Kondo correlation and spin-orbit interaction in an InSb nanowire quantum dot coupled to the Nb contacts

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We report the fabrication and electrical measurements of Kondo correlation and spin-orbit interaction in a Nb-InSb nanowire quantum dot-Nb hybrid device. Our work is motivated by recent proposals [1, 2] for the realization of Majorana fermions in semiconductor nanowires with strong spin-orbit interaction coupled to s-wave superconductors and encouraging experimental results [3, 4]that show the signatures of Majorana fermions . Through the transport measurements to the device, Kondo effects and spin-orbit interaction are investigated in the presence of a proximity effect induced superconducting energy gap in the Nb-covered InSb nanowire segments.

The device is fabricated from an InSb segment of an epitaxially grown InAs/InSb heterostructure nanowire. Two Nb-based superconductor thin film contacts with a spacing of 120 nm between them are defined by electron beam lithography and magnetron sputtering. A quantum dot is naturally formed in the nanowire segment between the two contacts. Transport measurement is performed in a dilution refrigerator at a base temperature of 25 mK.

At low temperature, the Nb-covered InSb nanowire segments turn to be superconductors with a superconducting energy gap Δ in the order of 0.25 meV due to the proximity effect [5]. Between the two superconducting segments, a Josephson-quantum dot junction structure is formed together with the InSb nanowire quantum dot. Although in the presence of the proximity effect induced superconducting energy gap, the conventional Kondo effect induced conductance enhancement at zero magnetic field and the integer-spin Kondo effect induced conductance enhancement at finite magnetic fields are observed. In the strong coupling regime, the Kondo effect induces a zero-bias conductance peak in the form of Cooper pair cotunneling enhancement. However, the integer-spin Kondo effect causes two conductance peaks at finite bias voltages and shows an anti-crossing behaviour in the magnetic field evolution due to the existence of spin-orbit interaction. We have deduced the spin-orbit interaction energy Δ_{so} from the anti-crossing and compared it to the values that determined by the anti-crossing behaviour of quasi-particle cotunneling through excited states of the quantum dot [6].

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