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Heat Transfer between Graphene Layers in Graphene/*h*-BN/Graphene van der Waals Heterostructure

Here, we detect a heat transfer between two graphene sheets that is electrically and spatially isolated by thick *h*-BN in graphene/*h*-BN/graphene vdW heterostructure. Devices are prepared by either wet release transfer [1] or dry release transfer method [2]. Two different geometries are investigated.

(1) Vertically stacked graphene/*h*-BN/graphene

As schematically illustrated in Figs. 1(a) and 1(b), we fabricated *h*-BN/top-graphene/*h*-BN/bottom-graphene/h-BN stack. The top graphene is used as heat source with a Joule heating, while bottom-graphene is used as a thermoelectric temperature sensor. Two graphenes are electrically isolated by 41-nm-thick *h*-BN. Under the application of current to the top graphene with a power of P_{TopGr}, we detect a thermoelectric voltage V_{ind} in bottom-graphene to determine the increase of bottom-graphene's electron temperature T_{e}. As shown in Fig. 1(d), the back-gate voltage V_{BG} dependence of V_{ind} measured at constant $P_{\mathrm{TopGr}} = 4\times10^{-7}$ W exhibits clear signature of Seebeck effect of the graphene. By changing injected power to the top graphene P_{TopGr}, increase of T_{e}(Top-Gr) and T_{e}(Bottom-Gr) are determined at the measurement temperature of ~6 K and plotted in Fig. 1(d). Both T_{e}(Top-Gr) and T_{e}(Bottom-Gr) increase monotonically with P_{TopGr} suggesting that there is a significant heat transfer between two graphene layers. We also fabricated *h*-BN/top graphene/h-BN/bilayer graphene/h-BN/bottom graphene/*h*-BN device in which *h*-BN/bilayer graphene/*h*-BN stack is works as heat blocking layer. The results obtained from this device are also plotted in Fig. 1(d) showing that the insertion of bilayer graphene exhibits rather small effect for total heat transfer.

(2) Laterally arranged two graphene channels on *h*-BN

The schematic illustration of the device is shown in Fig. 1(f). Here, we transferred two different flakes of graphene on a thick *h*-BN substrate with a lateral separation between graphene of ~3 μm. Similar to the experiment (1), we used one of the graphene as Joule heater and another graphene as a temperature sensor. Application of the Joule heating with a power of $P = 5\times10^{-7}$ W to the heat graphene generate few-tens of μV of thermoelectric voltage in the detector graphene; this thermoelectric voltage is almost comparable to the experiment (1) although the separation between graphene layers are much larger in experiment (2) [(1) ~40 nm versus (2) ~3 μm].

These results demonstrate significant heat transfer between two graphenes isolated by *h*-BN. Results are showing that the heat transfer effect is rather efficient at low temperature and can be long distance. These highlights the importance of the heat transfer effect between graphenes in vdW heterostructure.

References

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Figure

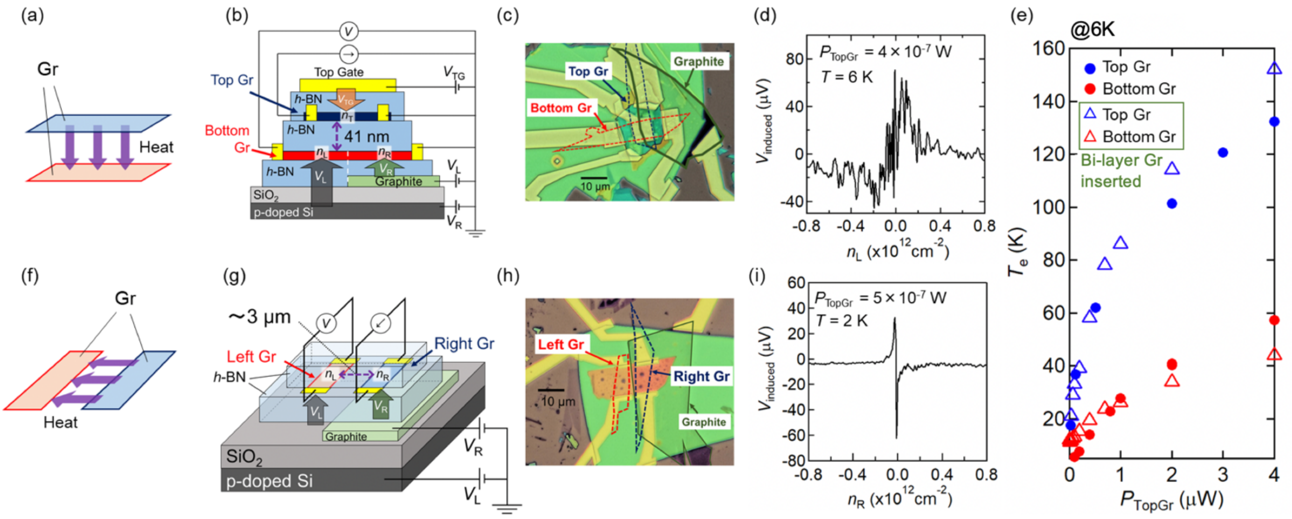

Figure 1: (a-e) Het transfer in vertically stacked graphene/h-BN/graphene. (a) Illustration of the device concept. (b) Device structure. (c) Optical micrograph of the device. (d) Thermoelectric signal generated at the detector graphene. (e) Change of electron temperature in Top- and Bottom-graphene under the application of heater power P_{TopGr} in Top graphene. (f-i) Heat transfer in laterally positioned two graphenes. (f) Illustration of the device concept. (g) Device structure. (h) Optical micrograph of the device. (i) Thermoelectric signal generated at the detector graphene.