Supplementary Information

"Dynamic Manipulation of Microwave Polarization Based on Anisotropic Graphene Meta-device"

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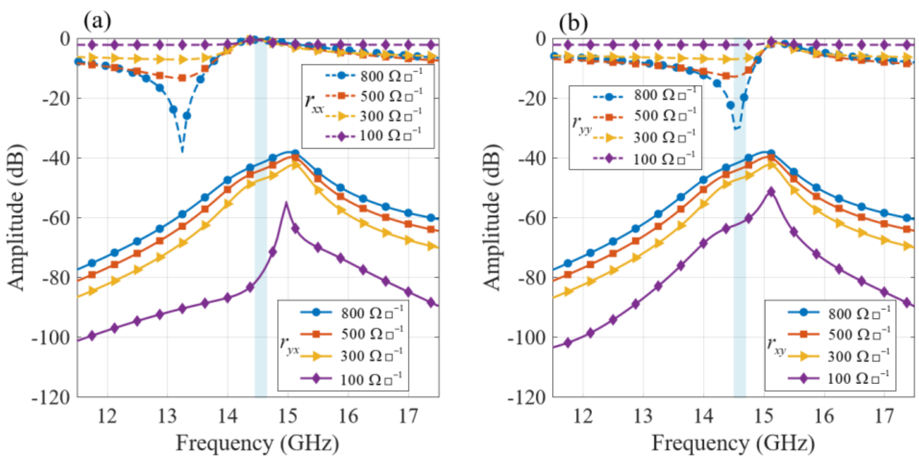
Supplementary Note 1: Cross-polarized reflection data

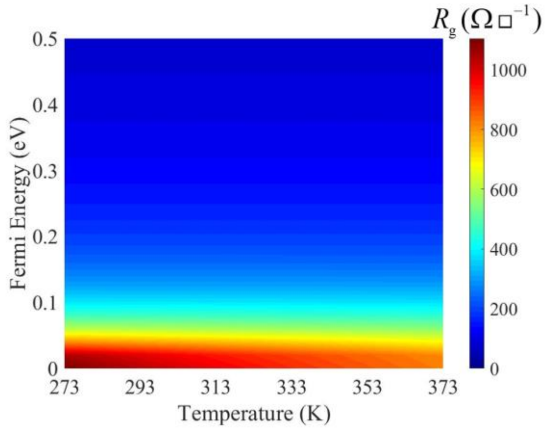
we provide the co- and cross-polarized reflection data here in Supplementary Figure 1, showing that both r_{xy} and r_{yx} are much less than both r_{xy} and r_{yy} at working frequency of 14.6 GHz when graphene's sheet resistance varies from 800 $\Omega\,\square^{-1}$ to 100 $\Omega\,\square^{-1}$.



Supplementary Figure 1: Co- and cross-polarized reflected responses for (a) *x*-and (b) *y*-polarizations.

