Supporting Information

One-Dimensional Quantum Confinement Effect Modulated Thermoelectric Properties in InAs Nanowires

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Temperature calibration The temperature gradient ΔT is one of the key points of thermopower measurement especially due to the small size of nanowire device. The temperature of sample holder (bath temperature, T) was monitored by the thermometers built-in on PPMS sample chip carriers. Helium gas (760Torr at 300K) was introduced into the PPMS chamber to assistant heat transfer and speed up the thermalization speed. The local temperature and temperature difference ΔT at two ends of nanowire was calibrated by using the four-wire resistances of the two electrode lines as thermometer #1 (TM_1) and thermometer #1 (TM_2).

A two-step measurement was taken for the temperature calibration. In step one, we ramped the bath temperature stepwise with 1K increment and recorded the thermometer's resistance after thermal equilibrium was reached. The linear relationship of bath temperature T vs. R_i (i=1, 2) serve as basic calibration curves for using their resistances R_i as thermometry. Fig. S1 a and c show the T vs. R_i around 300K as an example. In step two, while keeping a constant bath temperature T, stepwise increase in heater voltage was applied and corresponding resistance changes were recorded, as shown in Fig. S1 b and d for T=300K. When there was a step increase of heater voltage, the thermometer resistances R_i jumped up abruptly and reached equilibrium after several oscillations due to PPMS's temperature control mechanism to maintain the constant T after the extra heating power was applied by the heater on nanowire chip (2V on heater can cause the bath temperature to fluctuate for ~0.2K right after the application of heating voltage). After the bath temperature and thermometer resistance stabilized, we compared the values of resistances at each V_h and the $T(R_i)$ temperature curves obtained at V_h=0 to obtain the actual temperatures of the two thermometers, T_1 and T_2 at each V_h or heater power P. The temperature increase ΔT_1= T_1 - T and ΔT_2= T_2 - T for both thermometers and the temperature gradient

$\Delta T = \Delta T_1 - \Delta T_2$ can be calculated accordingly.

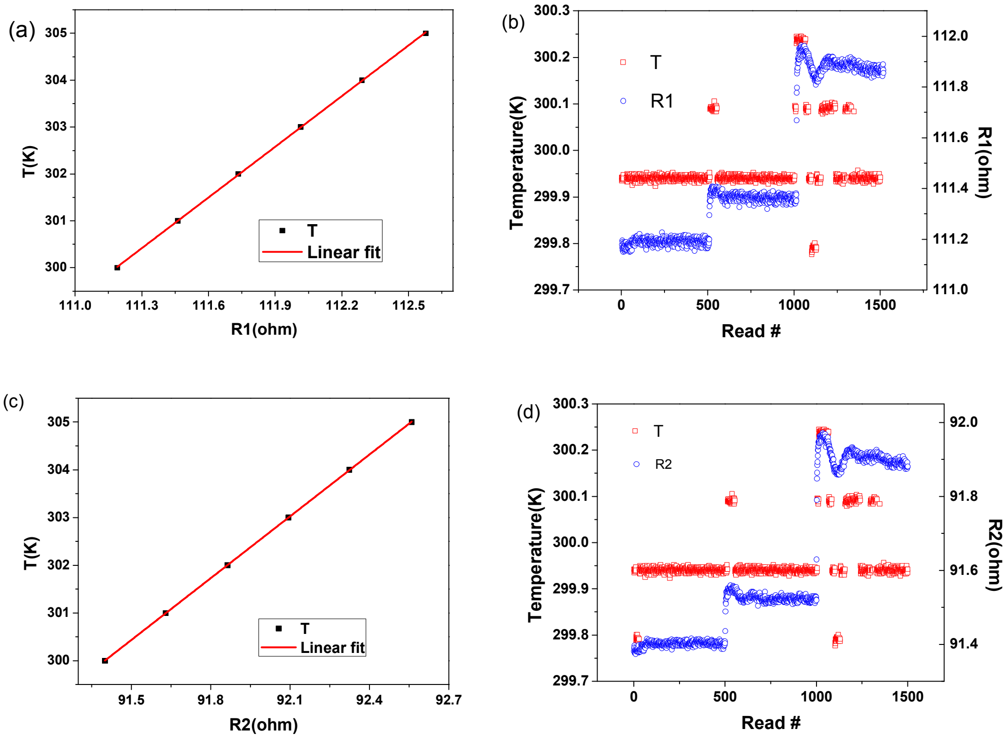

Figure S1. Thermometer calibration. Measured resistance of both thermometers #1 (TM_1) and thermometer #1 (TM_2) as a function of bath temperature in the cryostat around 300K (a) (c). Corresponding resistance changes in response to the stepwise increase in heater voltage (b) (d) (blue trace, right y-axis). The heater voltage was set to 0, 1 and 2V at reading number 0, 500 and 1000 in (b) and (d).

Such temperature calibration was performed from T=300 to 40K at a number of temperatures. Fig. S2 shows ΔT_1, ΔT_2 and ΔT at various temperatures with 2V heater voltage. Since the sample was already significantly overheated at low temperature (ΔT_1, ΔT_2 ~6K at 40K), we did not attempt thermopower measurement at T<40K.

