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Supplementary Material for:

Sub-9 nm high-performance and low-power transistors based on in-plane $NbSe_2/MoSe_2/NbSe_2$ heterojunction

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The transport properties of vertical $NbSe_2/MoSe_2$ van der Waals heterojunction FET

The vertical $NbSe_2/MoSe_2$ van der Waals (vdW) heterojunction is constructed as shown in Fig. S1 (a), where the electrons are transported along z-axis. We have calculated the transport properties of vertical $NbSe_2/MoSe_2$ vdW heterojunction FET, and in-plane $NbSe_2/MoSe_2/NbSe_2$ heterojunction FET at the gate length of 5 nm as shown in Fig S1 (b). It is clear from Fig. S1 (b) that the in-plane $NbSe_2/MoSe_2/NbSe_2$ heterojunction FET has larger on-currents (I_{on}) and sharper slopes than the vertical $NbSe_2/MoSe_2$ vdW heterojunction FET. And in Table 1, the complete findings are displayed. These findings demonstrate that, in addition to having a smaller subthreshold swing (SS), the magnitude of the on-currents (I_{on}) of in-plane $NbSe_2/MoSe_2/NbSe_2$

heterojunction FET (311μAμm^{-1}) is more than 80 times that of vertical $NbSe_2/MoSe_2$ vdW heterojunction FET(3.52 μAμm^{-1}). This could be because there is more overlap between the electrodes and the gate of the in-plane heterojunction when the gate size is smaller. As a result, the in-plane heterojunction has a larger built-in electric field for the same gate, which worsens the upward-bending of the valence band and narrows the channel barrier. Then carriers can transport between the source and drain more quickly, resulting in higher current and lower SS of in-plane $NbSe_2/MoSe_2/NbSe_2$ heterojunction FET.

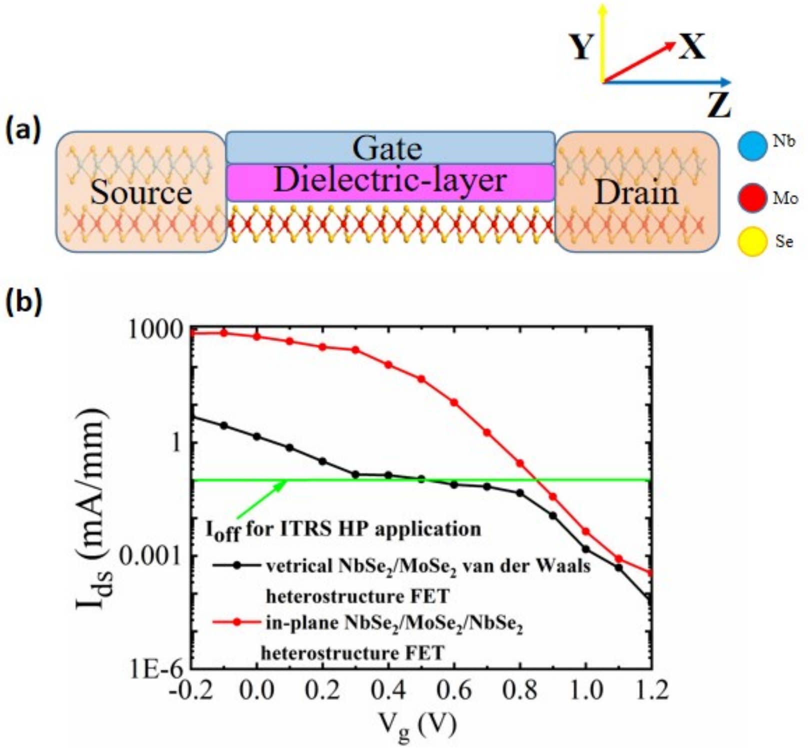

Fig. S1 (a) Schematic of the vertical $NbSe_2/MoSe_2$ vdW heterojunction FET, where the electrons are transported along z-axis, (b) transport characteristic curves at a gate length of 5 nm, here, the black and red solids represent the I_{ds} for vertical $NbSe_2/MoSe_2$ vdW heterojunction FET and in-plane $NbSe_2/MoSe_2/NbSe_2$ heterojunction FET, respectively, and green solid represents I_{off} for ITRS HP application.

Table S1 Comparison of transport properties between in-plane $NbSe_2/MoSe_2/NbSe_2$ heterojunction FET and vertical $NbSe_2/MoSe_2$ van der Waals heterojunction FET.

	I_{on} [μA/μm]	I_{on}/I_{off}	SS [mV/dec]
In-plane $NbSe_2$ / $MoSe_2/NbSe_2$ heterostructure FET	311	3.11×10^4	118
Vertical $NbSe_2$ / $MoSe_2$ van der Waals heterostructure FET	3.52	35.2	144