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Coulomb and vibration effects in spin-polarized current through a single-molecule transistor

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In recent years nanoscale transistors gain more scientific interest. The single-molecule transistor, where vibrating molecule is placed between two massive electrodes, appears to be a challenging device for further fundamental study and application in electronics. In this device along with the possibility of elastic tunneling the electrons can tunnel inelastically, emitting or absorbing vibrons. New transport phenomena also occur while the current of spin-polarized carriers through molecular transistor is controlled by an external magnetic field, providing an application in spintronics.

The current through spintronic molecular transistor in an external magnetic field is studied. We consider a molecule placed between electrodes, which are fully spin-polarized in opposite directions. The electron-vibron interaction and the Coulomb correlations in the system are taken into account. It is known that the dependence of the current on bias voltage in molecular transistors at low temperatures have form of step-like function (see e.g. [1]). Current jumps (Franck-Condon steps) occur, when new inelastic tunnel channels open.
<img src=”https://indico.bitp.kiev.ua/event/7/contributions/186/attachments/76/149/Fig.1.jpg” width=”500” height=”600”>
Fig.1: The dependence of current on bias voltage $I(V)/I_0$ for spintronic molecular transistor at low temperatures for different values of Coulomb interaction (solid thin curve corresponds to negligibly small Coulomb interaction). $I_0 = e\Gamma/(2\hbar)$, where Γ is the tunneling level width. The bias voltage in energy units is normalized to molecule's vibration quantum.

The average current has been found using the density matrix method in perturbation theory over tunnel coupling. It has been obtained that the current dependences in our model have doubled number of Franck-Condon steps (Fig. 1) compared to an "ordinary" molecular transistor. The doubling is due to the appearance of second elastic channel in the system with Zeeman splitting. It has been revealed that for strong Coulomb interaction the heights of Frank-Condon steps are suppressed (solid thick, dotted and dashed curves, Fig. 1) and the regions without steps on the current-voltage characteristics appear (dotted and dashed curves, Fig. 1). The effects are caused by interplay of Franck-Condon and Coulomb blockade lifting by bias voltage. It has been also shown that the lifting of the Coulomb blockade in the Zeeman split system procceds in stages. It has been obtained that the temperature dependence of a conductance of spintronic molecular transistor for strong electron-vibron interaction is anomalously nonmonotonic in the region of intermediate temperatures in a wide range of external magnetic fields and at arbitrary Coulomb energy.
The results lead to a better understanding of the transfer of the current of interacting carriers in complex systems, allow one to interpret the data of tunnel experiments, provide background for engineering of nanoelectronic devices controlled by an external magnetic field.

Primary authors: Dr SHKOP, Anastasiia (B. Verkin Institute for Low Temperature Physics and Engineering of the NAS of Ukraine); BAHROVA, Olha (B. Verkin Institute for Low Temperature Physics and Engineering of the NAS of Ukraine)

Presenter: Dr SHKOP, Anastasiia (B. Verkin Institute for Low Temperature Physics and Engineering of the NAS of Ukraine)

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