Supplementary Information-Towards photodetection with high efficiency and tunable spectral selectivity: Graphene plasmonics for light trapping and absorption engineering

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Besides electrical tuning, the plasmonic resonances and absorption spectra of our proposed devices can also be tuned through geometric variations of the graphene nanodisks. As shown in Figure 1s, the dipolar plasmonic resonance depends on the diameter of graphene nanodisks. As the diameter increases from $D = 160$ nm to 320 nm, the resonance wavelength red shifts from 11.65 μm to 19.17 μm. At the same time, the absorption in the absorptive layer increases from 18.5% at $D = 160$ nm to 28.8% at $D = 320$ nm which is due to the increase of scattering cross section for bigger graphene nanodisks. For small graphene nanodisks, the resonance intensity and absorption peak may be increased by reducing the period of the array.

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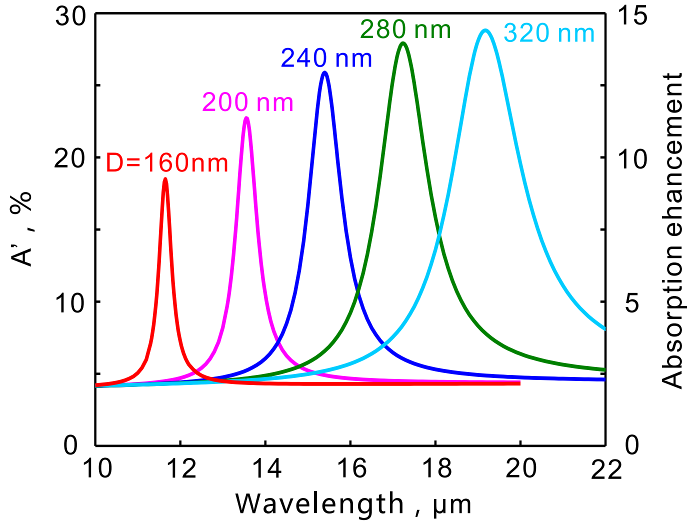

Figure S1: Spectral tuning of absorption in the absorptive layer and its enhancement factor through geometric variations of the graphene nanodisks. The schematic of the device is the same as shown in Figure 1 of the main text. The period is $P = 400\ nm$. The diameter of the graphene nanodisk varies from $D = 160\ nm$ to $320\ nm$. The Fermi energy is $E_F = 0.6\ eV$. The thickness of the insulator layer is $s = 20\ nm$. The light-absorbing layer is $t = 100\ nm$ thick with an absorption coefficient $\alpha = -0.1\ \mu m^{-1}$ corresponding to a small absorption of only about 2% in an impedance matched medium.

Perfect light absorption can be realized by placing a mirror at the bottom of the device. Figure 2s(a) shows the schematic and geometric parameters of a graphene plasmonic opto-electronic device with a gold mirror. The gold mirror is 200 nm thick and the permittivity of bulk gold was described by the Drude model with plasma frequency $\omega_p = 1.37 \times 10^{16}\ s^{-1}$ and the damping constant $\omega_\tau = 1.23 \times 10^{14}\ s^{-1}$ which was three times larger than the bulk value. As shown in Figure 2s(b), the total absorption reaches 99.9% at the resonance wavelength of $\lambda = 15.66\ \mu m$ and the absorption in the absorptive layer is about 67.8%. The plasmonic enhancement of absorption in the light-absorbing layer exceeds 33 times. It should be noted that the absorption without graphene is about 16.7% with an enhancement factor of about 8 at this wavelength. This enhancement is due to the interference effects which also lead to light trapping in the absorptive layer.

In Figure 3s, we show that light trapping and enhancement of absorption can also be realized by a doped graphene sheet with an array of periodical nano-holes. Similar to the

