Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information

High-efficiency modulation of coupling between different polaritons in an in-plane graphene/hexagonal boron nitride heterostructure

Xiangdong Guo,[a,b,c,d] Hai Hu,[a,c] Debo Hu,[a] Baoxin Liao,[a,c] Ke Chen,[a,c] Lei Liu,[e] Xing Zhu,[a,b,d] Xiaoxia Yang,*[a,c] Qing Dai*[a,c]

[a] *Division of Nanophotonics, CAS Center for Excellence in Nanoscience, National Center for Nanoscience and Technology, Beijing 100190, P. R. China*

[b] *Academy for Advanced Interdisciplinary Studies, Peking University, Beijing 100871, P. R. China*

[c] *University of Chinese Academy of Sciences, Beijing 100049, P. R. China*

[d] *State Key Lab for Mesoscopic Physics, School of Physics, and* [e] *College of Engineering, Peking University, Beijing 100871 , P. R. China.*

†Corresponding E-mail: daiq@nanoctr.cn, yangxx@nanoctr.cn

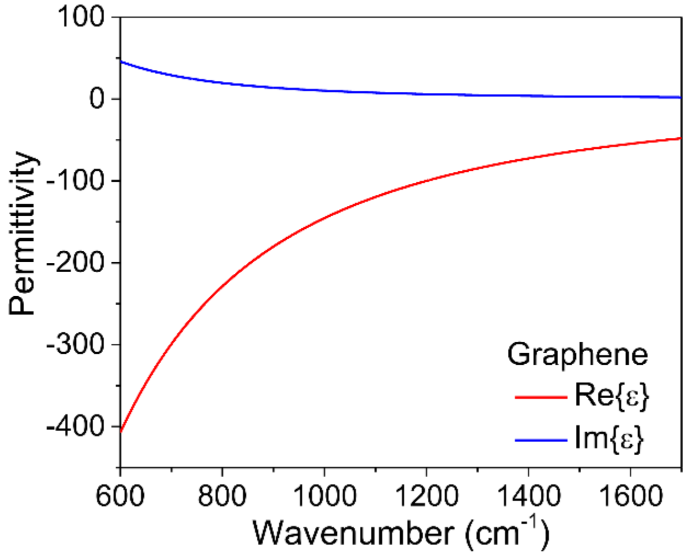

Fig. S1 Permittivity of graphene, which is calculated by the surface conductivity ($\sigma(\omega)$). The red (green) line represents the real (imaginary) part of permittivity.

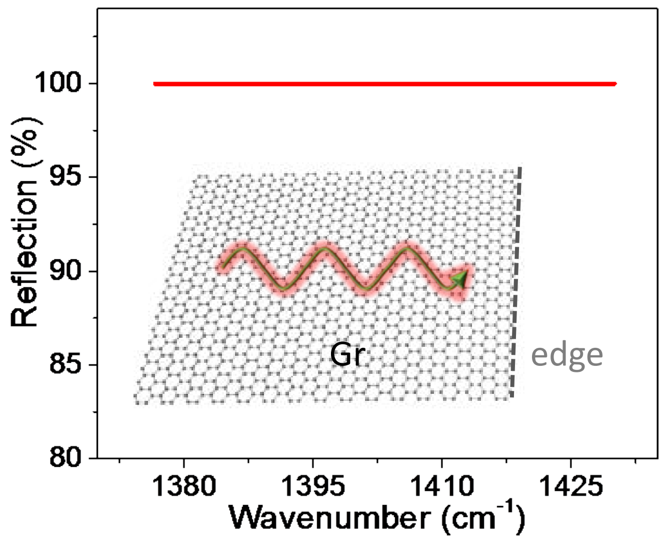

Fig. S2 The reflection of graphene (Gr) natural edge at the different frequencies. The schematic of the boundary reflection is in the inset. The reflection is always 100%, which can be used as a blank control to calculate the transmission in the simulation of s-SNOM experiment.

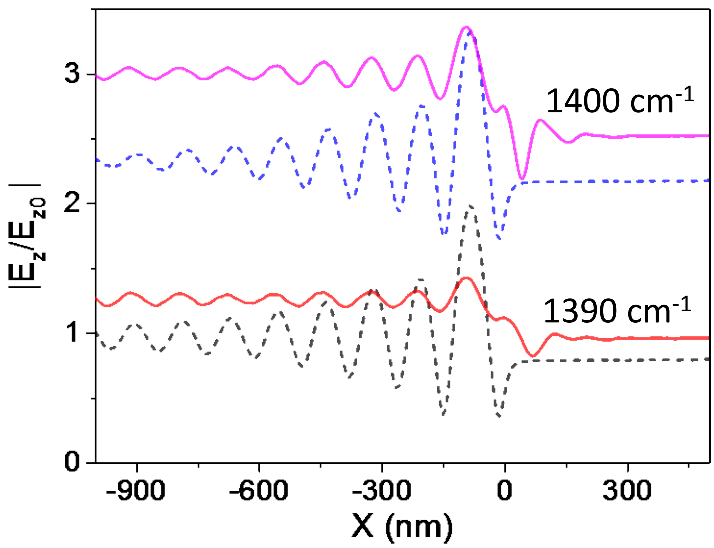

Fig. S3 Line profiles of electric field, $|E_z / E_{z0}|$, are at the 1390 and 1400 cm^{-1}. The solid (dash) line is extracted from the graphene/BN (graphene/air) at in Fig. 4b. The transmission in Fig. 4d can be calculated from these data.

