Charge and spin Seebeck effects in hybrid quantum dot junctions

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The study of thermoelectric transport in nanodevices is of theoretical and practical interest. Here we shall discuss two different devices. One consists of a molecule between two normal metallic electrodes and in the second case the device consists of the quantum dot placed between three electrodes: one normal metallic (N), other ferromagnetic (F) metal and the third superconducting (S). The main focus of the first model is to analyze strong coupling of charge and vibrational degrees of freedom, which may lead to effective attraction of electrons on a molecule. In this negative U model the pair tunneling is the main transport mechanism in the limit of weak coupling to the electrodes. In the second model due to the presence of ferromagnetic electrode the device is an efficient source of the pure spin current.

The molecule characterized by the negative effective charging energy $U<0$ has been modeled by the Anderson Hamiltonian. The electrical conductance, thermopower, and thermal conductance of the system have been calculated as a function of gate voltage in the weak coupling limit within the rate equation approach. In the linear regime the analytic formulas for the transport coefficients in the pair-dominated tunneling are presented. The effects found in the nonlinear transport include *inter alia* the rectification of the heat current. The sense of forward (reverse) direction, however, depends on the tuning parameter (distance from electron-hole symmetry point) and can be controlled by the gate voltage. We also discuss the quantization of the thermal conductance and the departures from the Wiedemann-Franz law.

The thermoelectric transport in the system composed of a quantum dot in contact with superconducting, ferromagnetic and normal metal electrodes can support pure spin current in the normal electrode. In the limit of a large superconducting gap and weak coupling between the dot and the electrodes we investigate the sub-gap charge and spin transport via Andreev mechanism using the standard master equation technique, which is known to be valid in the sequential tunneling regime. The Zeeman splitting of the dot level induces pure spin current in the ferromagnetic electrode under an appropriate bias. This opens a novel possibility to switch the spin current between two electrodes by electric means. The calculated spin and charge thermopower coefficients attain very large values, of the order of a few hundreds $\mu V\ K^{-1}$, and show similar dependences on the position of the on-dot energy level and temperature.

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References:

1. **K. I. Wysokiński**
   Thermal transport of molecular junctions in the pair tunneling regime,
   Phys. Rev. B **82**, 115423 (2010).
2. **Karol I. Wysokiński,**
   Thermoelectric transport in the three terminal quantum dot,
   J. Phys. Condensed Matter **24,** 335303 (2012)