Electronic Supplementary Information - Tunable light trapping and absorption enhancement with graphene ring arrays

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The light trapping and absorption enhancement could also be tuned with the geometric variations of the structure in addition to manipulating the Fermi energy of graphene. In Figure S1 (a) and (b), the dependences of absorption in the absorbing layer on both the radius and the width of the graphene ring are respectively presented. As the radius increases from $R = 65$ nm to $R = 85$ nm, the resonance undergoes a redshift from 18.4 μm to 24.1 μm, which agrees with the prediction from the equation (5). Meanwhile the absorption in the absorbing layer increases from $A' = 16.2\%$ to $A' = 18.1\%$ due to the increasing filling factor of graphene, and for the same reason, the similar increment in absorption from $A' = 14.5\%$ to $A' = 18.5\%$ can be observed with the increase of the width from $W = 25$ nm to $W = 35$ nm.

The basic idea of the perfect light absorption is to minimize the reflection through impedance matching and simultaneously eliminate the transmission by maximizing the losses. To these ends, a newly added insulating layer and a gold mirror are introduced at the bottom of the original structure, as schematically shown in Figure S2 (a). The thickness of this insulating layer is set to $t_i' = 3$ μm and the permittivity is $\varepsilon_d = 1.96$, while the gold mirror is treated as 200-nm-thick film and the permittivity is described by the Drude model with the plasma frequency $\omega_{pl} = 1.37 \times 10^{16}$ s^{-1} and the damping constant $\omega_c = 1.23 \times 10^{14}$ s^{-1}, which is three times larger than the bulk value due to the surface scattering and grain boundary effects in thin films. In Figure S2 (b), perfect light absorption (99.0%) in the hybrid structure is obtained at 22.2 μm, where the absorption in the absorbing layer reaches as high as 52.3% with an enhancement factor of 26.1.

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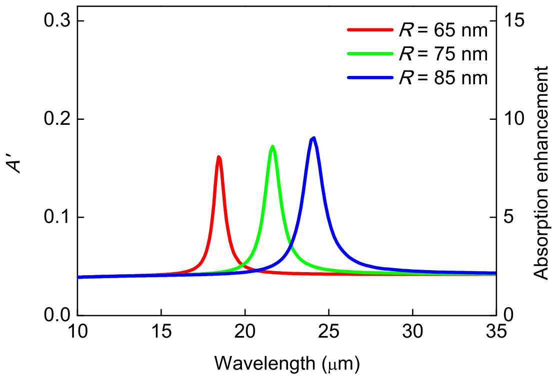
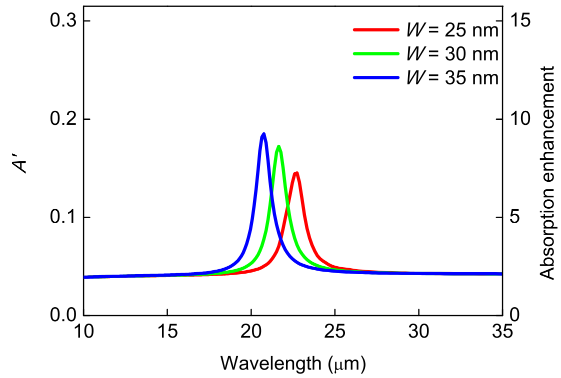
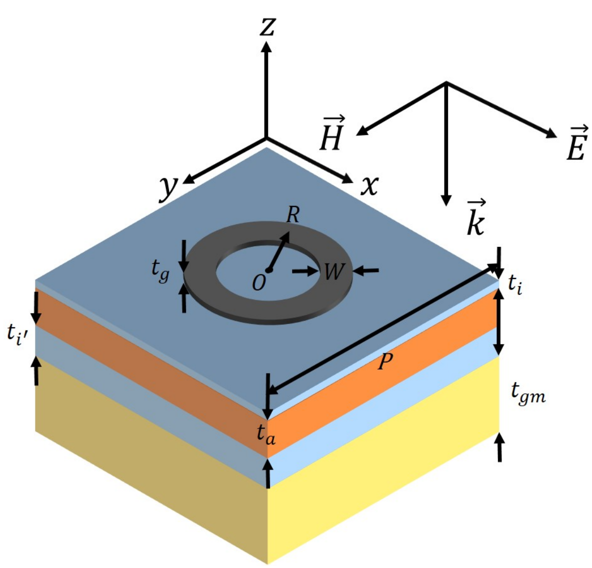


(a)

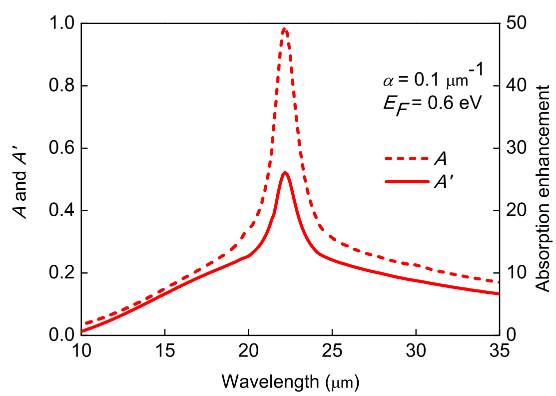


(b)

Figure S1: The simulated absorption in the absorbing layer A' with the attenuation coefficient $\alpha = 0.1$ μm^{-1}, the Fermi energy of graphene $E_F = 0.6$ eV and (a) the radius of graphene ring R ranging from 65 to 85 nm and (b) the width of the graphene ring W ranging from 25 to 35 nm. The enhancement factor of absorption in the absorbing layer is also shown compared to that in the impedance matched media.



(a)



(b)

Figure S2: Perfect light absorption in the hybrid structure and further absorption enhancement in the absorbing layer with a gold mirror. (a) The schematic geometry of the unit cell backed by a gold mirror and (b) the simulated absorption A and the absorption in the absorbing layer A' with the attenuation coefficient $\alpha = 0.1$ μm^{-1} and the Fermi energy of graphene $E_F = 0.6$ eV. The enhancement factor of absorption in the absorbing layer is also shown compared to that in the impedance matched media.