Supporting Information

Carrier Transport at the Metal-MoS_2 Interface

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S1 (Rc-T Plot of Pd-MoS_2 contact)

Figure S1(a) is the OM image of the Pd/Au contacted device with 9nm thick MoS_2 flake as channel for carrier transport with lengths of 1, 1.5, 2, 2.5, 3 μm respectively. Figure S1(b) shows Rc(T) of Pd-MoS_2 junction and a similar trend to that of Cr-MoS_2, indicating thermionic emission dominant up to 215K followed by tunneling at low temperature.

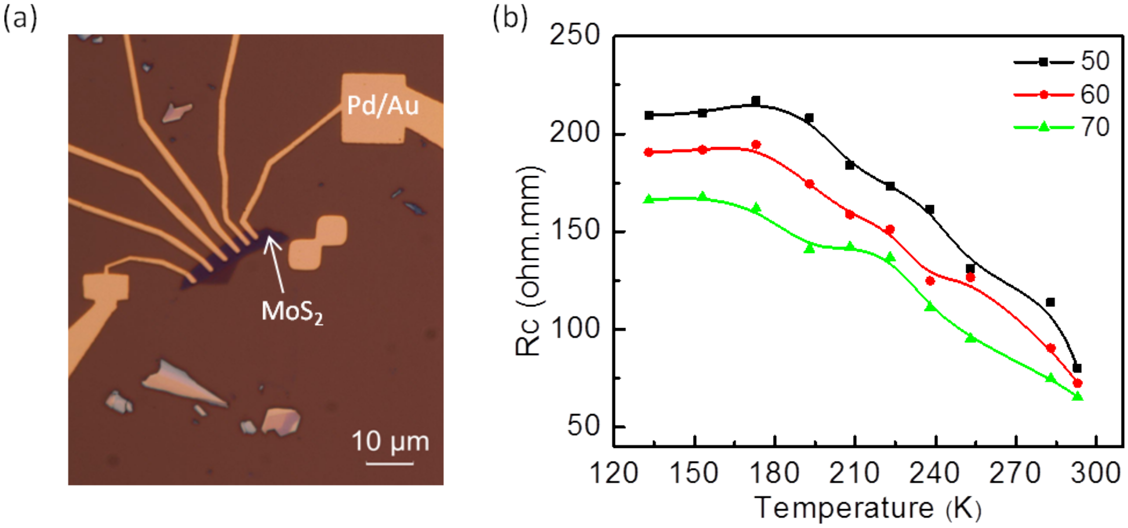

Figure S1(a) OM image of TLM patterned device with Pd/Au electrode and MoS_2 as channel. **(b)** the measured contact resistance of the device. Note that the drain bias is swept from -1 to 1 V during output curve measurement.

The higher value of R_c in Fig. S1(b) can be attributed to the large barrier formed across the Pd-MoS_2 contact due to high work function of Pd (5.0eV) with respect to MoS_2.

S2 (Theoretical calculation of current across Cr-MoS$_2$ interface)

Das *et al* proposed the carrier transport model for holes conduction across metal-MoS$_2$ interface,[1] but here we implemented that model to the electron conduction at the interface.

The current along the barrier is extracted in three components, one thermionic emission (I_{TH}) current and two of tunneling components (I_{TN-1} and I_{TN-2}), as shown in Fig. 3(a) of the main manuscript and they are measured by the following equations.

$$I_{TH} = q\int_{\Phi_B}^{\chi} M(E+\Psi_{DRIVE} - \Phi_B) f(E) dE \tag{1}$$

$$M(E) = \frac{2}{h^2}\sqrt{2m^* E} \quad and \quad f(E) = \frac{1}{1+\exp(\frac{E}{k_B T})}$$

$$I_{TN-1} = q\int_{\Phi_B - E_g}^{\Phi_B} M(E+\Psi_{DRIVE} - \Phi_B) T_1(E) f(E) dE \tag{2}$$

$$T_1(E) = \exp(-\frac{8\pi}{3h}\sqrt{2m^*(\Phi_B - E)^3} \times \frac{\lambda}{\Psi_{DRIVE}})$$

$$I_{TN-2} = q\int_{\Phi_B - \Psi_{DRIVE}}^{\Phi_B - E_g} M(E+\Psi_{DRIVE} - \Phi_B) T_2(E) f(E) dE \tag{3}$$

$$T_2(E) = \exp(-\frac{8\pi}{3h}\sqrt{2m^* E_g^3} \times \frac{\lambda}{\Psi_{DRIVE}})$$

$$\Psi_{DRIVE} = q\left[V_D + \left|(V_G - V_{MIN} - V_{FB})/\gamma\right|\right] \tag{4}$$

$$\lambda = \sqrt{t_{ox} t_{body} \times \frac{\varepsilon_{body}}{\varepsilon_{ox}}} \tag{5}$$

$$R_c = 1/I.q \tag{6}$$

Here, q is the charge of electron, ΦB denotes the Schottky barrier height for electrons, χ is the electron affinity of MoS_2, $M(E)$ is the number of conduction modes in $(eV.m.s)^{-1}$, $f(E)$ is the Fermi-Dirac constant, m^* is the effective mass of electrons in MoS_2, $T_1(E)$ and $T_2(E)$ are the tunneling efficiencies of carriers over their respective regions, Ψ_{DRIVE} denotes the amount of band bending by applied bias, γ is the band movement factor, V_{FB} is the flat band voltage and λ is the screening length extracted from equation (5). The parameter values used in our calculations are given in table S1.However, V_{MIN}, V_{FB}, γ and Ψ_{DRIVE} are calculated from transfer curve [Fig. S2 (a) and (b)]. The flat band voltage is approximately equal to the point at which the slope of $\log(I_d)$ versus V_g-V_{MIN} deviates from linearity *i.e.* 2.9V in Fig. S2(b) and using the linear region slope that is equal to the 60γ mV/decade, γ is extracted. For our device, it is around 23.8 and ΦB is extracted from thermionic emission theory [Fig. S2(c)].

