Ultrashort Channel Length Black Phosphorus Field-Effect Transistors

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Supporting Information

S1. Transfer characteristics of back-gated BP transistor with a channel length of 20 nm.

For ultrashort channel length field-effect transistors, the dielectric layer needs to be very thin to allow sufficiently strong gate control over the channel carrier concentration. For the back-gated (300 nm SiO_2) BP FETs with a channel length of 20 nm, the transfer characteristics were measured by sweeping the back-gate voltage from -80 to 80 V. As shown in Fig. S2, it is obvious that the device cannot be fully depleted. This is expected due to the weak back-gate stack with 300-nm-thick SiO_2 dielectric layer. For a channel length of 20 nm, drain-induced barrier lowering is significant. As a result, the drain terminal could actually have more control over the channel compared to the gate terminal, resulting in device with very weak gate dependence. Taking the above into consideration, in order to achieve a decent transistor performance in ultrashort channel BP FETs, it is crucial to have a very strong top gate with thin gate dielectric layer, which is why 10-nm-thick Al_2O_3 was used in this work for top-gated BP FETs.

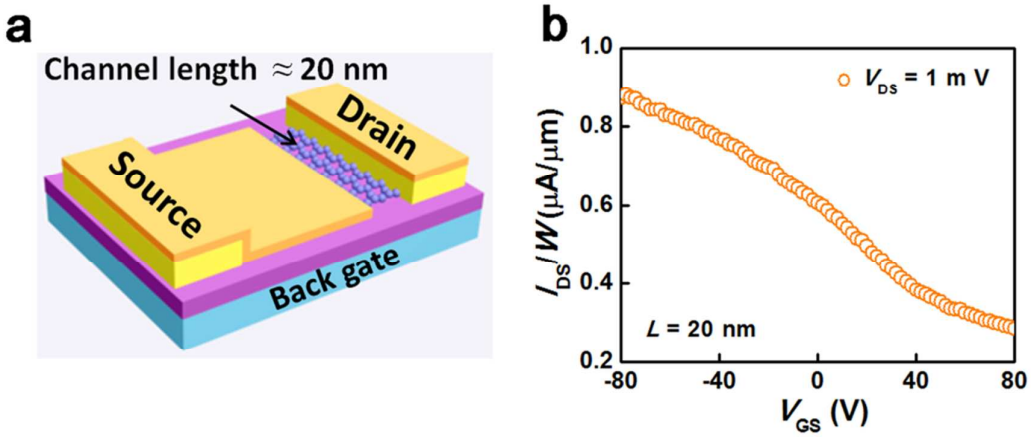

Figure S1: Transfer characteristics of a back-gated BP FET with a channel length of 20 nm measured at V_{DS} = 1 mV.