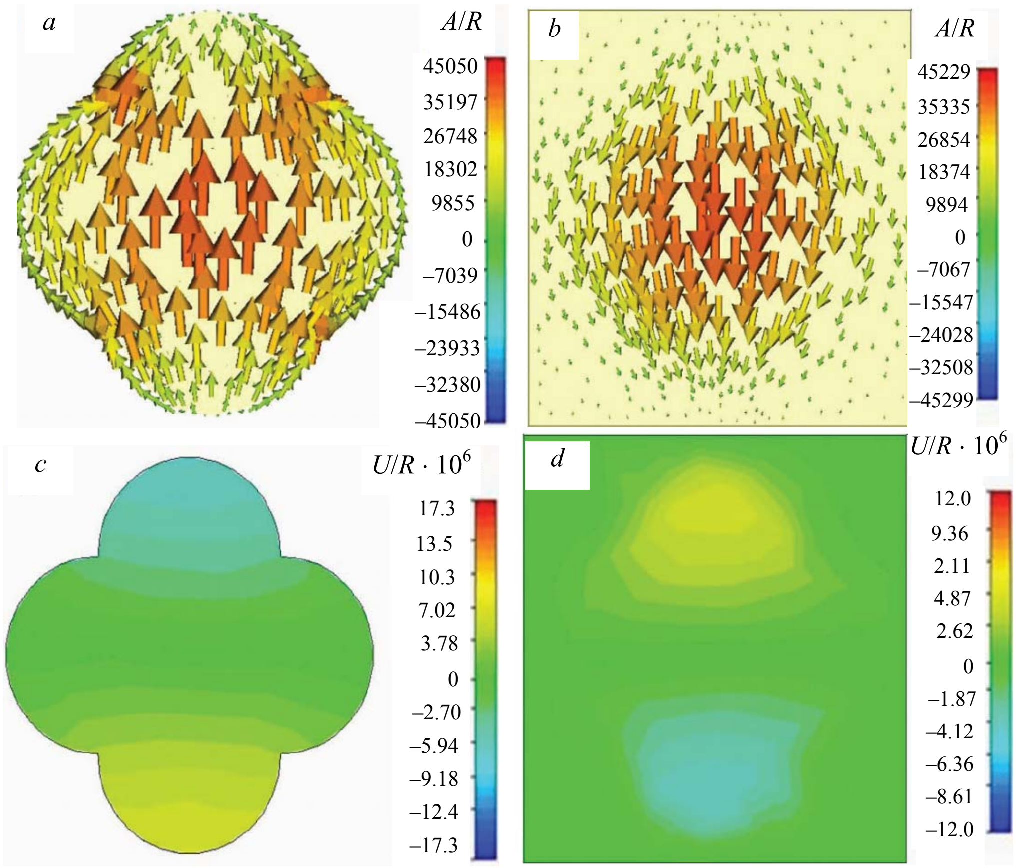

Fig. 4. The surface current and *z* component of the bio-absorber.

To have a better understanding of electromagnetic resonance, the equivalent circuit of electromagnetic resonance is shown in Fig. 5, and the resonant frequency of equivalent circuit can be expressed as [12]

$$f = (2\pi\sqrt{L_e C_e / 2})^{-1}$$

for which the equivalent inductance $L_e = Dt/w$, and the equivalent capacitance $C_e = wD/2t$. Here, D is the total length of the metal, W is the side length of the square, $D = 2w$, and t is the thickness of dielectric layer. The resonance frequency is inversely proportional to the square root of L_eC_e, while L_eC_e is proportional to D^2, so the resonance frequency is inversely proportional to D, this is confirmed by the simulation result.

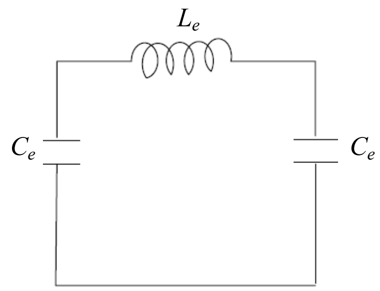

Fig. 5. The equivalent LC circuit of the bio-absorber.