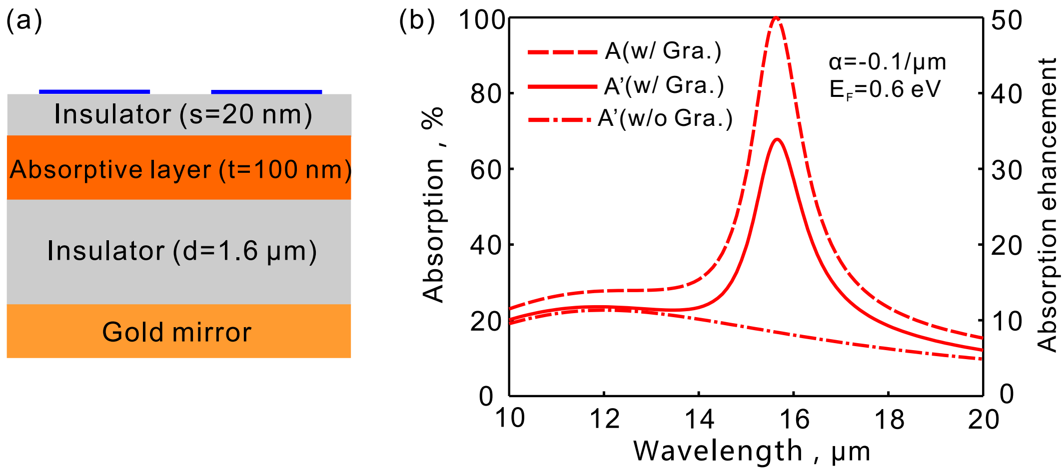

Figure S2: Perfect total absorption and further absorption enhancement in the light-absorbing layer with a back mirror. (a) Cross section and geometric parameters of the proposed device design. From the top to the bottom are the graphene nanodisk array, a thin insulator layer, the light-absorbing layer and the whole device is backed by a gold mirror which blocks the transmission. The light-absorbing layer is $t = 100\ nm$ thick with an absorption coefficient $\alpha = -0.1\ \mu m^{-1}$. The thickness of the insulator layer is $s = 20\ nm$ and the separation between the light-absorbing layer and the mirror is $1.6\ \mu m$. (b) Simulated spectra of absorption (total absorption A and absorption in the underlying absorptive layer A'). The enhancement factor of absorption in the absorptive layer is also shown compared to that in an impedance matched medium. As a reference, the absorption in the light-absorbing layer without graphene is also shown (the flat dot-dashed line).

graphene nanodisks, localized graphene plasmons can be excited around the nano-holes. For an array of nano-holes with diameter $D = 240\ nm$ and period $P = 400\ nm$, the resonance happens at around $\lambda = 13.5\ \mu m$ at the Fermi level of $E_F = 0.6\ eV$. The total absorption and absorption in the underlying absorptive layer are 22.7% and 17.1%, respectively. The absorption enhancement here is about 8 and higher enhancements may be realized by optimizing the geometric parameters of the graphene nanostructure.

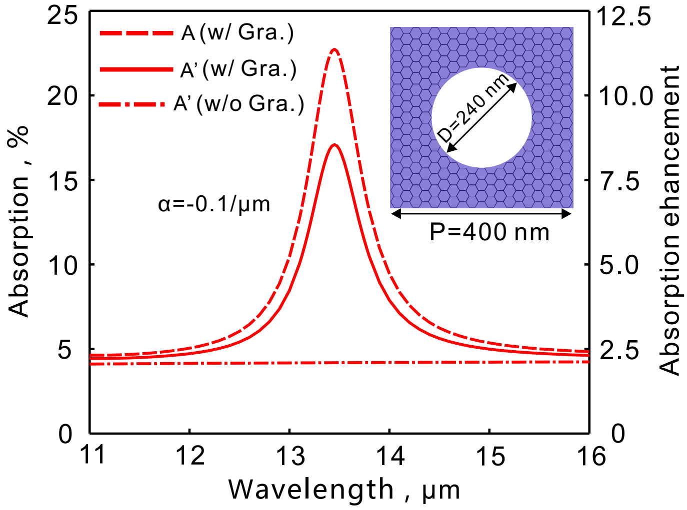

Figure S3: Light trapping and enhancement of absorption by a doped graphene sheet with an array of periodical nano-holes. The geometric parameters here is similar to those in Figure 1 of the main text but the graphene nanodisk array is replaced with a graphene sheet patterned with an array of periodical nano-holes (inset). The diameter of nanoholes is $D = 240\ nm$ and the Fermi energy of graphene is $E_F = 0.6\ eV$. The light-absorbing layer is $t = 100\ nm$ thick with an absorption coefficient $\alpha = -0.1\ \mu m^{-1}$ and the thickness of the insulator layer is $s = 20\ nm$.