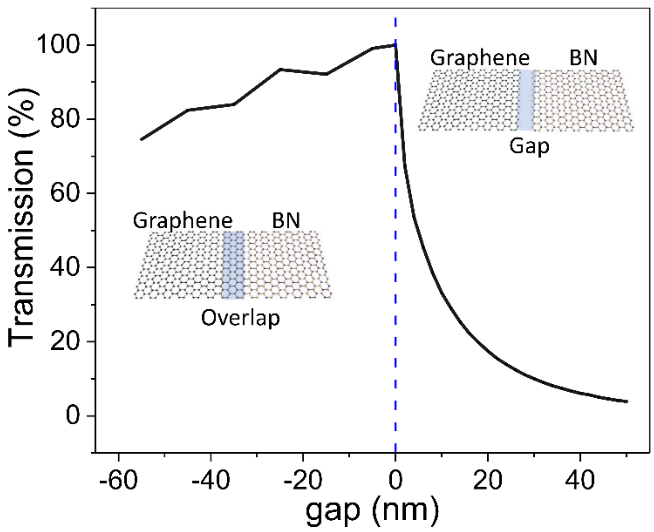

Figure S4. Different transmission for the presence of gap, perfect matching connection and overlap for graphene/BN in-plane structures. When the gap distance is negative, this represents an "Overlap" condition, and conversely there is a "Gap" condition. The dash line represents a gap of 0 nm, which is a perfect matching connection.

In the Fig. S4, we calculate coupled transmission process in the heterostructures with gap and overlap, respectively, and compared the results with the results of perfect matching connection. As shown, the perfect matching connection is the optimal situation for the energy coupling. The coupling efficiency (represented by transmission) decreases as the gap increases due to the discontinuous boundary electromagnetic loss. In the case of overlap, the transmission is not monotonically reduced as the overlap region increases due to the vertical electromagnetic field coupling between the overlapped layers, but it is certainly smaller than the transmission of the perfectly matched connection also due to the discontinuous boundary electromagnetic loss.

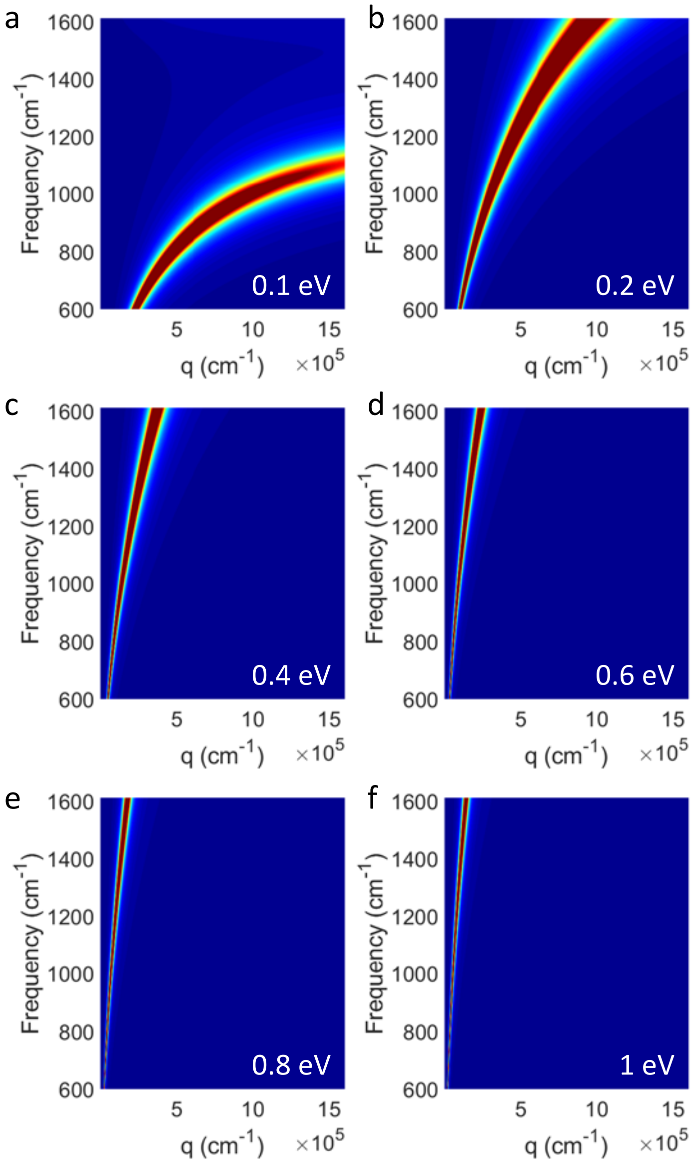

Figure S5. The dispersion relationship of graphene plasmons under different graphene Fermi energy (E_F=0.1~1 eV).