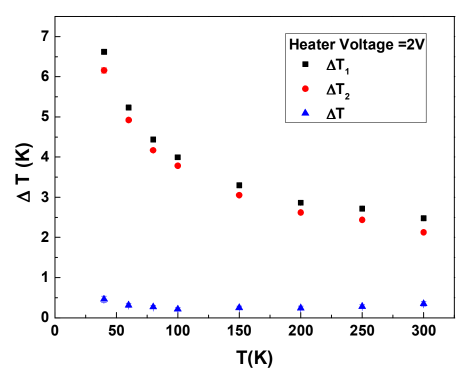

Figure S2. Bath temperature dependence of the temperature gradient ΔT and the respective temperature rise (ΔT_1, ΔT_2) at each thermometer with 2V heater voltage.

Comparing the relative modulation of thermoelectric power factor at different temperatures Due to the rapidly oscillating 1D density of states of 1D sub-bands, the thermoelectric power factor of InAs nanowire oscillates more drastically as the thermal energy becomes smaller than the subband energy separation, as shown in the scaled power factor in Fig.S3.

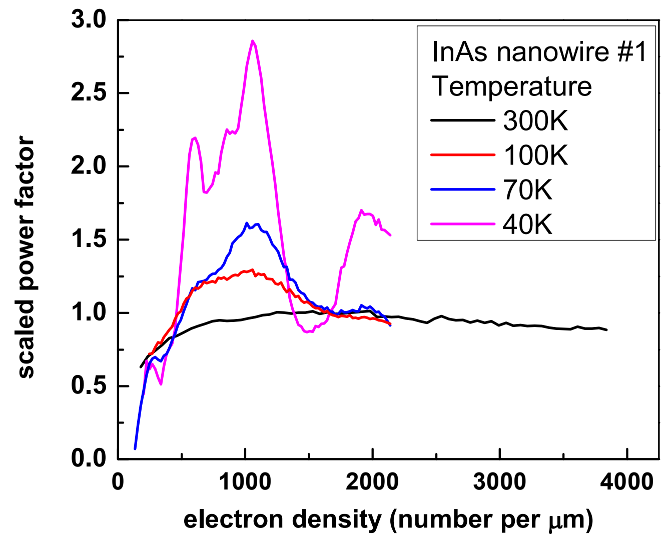

Figure S3. The power factor σS^2 at different temperature normalized by its value at the optimal density for 300K (c.a. 1600 electrons/micron), to illustrate that the 1D subband quantization induces more drastic oscillation of σS^2 when the 1D subbands become discernible.

Thermoelectric data on additional InAs nanowire devices

The gate modulated thermoelectric properties (electrical conductivity, thermopower and power factor) of two additional InAs nanowires were measured and included below.

InAs nanowire #2(diameter of 25nm and length of 7.5μm)

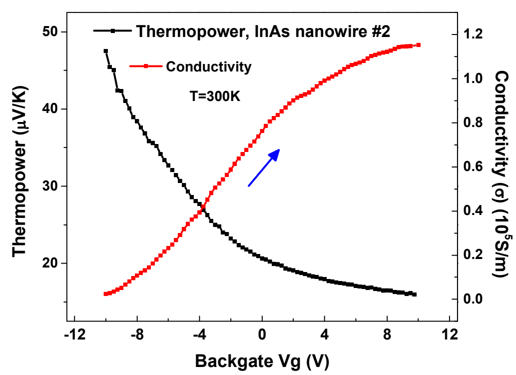

Figure S4. Thermopower (S) and conductivity of InAs nanowire #2 vs. backgate voltage at *T*=300K and 2V heater voltage. Blue arrow marks the gate sweep direction. This nanowire has peak mobility ~3300cm^2/Vs at 300K.

