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Supplementary Materials for

Thermionic transport across gold-graphene-WSe_2 van der Waals heterostructures

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Section S1. Series resistor model

We model the resistances of the interfaces as measured via TDTR using a series resistor model. The Al-Gr-3WSe_2-Gr-SiO_2 conductance values can be modeled as follows

$$\frac{1}{h_{k,measured,Al-Gr-3WSe2-Gr-SiO2}} = \frac{1}{h_{K,Al-Gr}} + \frac{1}{h_{K,Gr-3WSe2-Gr}} + \frac{1}{h_{K,Gr-SiO2}} \quad \text{(S1)}$$

In this equation, $h_{K,measured,Al-Gr-3WSe2-Gr-SiO2}$ is the conductance measured via TDTR of the device, while $h_{K,Al-Gr}$ and $h_{K,Gr-SiO2}$ are representative of the associated conductance values with the Al-Gr and Gr-SiO_2 interfaces, respectively. The variable $h_{K,Gr-3WSe2-Gr}$ encompasses the intrinsic resistances of the graphene and WSe_2, as well as the associated resistances at the two Gr-WSe_2 interfaces. Similarly, the Al-Gr-SiO_2 conductance values are governed by the equation

$$\frac{1}{h_{k,measured,Al-Gr-SiO2}} = \frac{1}{h_{K,Al-Gr}} + \frac{1}{h_{K,Gr-SiO2}} \quad \text{(S2)}$$

So long as the cross-plane thermal conductivity of the graphene layer is on the order of 1 W m^{-1} K^{-1}, it will have a negligible contribution to the measured conductance, hence the negligence of the contribution from the graphene layer. By subtracting Eq. S2 from Eq. S1, the conductance of the Gr-3WSe_2-Gr layer can be extracted to be

$$\frac{1}{h_{K,Gr-3WSe2-Gr}} = \frac{1}{h_{k,measured,Al-Gr-3WSe2-Gr-SiO2}} - \frac{1}{h_{k,measured,Al-Gr-SiO2}} \quad \text{(S3)}$$

