Two-Terminal Spin Filter Using Quantum Dot with Spin-Orbit Interaction in Magnetic Field

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The spin injection in semiconductors is an important issue for the spin-based electronics, "spintronics." We propose an efficient spin filter utilizing a quantum dot (QD) with spin-orbit interaction. In the absence of magnetic field, a QD must be connected to three or more leads (or conduction channels) for the spin filter.[1] We show that the conventional geometry of two-terminal QD works as a spin filter in a magnetic field. First, we examine a QD with two energy levels, $|1\rangle$ and $|2\rangle$, as a minimal model. The levels are mixed by the SO interaction, $\langle 2|H_{\rm SO}|1\rangle \equiv i\boldsymbol{\sigma}\cdot\boldsymbol{h}_{\rm SO}$, and the magnetic field, $(|e|/2m^*)\langle 2|(\boldsymbol{p}\cdot\boldsymbol{A}+\boldsymbol{A}\cdot\boldsymbol{p})|1\rangle \equiv ib$, where $\boldsymbol{A}$ is the vector potential. The spin-dependent conductance is given in an analytical form around current peaks of the Coulomb oscillation where the electron-electron interaction can be neglected. When an unpolarized current is injected to the QD from a lead, the spin-polarized current is ejected to the other lead. The spin polarization is enhanced to $\sim 80\%$ by the resonant tunneling if the magnetic field is tuned to be $b \sim |\boldsymbol{h}_{\rm SO}|$. Second, a realistic model for the QD and tunnel barriers is made by discretizing the space.[2] The efficiency of the QD spin filter is evaluated by the numerical calculation.

[1] M. Eto and T. Yokoyama, J. Phys. Soc. Jpn. **79**, 123711 (2010).
[2] T. Ando, Phys. Rev. B **44**, 8017 (1991); T. Yokoyama and M. Eto, Phys. Rev. B **80**, 125311 (2009).