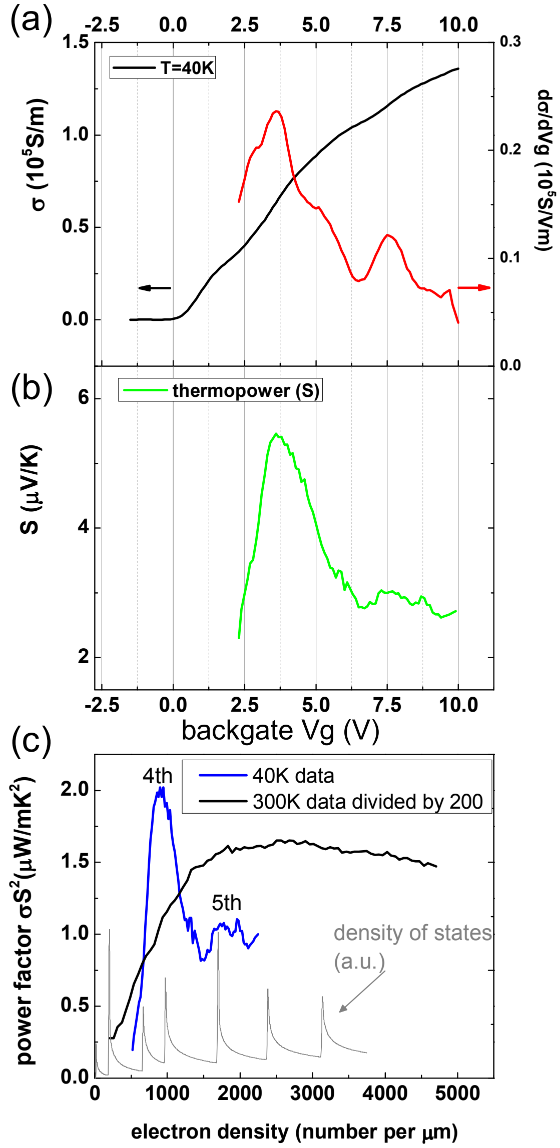

Figure S5. (a, b) Gate dependence of Conductivity (σ) and thermopower (S) of InAs nanowire #2 at 40K. The peaks and dips of thermopower oscillations match gate voltage derivative of conductivity (dσ/dVg). (c) Comparing the power factor vs. electron density at 40K and 300K. The 300K data has been divided by a factor of 200. By comparing to calculated density of states (grey line) for *d*=23nm InAs nanowire (after subtracting ~2nm oxide thickness), the oscillations in power factor at 40K are attributed to the filling of the 4th and 5th 1D subbands.

InAs nanowire #3 (diameter of 25.8nm and length of 5.42μm)

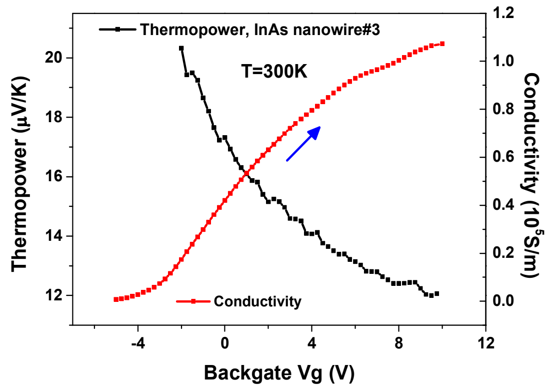

Figure S6. Thermopower (S) and conductivity of InAs nanowire #3 vs. backgate voltage at T=300K and 2V heater voltage. Blue arrow marks the gate sweep direction. This nanowire has peak mobility ~1312cm^2/Vs at 300K.

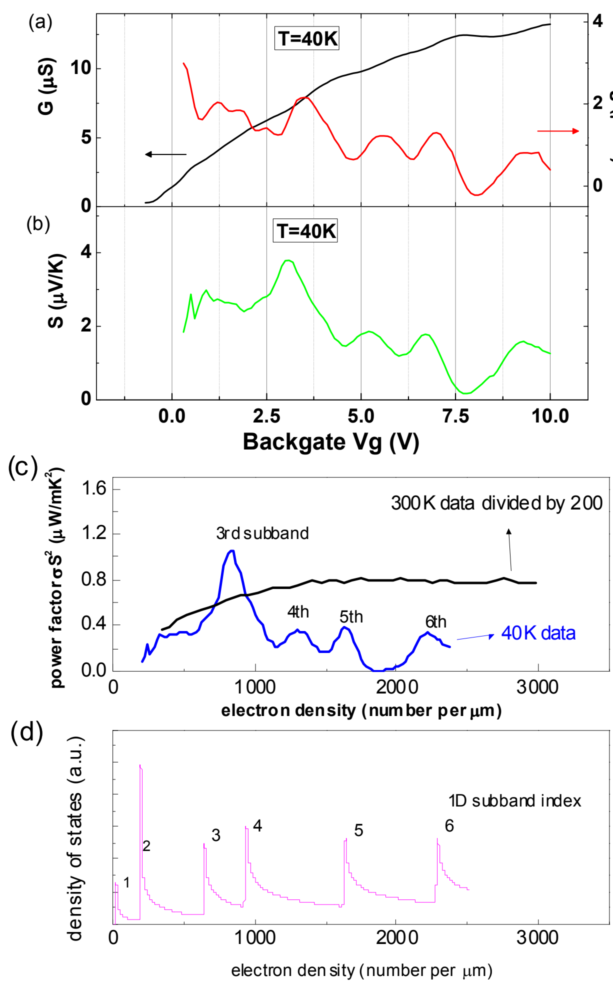

Figure S7. (a, b) Gate dependence of Conductance (G) and thermopower (S) of InAs nanowire #3 at 40K with 2V heater voltage. The peaks and dips of thermopower oscillations match gate voltage derivative of conductivity (dG/dVg) with small shift (~0.3V) due to hysteresis. (c) Comparing the power factor vs. electron density at 40K and 300K. The 300K data is divided by a factor of 200. (d) Calculated density of states for *d*=24nm InAs nanowire (after subtracting ~2nm oxide thickness). The oscillations in power factor at 40K are attributed to the filling of the 3^{rd} to 6^{th} 1D subbands. The offsets in the positions for the 3^{rd} and 4^{th} peak in powerfactor data compared to the band edges in the calculation might be due to the hysteresis or disorder broadening of density of states which was not included in (d).