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Master thesis:

Device preparation and transport measurements of coupled quantum dots in InSb nanowires

Design illustration

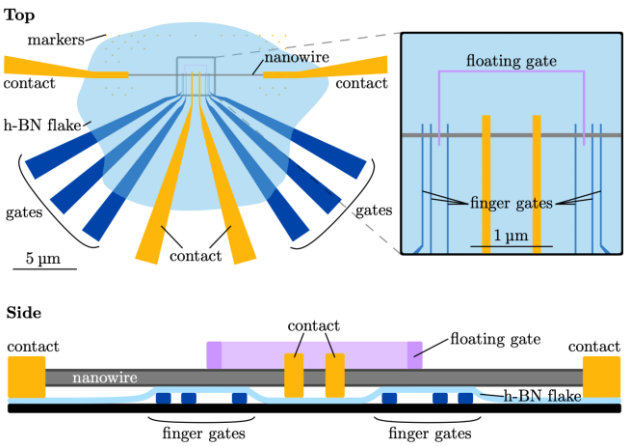

Fig. 1: Design of the device with two quantum dots and a floating gate in top view (top) and side view (bottom).

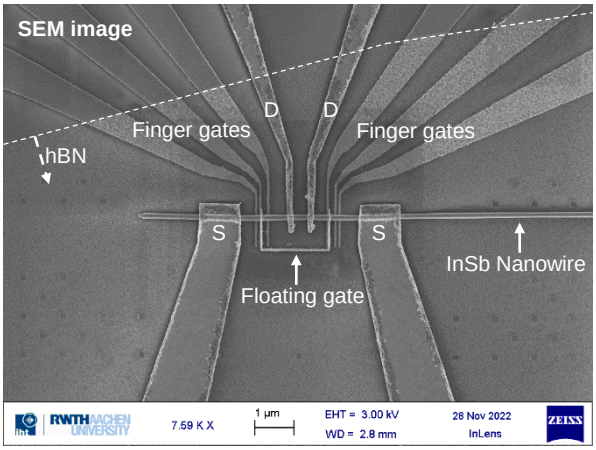

Fig. 2: Electron microscopy image of a completed device.

Motivation:

Scanning tunneling microscopy (STM) is a common tool for surface analysis, e.g., for probing complex electron systems. In conventional STM, the measured tunneling current of 1 nA – 1 pA, corresponds to, at least, 10^3 – 10^4 electrons per data point. Hence, the time sequence of individual tunneling events, which contains crucial information on electron-electron correlations, is averaged out. To overcome this limitation, our institute is building an STM with single-electron detection, exploiting quantum dots (QD) in a nanowire to count the tunneling electrons individually. So far, STM measurements with atomic resolution using InAs nanowires [1] and the preparation and measurement of single QDs in InSb nanowires (Fig. 3) using finger gates and exfoliated hexagonal boron nitride (h-BN) flakes as dielectric [2] have been demonstrated. The next target is to create stable double QDs in the nanowire and to detect the sequence and direction of the tunneling electrons: a floating gate couples capacitively to another QD and changes the current there, dependent on the charge state of the first QD structure (Fig. 1, 2).

Outline of the thesis:

The project consists of the cleanroom preparation of several devices with quantum dots in InSb nanowires and a floating gate between them, as shown in Fig. 1 and 2. After preparing the devices, electrical transport measurements are carried out at 300 mK to probe the functionality, i.e., to check if the device configuration with floating gate is suitable for the single electron detection.

Tasks and Skills:

Your task is the optimization of the device fabrication within the cleanroom based on the feedback of the transport results. Good knowledge in solid state physics and a strong interest/skills for experimental work are helpful. You will gain experience in:

- Nanofabrication including stacking of nanowires and 2D materials, electron beam lithography, and metallization
- Surface analysis by scanning electron microscope (SEM) and atomic force microscope (AFM)
- Cryogenic transport measurements

If you are interested, you are welcome to contact Kanji Furuta (furuta@physik.rwth-aachen.de).

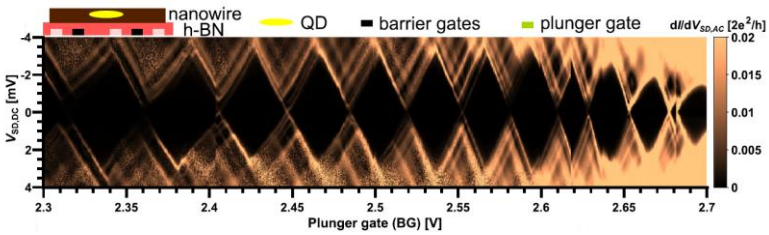

Fig. 3: Conductivity of a single QD, dependent on source-drain and backgate voltage [2].

[1] K. Flöhr *et al.*, Appl. Phys. Lett. **101**, 243101 (2012).
[2] F. Jekat *et al.*, Appl. Phys. Lett. **116**, 253101 (2020).