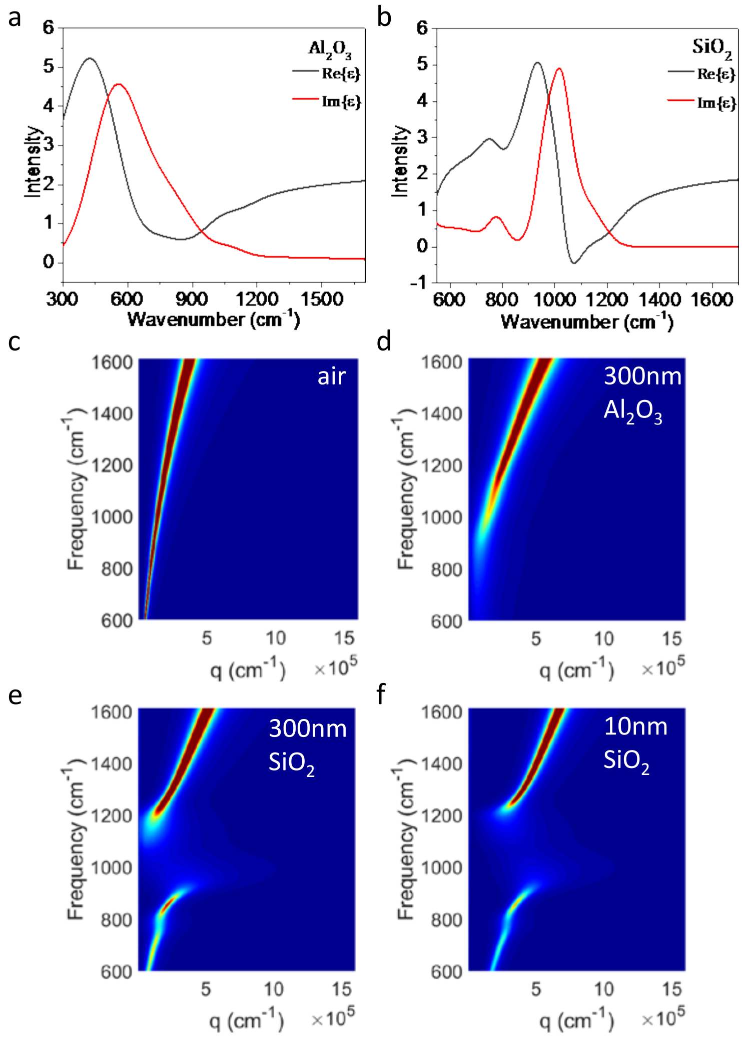

Figure S6. (a-b) The optical constant of SiO_2 and Al_2O_3, respectively. These two materials can be used as a substrate for graphene. (c-f) The graphene plasmon dispersion relationship on different substrates. By comparing c and d, it is obvious that the frequency in the dispersion relationship changes due to the influence of the dielectric function of the substrate. In the e and f, the dispersion relationship has an anti-crossing phenomenon when the SiO_2 phonons are coupled with graphene plasmons.

We take the most widely used SiO_2 and Al_2O_3 as examples to illustrate the substrate's effect, as shown in Fig. S5. On the one hand, the refractive index or dielectric function of the substrate changes the frequency of the plasmon polariton dispersion relationship in Fig. S5c and d. On the other hand, the coupling between the phonons of the substrate and the graphene plasmons will produce an anti-crossing phenomenon in the dispersion relationship in Fig. S5e and f. The effects of substrates can also be found in our previous papers.[1, 2] However, these effects in the graphene plasmon dispersion would not change the calculated coupling efficiency relation as a function of frequency in the graphene/h-BN heterostructure. The aim of this research is to find out a method to efficiently control two different polaritons coupling, thus we did not consider the effect of substrate in the manuscript.

References

1. X. Yang, X. T. Kong, B. Bai, Z. Li, H. Hu, X. Qiu and Q. Dai, *Small*, 2015, **11**, 591-596.
2. X. Yang, F. Zhai, H. Hu, D. Hu, R. Liu, S. Zhang, M. Sun, Z. Sun, J. Chen and Q. Dai, *Advanced materials*, 2016, **28**, 2931-2938.