Supplementary Note 2: Influences of temperature

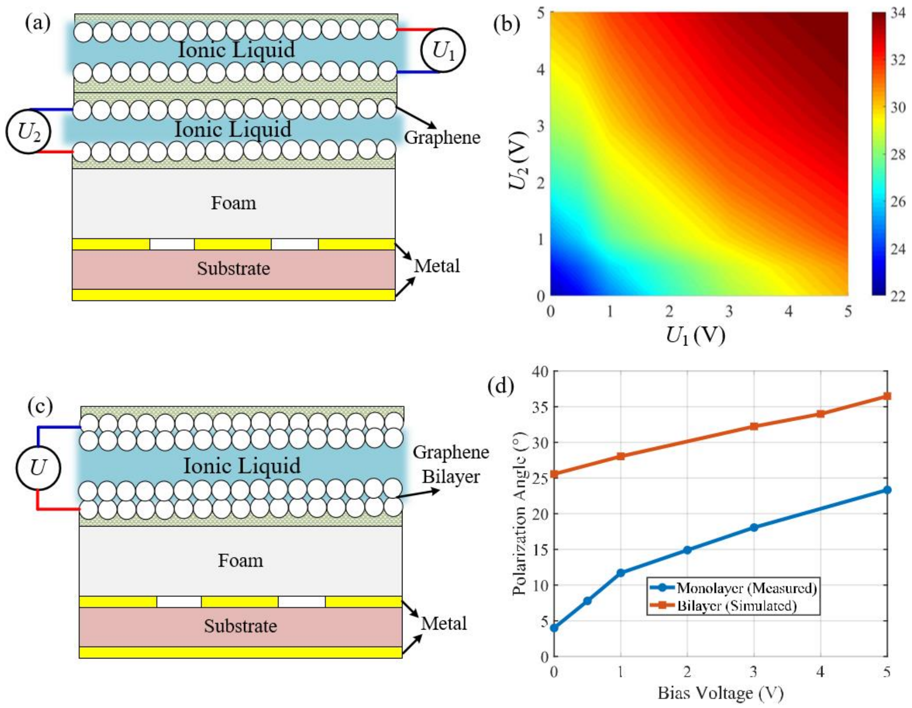
According to Kubo formula, the sheet resistance of graphene is determined by Fermi energy E_F and temperature T and their relation is shown in Supplementary Figure 2. The sheet resistance of grapehene experiences an obvious decrease from over 800 $\Omega\,\square^{-1}$ to nearly 50 $\Omega\,\square^{-1}$ when increasing the Fermi energy from 0 to 0.5 eV. The figure also shows that the temperature only has influence on R_g when Fermi energy is lower than 0.05 eV. Specifically speaking, the highest value of R_g for T=273K (0°C) is over 1000 $\Omega\,\square^{-1}$, then decreases to nearly 900 $\Omega\,\square^{-1}$ or T=300K (room temperature) and at last less than 800 $\Omega\,\square^{-1}$ for T=373K (100°C). However, Figure 3h shows the max tunable range of polarization angle θ_p is from 0 ° to 45 ° refer to R_g varies from 50 $\Omega\,\square^{-1}$ to 800 $\Omega\,\square^{-1}$, which means that the performance deteriorates with extremely high exposure temperature (over 100°C). In addition, the ionization effect in electrolyte layer will be gradually weakened when decreasing the exposure temperature that makes R_g could not reach to as low as 50 $\Omega\,\square^{-1}$ and finally narrows the tunable range of polarization angle θ_p. In a word, extremely high or low temperature will deteriorate the tunable performance of the proposed structure.



Supplementary Figure 2: Simulated relations between tunable R_g and temperature T

Supplementary Note 3: Simulations multilayer-graphene structures

We have proposed two types of multilayered graphene structured meta-devices and simulated their tunable range of polarization angle. As shown in Supplementary Figure 3(a), the first type of meta-device is designed by stacking two graphene based sandwich structures applied to two bias voltage U_1 and U_2 independently. It is seen in Supplementary Figure 3(b) that the maximum tunable range of polarization angle θ_p is about 12 ° (from 22 ° to 34 °). Supplementary Figure 3(c) demonstrates the other type of meta-device in which bilayered graphene is used instead of monolayered graphene. The comparison of tunable range between monolayer and bilayer graphene configuration is shown in Supplementary Figure 3(d). It is seen that when increasing bias voltage from 0 to 5 V, the maximum tunable range of θ_p for monolayer graphene is about 20 ° (from nearly 4 ° to 23 °), while that for bilayer graphene is only 11 °(from 25 °to 36 °). Although low-loss Tamm surface plasmons supported by multilayer graphene based metamaterials may enhance the interaction of the incident waves in THz or visible region [1], however, at microwave frequencies. it seems that the tunable efficiency of proposed meta-device could hardly be improved by using multilayered graphene structure.



Supplementary Figure 3: Two types of multilayerd graphene-based meta-devices and their tunable polarization performances. (a) Meta-device based on stacking two graphene based sandwich structures applied to two bias voltage U_1 and U_2 independently and (b) simulated spectrum of maximum polarization angle θ_p. (c) Meta-device based on graphene bilayer sandwich structure and (d) simulated spectrum of maximum polarization angle θ_p.

Supplementary reference

[1] Hajian, H, Humeyra C, and Ekmel O. Long-range Tamm surface plasmons supported by graphene-dielectric metamaterials. *J. Appl. Phys.* **3**, 033101(2017).