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Heat spreading in 2D material black phosphorus (BP) *via* van-der Waals heterostructure

Two-dimensional (2D) layered materials have sparked significant interest due to their versatile properties. One of the biggest challenges in all the operational electronic devices is the generation of excessive heat. This problem is very severe in nano-devices due to the reduction of their physical dimension that may cause catastrophic failure. [1] The devices based on 2D material BP exhibit promising electronics, photonics, thermal and mechanical properties. [2] However, BP exhibit low thermal conductivity ($\kappa \approx$ is merely 28.8 W/m·K) and large power density due to their miniaturized physical structure that causes early Joule breakdown and thermal spreading problems.[3] Therefore, we study the heat spreading issue in 2D material BP devices to understand the self-heat spreading mechanism.

Here, we report that the back-gate BP device suffers Joule breakdown merely under few MVm^{-1} electric field value with the centrally localized fracture due to non-uniform temperature distribution in BP channel and the hot-spot is located at the center of the cannel. Further we confirmed this by getting the position dependent Raman peaks from spatial micro-Raman spectroscopy as shown in Fig.1a. Furthermore, to mitigate the early breakdown and uneven spreading, we assemble vertical van-der Waals structure. We observed that the vertical devices are more thermally stable and showed more than 5 times higher electrical power than the lateral devices as shown in Fig.1b, due to favorable device geometry for self-heat removal.

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References

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Figures

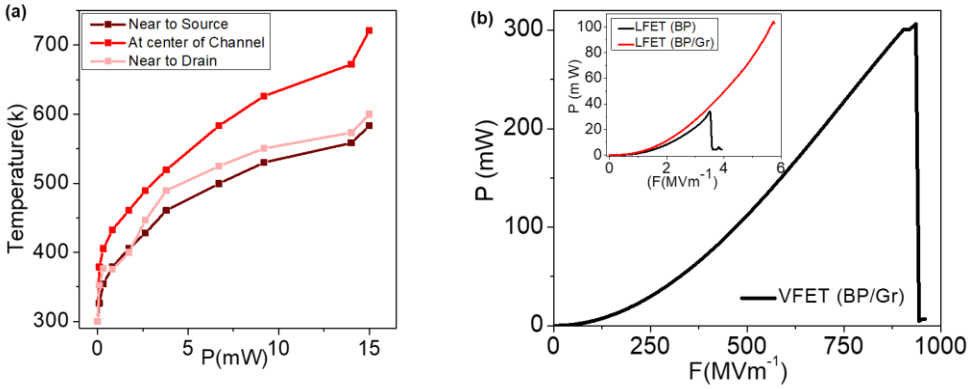

Figure 1: (a) Comparison of obtained temperature values by analyzing A^2_g Raman mode of BP at different position as a function of applied electrical power.(b) Comparison of breakdown phenomena of verical device and Insets shows the results from lateral device.