Thermal Conductance of a Single-Electron Transistor

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Heat flow at mesoscopic scale is a fundamentally important issue, in particular, if it can be converted into energy by thermoelectric effect. While the understanding of charge transport in mesoscopic system has reached a great level of maturity, heat transport lagging far behind. According to the celebrated Wiedemann-Franz law, the charge conductance is proportional to the thermal conductance. In nanoscale devices, this law is predicted to be violated in the presence of strong electron-electron interaction [1].

We have carried out a combined measurement of heat and charge transport through a single-electron transistor (SET) (Figure 1, (a, b)). A thermal gradient across the SET is created by cooling (heating) the source using a (pair of) NIS junction, while the bulky drain is at bath temperature. The electronic temperature of the source is measured simultaneously. A periodic modulation of the source temperature (Figure 1, (c)) as a function of gate voltage is observed, giving an evidence of heat flow through the SET. The device thus acts as a heat switch actuated by the voltage applied on the gate. The Lorentz ratio L/L_0 (L_0 being the Lorentz number) is calculated by comparing the charge and heat transport data (Figure 1, (d)). While the Wiedemann-Franz law predicts a unity value for the Lorentz ratio, a value up to 4 is observed [2]. These observations agree well with theoretical calculations [1].

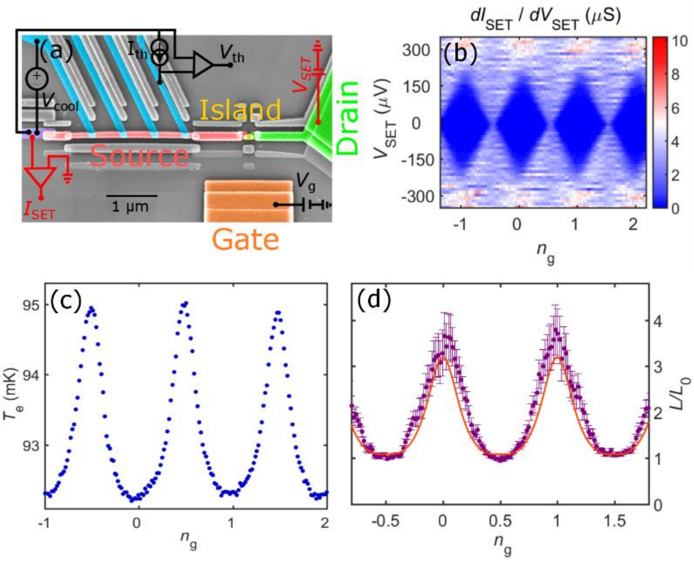

Figure 1: (a) SEM image of the device with different elements shown in color; (b) Coulomb diamonds in the charge conductance map of the SET; (c) temperature modulation of the source (when it is colder than drain) by the applied gate voltage; (d) Lorentz ratio as a function of the gate, with the theoretical curve shown as solid line.

[1] B. Kubala, J. König, J. P. Pekola, *Violation of Wiedemann-Franz Law in a Single-Electron Transistor*, Phys. Rev. Lett. **100**, 066801 (2008).

[2] B. Dutta, J. T. Peltonen, D. S. Antonenko, M. Meschke, M. A. Skvortsov, B. Kubala, J. König, C. B. Winkelmann, H. Courtois, J. P. Pekola, *Thermal Conductance of a Single-Electron Transistor*, Phys. Rev. Lett. **119**, 077701 (2017).