Actively tunable and switchable terahertz metamaterials with multi-band perfect absorption and polarization conversion: supplement

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Supplementary S1: The influence of different patterns of VO_2 and Au on the properties of metamaterials

During the design process, we had explored different configurations on the top layer of metamaterials, such as rectangles, squares, circles, and ellipses. After plenty of sweeping calculations, we found that when the shape of top patterned configuration is square or circular, the proposed metamaterials cannot achieve efficient polarization conversion effect as shown in Figure S1 (a). Moreover, when the top pattern is rectangular, the proposed metamaterials cannot act as perfect multi-band electromagnetic absorber as shown in Figure S1 (b). Therefore, only the current elliptical patterns can simultaneously obtain the perfect absorption, high PCR, and ideal ellipticity

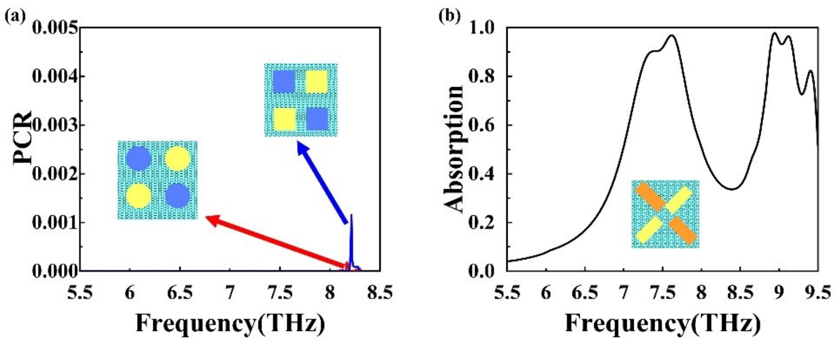

Figure S1. (a) The curves of PCR for different configurations on the top layer when VO_2 is in insulating state; (b) Absorption spectrum when the top pattern is rectangular (VO_2 is in the metallic state)

Supplementary S2: The influence of the thickness of SiO_2 on the absorption, PCR and ellipticity.

In our simulations, the dielectric layer is selected as lossless SiO_2 material. The thickness of SiO_2 is chosen as t_2 = 19 μm. Figure S2 shows the effects of the thickness of SiO_2 on the performance of the proposed metamaterial. One can see from this picture that the absorption spectra have a significant change when the thickness of SiO_2 is increased from 17 to 21 µm. Meanwhile, the spectra of PCR and ellipticity have a red-shift with the increasing of thickness of SiO_2. As t_2 increases, the ability of linear-to-linear polarization conversion weakens, while conversely, the effect of linear-to-circular polarization conversion improves.

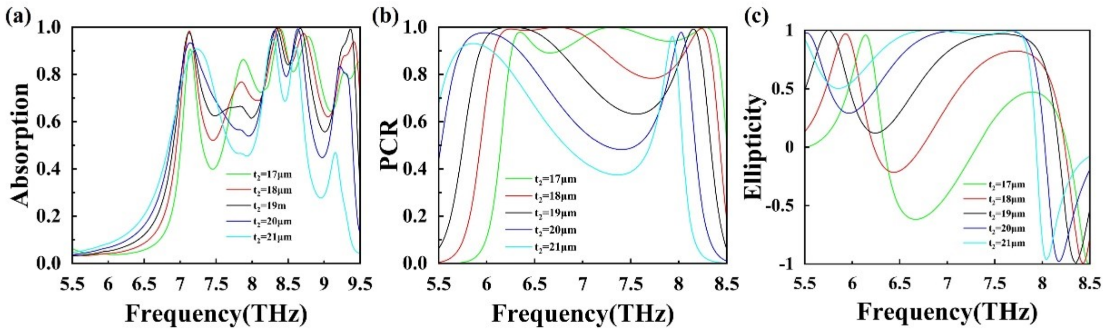

Figure S2. The influence of the thickness of SiO_2 on the (a) absorption, (b) PCR and (c) ellipticity.

Supplementary S3: The influence of the number of VO_2 and Au fragments on the absorption.

The number of VO_2 and Au fragments on graphene play an important role in achieving the above-mentioned multi-functionality. When the number of VO_2 and Au in the top layer decreases, the localized ability of the metal to electromagnetic waves weakens, making it impossible to achieve perfect absorption of electromagnetic waves. Figure S3 shows the absorption spectra corresponding to different numbers of ellipsoids.

