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Andreev and Josephson transport in InAs nanowire-based quantum dots

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Superconducting proximity effects are of fundamental interest and underlie recent proposals for experimental realization of topological states. Here we study superconductor-quantum dot-superconductor (S-QD-S) junctions formed by contacting short-channel InAs nanowire transistors with Nb leads. When the carrier density is low, one or more quantum dots form in the nanowire due to spatial potential fluctuations. Low-temperature electrical transport shows clear signatures of proximity superconductivity, such as regions of negative differential conductance, Multiple Andreev Reflections (MAR) and spectroscopic features hinting at the formation of Andreev Bound States (ABS). These features can coexist with the Coulomb diamond structure resulting from the dot charging energy. The theory of Andreev and Josephson transport in S-QD-S structures is invoked in order to elucidate the experimental data. Particular attention is devoted to an intermediate coupling regime, wherein the superconducting energy gap Δ is on the same order of magnitude as the tunnel coupling strength Γ, but smaller than the Coulomb charging energy of the dot U. In this model, a rich interplay exists between U, which favours a spin-doublet ground state for the quantum dot, Δ, which favours a BCS-like singlet ground state, and Kondo correlations in the dot, which favour a Yu-Shiba-Rusinov-like singlet ground state. A quantum phase transition can occur from the doublet to the BCS-like singlet ground state, marking a 0-π transition in the Josephson current of the junction. The significance of these results to the search for topological states in semiconductor

nanowire junctions is discussed.

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