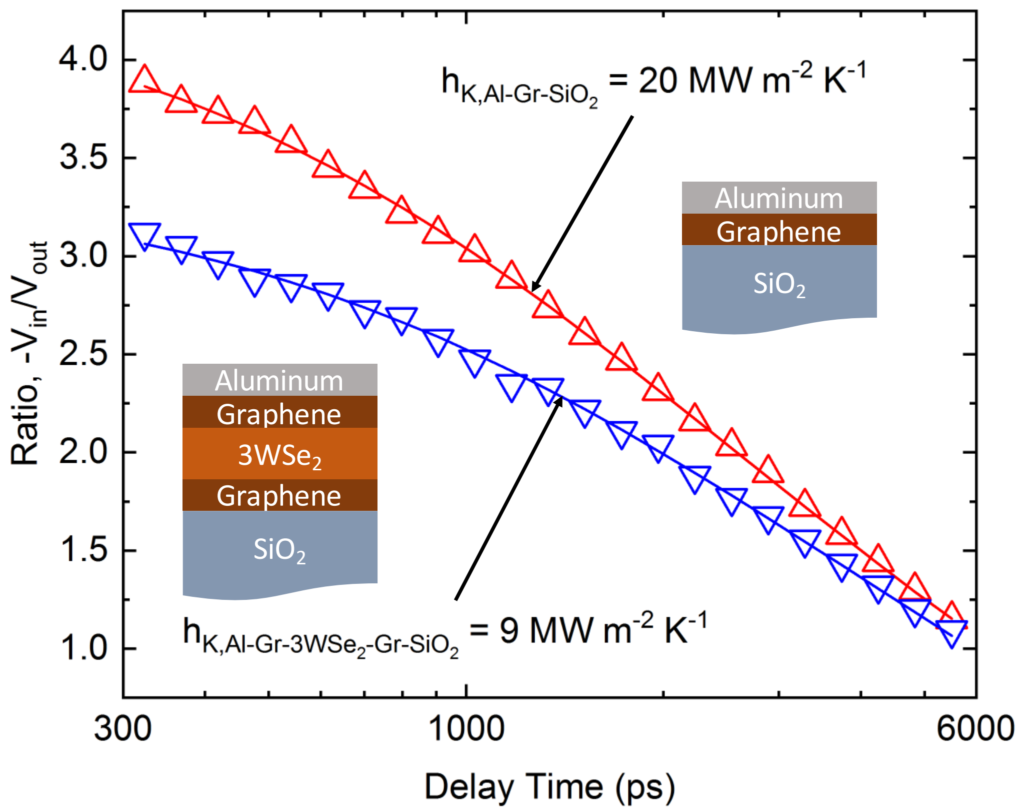

Fig. S1. TDTR measurement. Best fits for the Al-Gr-SiO_2 and Al-Gr-3WSe_2-Gr-SiO_2 interfacial regions.

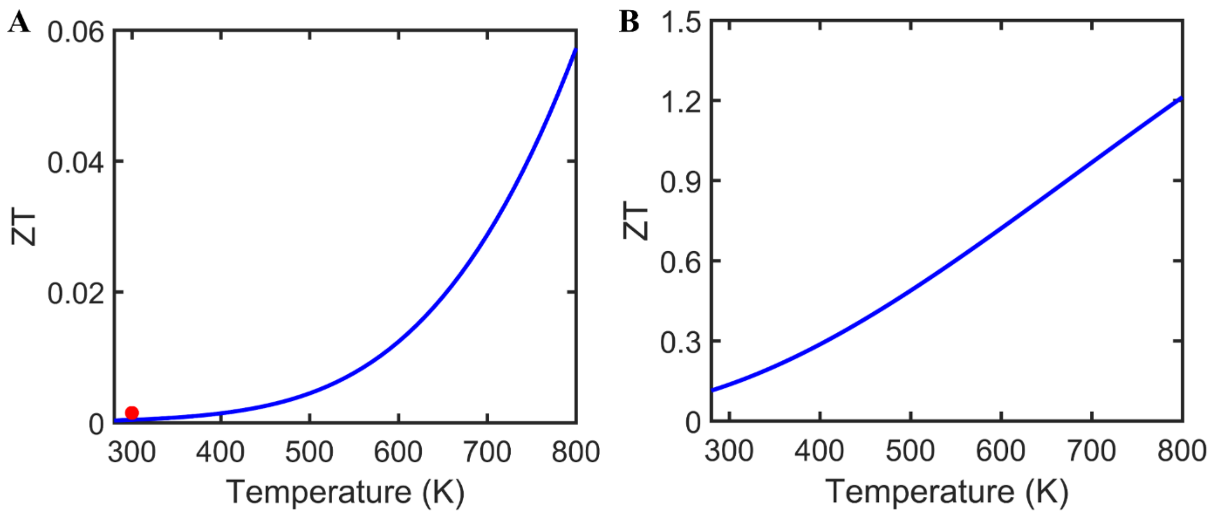

Fig. S2. Figure of merit (ZT) of Au-G-WSe_2-G-Au structure and Pt-G-WSe_2-G-Pt structure. (**A**) Calculated ZT vs temperature of Au-G-WSe2-G-Au structure shown by the solid blue line. Red circle is the experimentally measured ZT at room temperature. (**B**) Calculated ZT vs temperature of Pt-G-WSe2-G-Pt structure.

