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Tunable Few Electron Double Dots in InAs Nanowires

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1. Introduction

Tunable few-electron quantum dots (QDs) in InAs nanowires (NWs) have been fabricated also a highly sensitive charge detectors are demonstrated. The realized devices are prepared in view of detecting and manipulating single charges and single spins. This is crucial for improving our understanding of the involved phenomena and also is the basis for applications in solid state quantum computing.

2. Experiment

InAs NWs are grown by metal-organic vapor phase epitaxy using Au colloidal particles as catalysts [1]. Two different methods are proposed to create QDs in the NWs: electrostatically by gate electrodes and physically by etching.

Gate defined QDs

QDs are created electrostatically between top gate fingers evaporated on top of a NW lying on an insulating substrate, Fig. 1 a). Top gates are made by electron beam lithography (EBL), physical deposition of Cr/Au metals and a lift-off process. The gates are electrically insulated from the NW by a thin native oxide covering the NW [2]. This original and simple technique produces very high quality and fully tunable double QDs containing a small number of electrons [3]. For particular spin configurations in the double dot, it has been shown that the current can be suppressed due to the Pauli exclusion principle. We use this Pauli blockade spectroscopy to investigate spin relaxation mechanisms, as well as mixing of spin states, which will limit the spin coherence time in these systems [4, 5].

Etched QDs

QDs are defined by local wet etching of a NW using electron beam lithography patterning and PMMA resist as an etch mask. A GaAs/AlGaAs based two-dimensional electron gas (2DEG) is used as a functional substrate. During the etching step, both the NW and the substrate are etched, Fig. 1 b). Thus, quantum point contacts (QPCs) in the 2DEG and QDs in the NW are created in a self-aligned way. The QPCs can be used as local gates to the QDs and as a charge read-out at the same time. The addition of one electron to the QD leads to a change of the conductance of the charge detector by typically 20% at 1.7 K. Charge stability diagrams measured by transport through the quantum dot and charge detection merge perfectly [6]. Experiments on counting of single electrons tunneling through the QD showed outstanding signal to noise ratio, more than 80 at 20 kHz bandwidth. We demonstrate electrical current measurements by counting electrons passing through the QD [7]. We also show that the device works as a tunable single photon detector in the meV range.

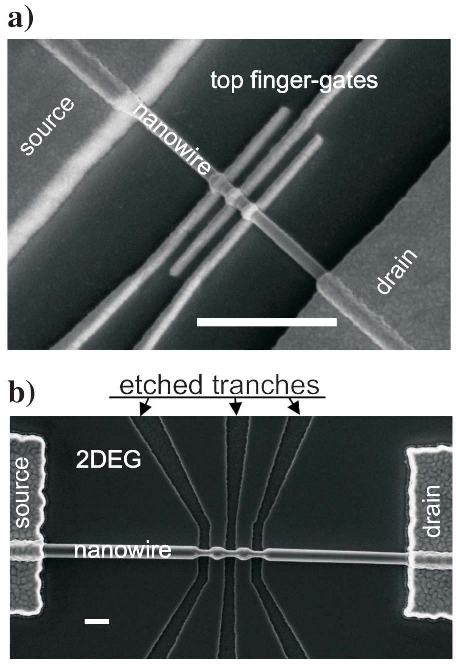

Fig. 1 Scanning electron microscope images of double QD devices defined by gates a) and by etching b). a) 30° tilt view, scale bar is 1 μm. b) Top view, scale bar is 200 nm.

3. Conclusions

Tunable few electron quantum dots in InAs nanowires and highly sensitive charge detectors are realized. The realized devices are useful to study single electron and single spin phenomena.

References

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