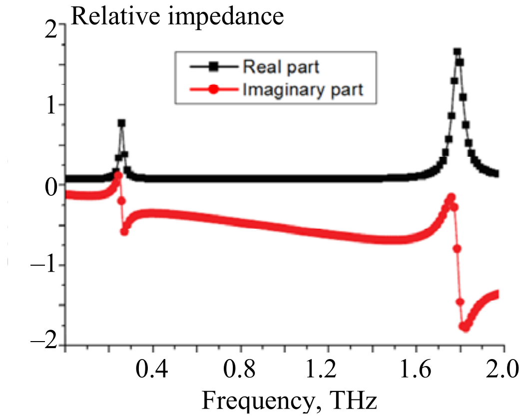

Fig. 6. The relative impedance of the bio-absorber.

In the effective medium theory [13], a bio-absorber is regarded as an equivalent medium. By adjusting the structure of the resonant cell and the distance between upper layer and lower layers to the relative input impedance $\tilde{Z}/Z_0 = \sqrt{(1+S_{11})^2 - S_{21}^2/(1-S_{11})^2 - S_{21}^2} = 1$, where Z_0 is the characteristic impedance of free space, the bio-absorber can realize perfect absorption under a specific frequency. Figure 6 shows the relative input impedance of the interface between surface and air.

Due to the symmetrical structure, the proposed bio-absorber is not sensitive to the polarization direction of incident wave. Under the condition of different polarization angles φ, the absorption frequency and efficiency of the two absorption peaks remain almost constant. Figure 7 shows the changes in the absorption peak with different polarization angles under the condition of vertical incidence. The polarization angle changes from 0 to 90°, while the absorption peak almost does not change, as can be seen from Fig. 7a.

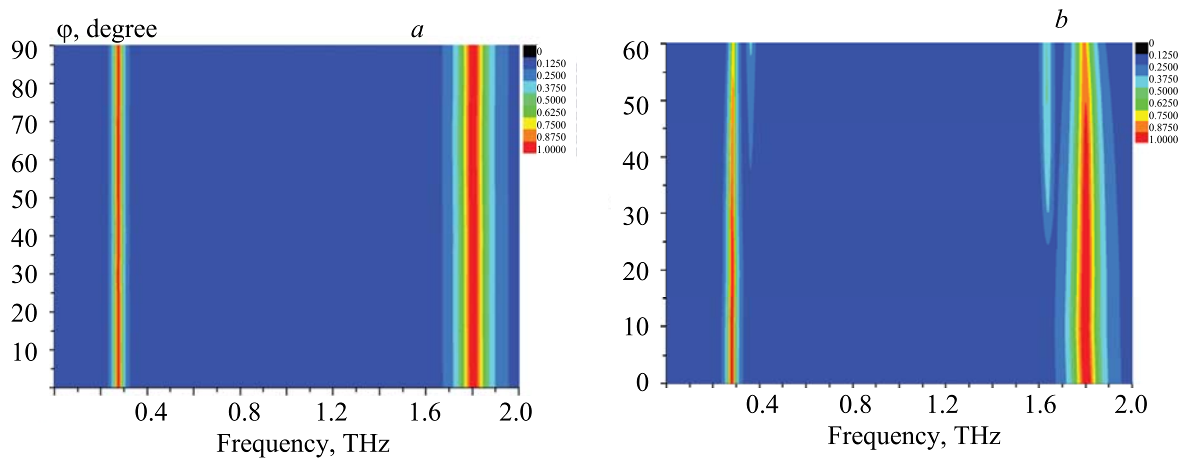

Fig. 7. The change in the absorption with different polarization (a) and incident (b) angles under the condition of vertical incidence.

In practical applications, the incident electromagnetic wave on the bio-absorber surface usually has an angle. Figure 7b shows the changes of the absorption with different incident angles under the same condition as in the case of vertical incidence. It can be seen that the absorption is not changed with different incident angles. With increase in incident angle, two increased absorption peaks at 0.3 and 1.7 THz can be seen.

Conclusion. This paper proposes a new terahertz bio-absorber with dual peaks by using plum flower curves. The bio-absorber not only is nonsensitive to incident wave polarization but can also maintain a high absorption rate in a large angle. The symmetrical structure confers the proposed bio-absorber the advantages of small size and double absorption. The bio-absorber can solve the problem of inability to work at higher frequency of the traditional bio-absorber. Compared with the traditional structure, the plum flower curves bio-absorber is more advantageous.

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