Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.
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Gate-tunable ion-electron hybrid phototransistor based on graphene/$RbAg_4I_5$ composite

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Section 1: The detailed calculation of fitting parameter

Based on the physical mode of dissociation of electron-ion bound states under light, we get the relationship of photocurrent and laser power for graphene/RbAg4I5 composite:

$$I_{ph} = a_{\lambda,g} \times \frac{b \times (h\omega - U_g) \times P}{1 + b \times (h\omega - U_g) \times P} \quad (1)$$

where U_g is an important parameter of which we need to know the specific value under different gates. Therefore, we modify the equation by replacing $b \times (h\omega - U_g)$ with $B_{\lambda,g}$, and the fitting equation is as follows:

$$I_{ph} = a_{\lambda,g} \times \frac{B_{\lambda,g} \times P}{1 + B_{\lambda,g} \times P} \quad (2)$$

For a given gate voltage, we can get $B_{\lambda,g}$ for 532-nm and 635-nm lasers by fitting the measured experimental data. With the help of two sets of known photon energy $h\omega$ and parameters $B_{\lambda,g}$, we can get the exact values of b and U_g by solving equation $B_{\lambda,g} = b \times (h\omega - U_g)$.

Section 2: The fitting of photocurrent versus power under different gates for 405-nm laser

Under the illumination of 405-nm laser, due to the high photon energy, photodesorption effect starts to appears.[1] Releases electrons from oxygen and water molecules would increase electron density, which further influences the interaction between electrons and silver ions. The fitting using original model and parameters has a small deviation with experimental data (the dash line in Fig. S1a). Therefore, we make the following modifications to the previous model according to reported work:[1]

$$I_{ph} = a_{\lambda,g} \times (1 - \frac{C \times P}{1 + D \times P}) \times \frac{b \times (h\omega - U_g) \times P}{1 + b \times (h\omega - U_g) \times P} \quad (3)$$

where $a_{\lambda,g}$ and b have the same meanings, C and D are introduced to describe photodesorption effect. The fitting results are greatly improved using modified model as shown in solid line in Fig. S1a. All the experimental data under different gates are fitted well with b=0.203 $mW^{-1}eV^{-1}$ and corresponding U_g obtained from results of 532-nm and 635-nm lasers (Fig. S1b). The parameters C and D have value of approximately -0.16 mW^{-1} and 0.25 mW^{-1} respectively, which change with the change of gate. The negative value of parameter C suggests that increased electron density from escaped molecules improve the dissociation of ion-electron bound state, as built model in the manuscript. The small value of ratio of C to D proves that photocurrent from photodesorption effect is just a modification to the whole photocurrent.

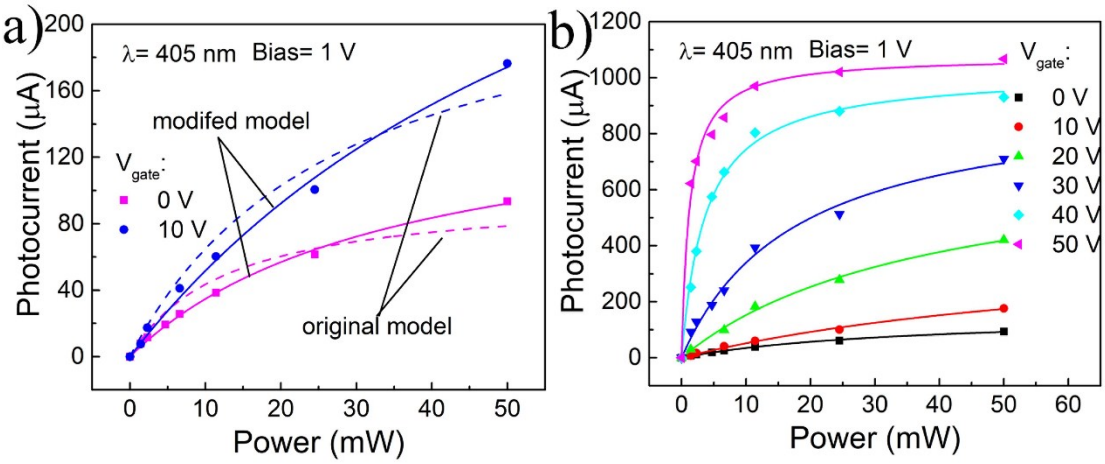

Fig. S1. (a) Comparison of fitting results using original model and modified model. The experimental data are photocurrent under gates of 0 V and 10 V. (b) Experimental data and theorical fitting curve of photocurrent versus power at gates of 0 V, 10 V, 20 V, 30 V, 40 V and 50 V.

References

1. Y. Y. Hsu, C. Y. Lin, Y. C. Lai, K. R. Wu, K. K. Ng, C. S. Chang, G. C. Chi, P. C. Yu and F. S. S. Chien. *Opt. Express*, 2015, **23**, 14344-14350.