Table S1. Parameter values used in this work

Gate oxide thickness (t_{ox})	285 nm
Dielectric constant of SiO_2 (ε_{ox})	3.9
Body thickness (t_{body})	14 nm
Dielectric constant of body (ε_{body})[1]	7.0
Effective mass (m*)[1]	0.46m
Schottky barrier height (Φ_B)	0.05 eV
Electron affinity (χ)	4.0 eV
Band gap (E_g)	1.2 eV

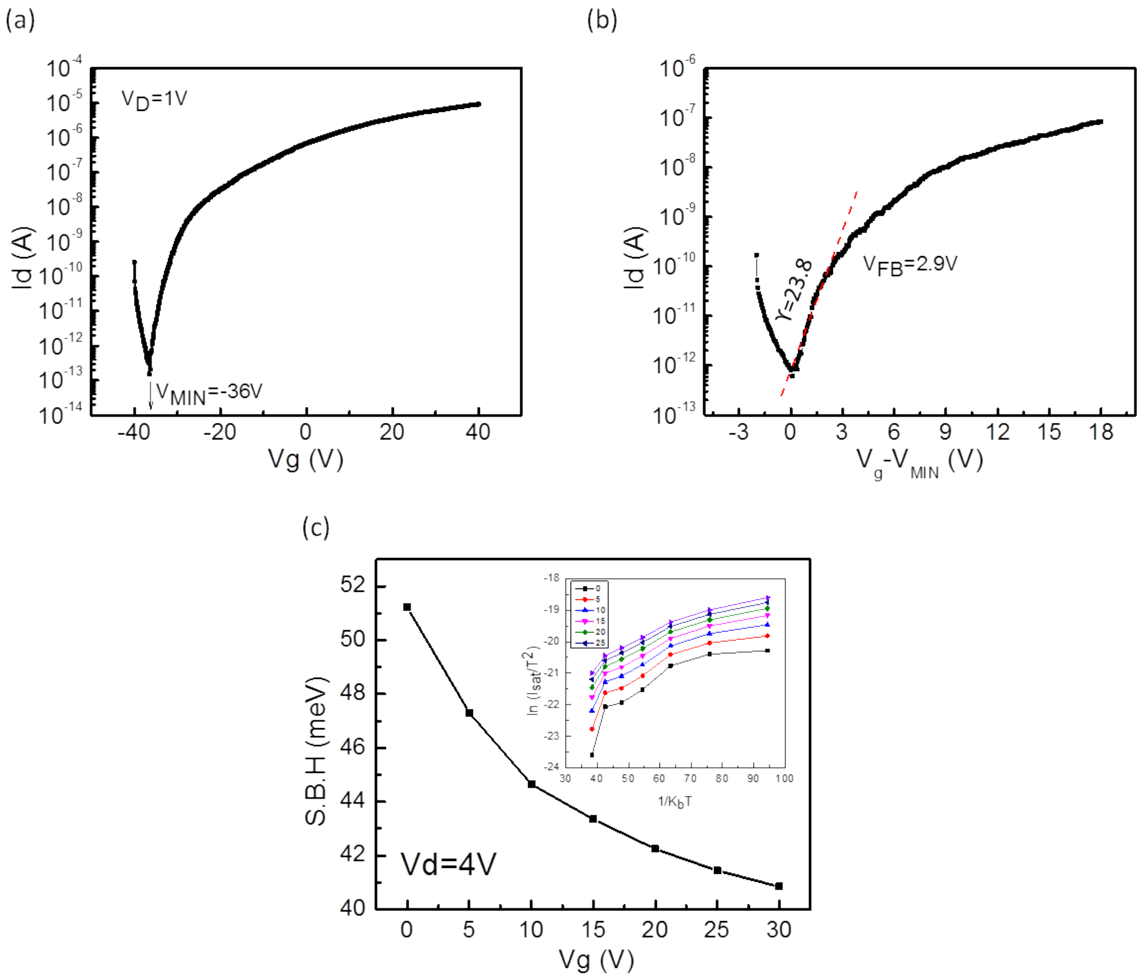

Figure S2 (a) The transfer curve of Cr-MoS_2 device on log scale showing typical n-type behavior. V_{MIN} is the gate bias at off-state of the device. **(b)** The calculation of flat band voltage (V_{FB}) and band bending factor (γ). **(c)** The calculated effective energy barrier variation against gate bias . Inset shows Arrhenius plot. Note that long channel (L_4) is used for these measurements.

From detailed temperature measurement, Schottky barrier height is extracted using thermionic emission theory.[2] The extracted barrier height for electrons is about 50 meV at estimated flat band voltage as shown in Fig. S2 (c) . The small value of barrier height can be attributed to the Fermi level pinning effect, *i.e.* the Fermi level at the interface is pinned very near to the conduction band edge of MoS_2.

The extrated values of all these parameters are used in equations from 1 to 5 to calculate all three current components as shown in the band diagram of Fig. 3(a) of the main manuscript, and their reuslts are shown in Fig. 3(b) in units of A/m. Finally, Rc is extracted by applying the Landauer theory,[3,4] to the measured current components as shown in equation (6), and their resutls are shown in Fig. 3(c) in the units of ohm·mm except $I_{TN-2.}$

References

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