Indian J Phys
https://doi.org/10.1007/s12648-023-02822-9

ORIGINAL PAPER

I–V characteristics of the single quantum dot within impurity Anderson model: the role of correlation regime

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Received: 13 September 2022 / Accepted: 15 June 2023

Abstract: Charge current through a single quantum dot coupled to a source and drain with an applied bias voltage is studied. The current–voltage characteristics are calculated using our treatment within the Anderson model. The dependence of the current–voltage characteristics on the Coulomb energy, temperature, gate voltage, and magnetic field is examined. A clear dependence of all the practical requirements, functions and parameters considered in our work to describe the electron transport throughout the quantum dot is highlighted. Our results can be experimentally realized and it is easy to tune practical parameters to determine the correlation regime for a certain spin.

Keywords: Anderson model; Quantum dot; Charge current; Magnetic field

1. Introduction

Electron transport through nano-electronic devices is topic one that has received great attention in recent years in both experimental and theoretical studies. These devices included such as molecules, quantum dots and carbon nanotubes as a basis for their structures [1–9]. The significant development in the techniques of manufacturing electronic devices has made electron transport possible by changing the bias voltage, the gate voltage and temperature, in addition to the coupling with the electrodes. Several experimental studies have dealt with electron transport through a single dot between metallic electrodes [10–12]. The characteristics of the current–voltage with different values of gate voltage, and temperature are the most important features of many experimental and theoretical studies because of their importance in determining the working mechanism of the device through the behavior of the current [12–16].

In the present work, electron transport occurs through quantum dot system when a bias voltage is applied to the right lead. The Anderson model for a single impurity is used to describe the quantum dot system [6, 17]. The current–voltage equation of a quantum dot system is related to Fermi distribution function of leads and the energy spectrum of the quantum dot. We used analytic formulas for the occupation numbers and the charge current [18] to calculate the *I–V* characteristics and investigate the role of all interesting physical parameters, such as correlation energy, gate voltage, temperature and Zeeman energy. The system may be in non-equilibrium because of either a temperature gradient or a bias voltage, which leads to a change in the chemical potential of the electrodes [15, 18–20]. At a non-zero bias, electrons can tunnel through the energy level $E^{\sigma}_{\mathrm{dot}}$ or/and $E^{-\sigma}_{\mathrm{dot}}$ if tunneling is attainable throughout the energy window that is opened between the chemical potentials of the leads. However, the energy levels that lie within the bias window determine the transport properties of the system.

2. Model calculation

We modeled a single quantum dot and leads using the Anderson Hamiltonian [17]:

$$H = \sum_{\sigma} E^{\sigma}_{\mathrm{dot}} n^{\sigma}_{\mathrm{dot}} + U n^{\uparrow}_{\mathrm{dot}} n^{\downarrow}_{\mathrm{dot}} + \sum_{\vec{k}\sigma\alpha} E^{\sigma}_{\vec{k}\alpha} c^{\sigma\dagger}_{\vec{k}\alpha} c^{\sigma}_{\vec{k}\alpha} + \sum_{\alpha} \sum_{\vec{k}\sigma} \left(V^{\sigma}_{\vec{k}\alpha} c^{\sigma\dagger}_{\vec{k}\alpha} d^{\sigma} + V^{\sigma *}_{\vec{k}\alpha} c^{\sigma}_{\vec{k}\alpha} d^{\sigma\dagger} \right) \quad (1)$$

$n^{\sigma}_{\mathrm{dot}}$ is the quantum dot occupation number which is spin-dependent, where $d^{\sigma\dagger}(d^{\sigma})$ is the operator of the creation (annihilation) of the electron in the quantum dot. Taking

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Published online: 11 July 2023