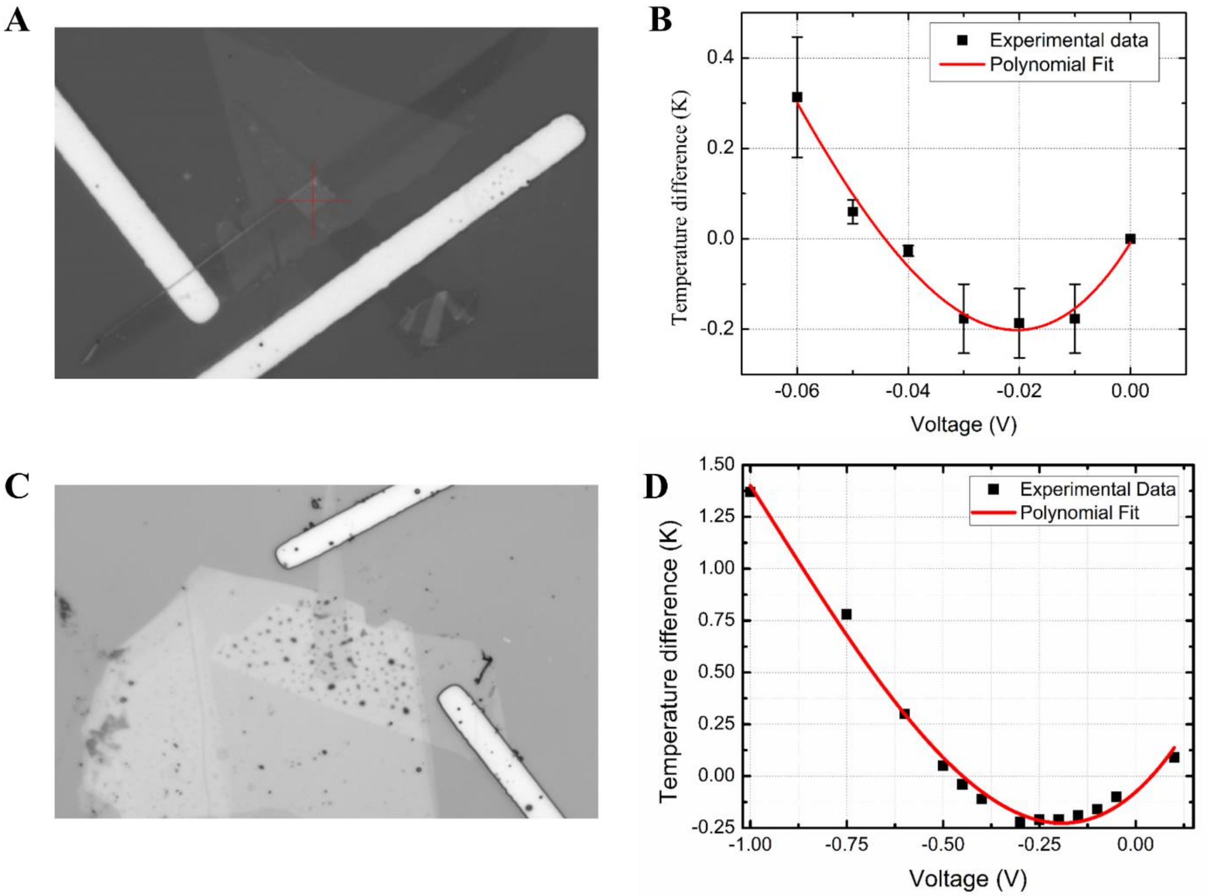

Fig. S3. Repeatable cooling curve measurement. (**A**) Optical image of first sample. (**B**) Cooling curve of first sample. (**C**) Optical image of second sample. (**D**) Cooling curve of second sample.