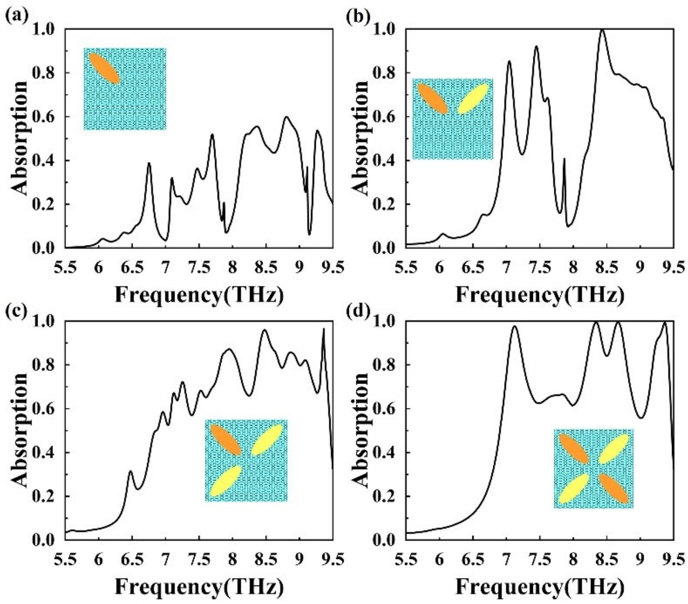

Figure S3. Absorption spectra of the metamaterials with different numbers of ellipsoids.

Supplementary S4: Convergence criteria for geometric parameter optimization process.

To obtain the optimized geometric parameters, we can perform the parameters sweeping by altering the sizes and the positions of the structural elements. During the optimization process, we aim to obtain the perfect absorption, high PCR, and ideal ellipticity. Specially, the absorption efficiency should be nearly 100% when the proposed metamaterial acts as an absorber. Moreover, the PCR and ellipticity should be 1 or -1 to achieve the perfect linear-to-linear and linear-to-circular polarization conversions.

Here we take the radii r_1 and r_2 of the ellipsoids as examples. To obtain the optimized radii r_1 and r_2 of the ellipsoids, we calculate the PCR, ellipticity and absorption spectra of proposed metamaterial as a function of frequency and radii r_1, separately, as shown in Figure S4-1. Moreover, we calculate the PCR, ellipticity and absorption spectra of proposed metamaterial as a function of frequency and radii r_2, separately, as shown in Figure S4-2. One can easily observe from Figure S4-1 and Figure S4-2 that when r_1= 8 μm, r_2 = 2.75 μm, the PCR is nearly equal to 1 at the frequency region from 6.09 to 6.43 THz and 8.15 THz, and the ellipticity is greater than 0.9 in the range from 7.16 to 7.89 THz. Meanwhile, the ellipticity is close to -1 at 8.34 THz. In addition, the proposed metamaterial exhibits a four-band nearly perfect absorption of electromagnetic waves at 7.12 THz, 8.33 THz, 8.67 THz, and 9.36 THz, separately. Therefore, we can determine the optimized radii r1 and r2 of the ellipsoids by sweeping the geometrical parameters. The optimization process of other geometric parameters of the metamaterials is also the same as these of r_1 and r_2.

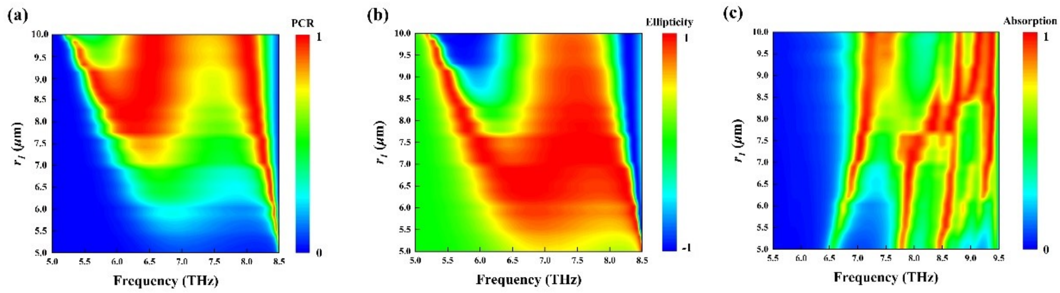

Figure S4-1. Optimization process of geometric parameter r_1

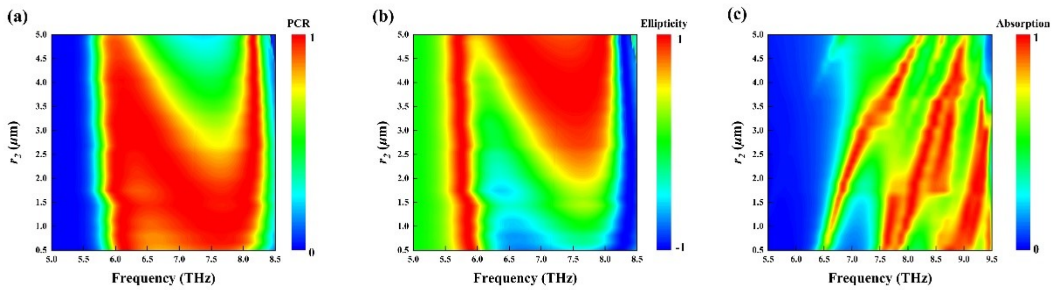

Figure S4-2. Optimization process of geometric parameter r_2