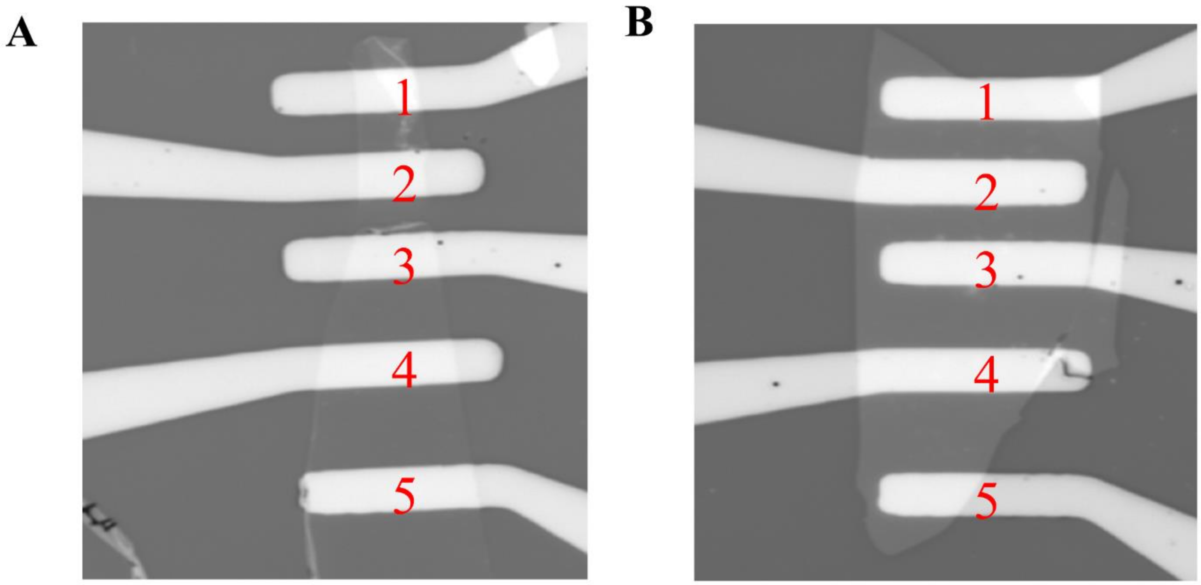

Fig. S4. Contact resistance measurement. Optical image of the samples fabricated to measure the contact resistance. (**A**) Sample 1. (**B**) Sample 2.

Section S2. Analysis of contact resistance

We extract the contact resistances from two probe and four probe resistance measurement to get a range of the contact resistance value.

The method explained here using sample 1 (see fig. S4). First, we measure two probe resistance (see table S1) between contact 2 and contact 3 which include resistance of contact 2 (R_2), resistance of contact 3 (R_3) and resistance of graphene flake between contact 2 and contact 3 (R_{23}). We can write

$$R_2 + R_3 + R_{23} = 3500\Omega \quad \text{(S4)}$$

From the four probe resistance measurement (current supplied between contact 1 and contact 4 and voltage measured between contact 2 and contact 3 (see table S2)) we get only the resistance of graphene flake (520Ω) between contact 2 and contact 3 (R_{23}). By subtracting value of R_{23} (520 Ω) from Eq. S4 we get

$$R_2 + R_3 = 2980\Omega \quad \text{(S5)}$$

Similarly, we can write

$$R_2 + R_4 = 1870\Omega \quad \text{(S6)}$$

$$R_3 + R_4 = 1975\,\Omega \quad \text{(S7)}$$

Solving equation S5, S6 and S7 we get the contact resistance of contact 2 (R_2), contact 3 (R_3) and contact 4 (R_4), which are summarized in table S3 bellow. Similarly, we can extract the contact resistance values for Sample 2. From our contact resistance analysis, we see that the contact resistance varies from ~0.5kΩ to ~2.0kΩ.

Table S1. Two-probe resistance data for samples 1 and 2.

No.	Resistance measured between contacts	Sample 1 Resistance (Ohm)	Sample 2 Resistance (Ohm)
1	2-3	3500	3500
2	2-4	2800	2100
3	3-4	2400	2400

Table S2. Four-probe resistance data for samples 1 and 2.

No.	Current supplied between contacts	Voltage measured between contacts	Resistance (Ohm) Sample 1	Resistance (Ohm) Sample 2
1	1-4	2-3	520	27
2	1-5	2-4	930	72
3	2-5	3-4	425	44

Table S3. Contact resistances.

Sample	Contact 2 resistance, R_2 (Ohm)	Contact 3 resistance, R_3 (Ohm)	Contact 4 resistance, R_4 (Ohm)
Sample 1	1437.5	1542.5	432.5
Sample 2	1900.0	1572.0	784.0