Gate Tunable Parallel Double Quantum Dots in InAs Double-Nanowire Devices

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Fabrication and characterization of InAs double wires with quantum dots

- Maybe useful for
  - Spin qubits
  - Topological circuits of non-locally entangled electrons
  - Majorana- and Parafermions

- In our case: Tunneling between the wires
  - Direct measurement of the band structure
Devices

- Nanowires: $d = 60 – 80$ nm; Wurtzite, grown by CBE

- Device A:
  - Finger bottom gates (Ti/Au) with an insulating silicon nitride layer
  - Parallel nanowires deposited using a polymer technique
    - Alignment parallel to the finger bottom gates
  - Contacts: Ti/Au with $(\text{NH}_4)_2\text{S_x}$ etch
  - Wire length $L \sim 150$ nm

- Device B:
  - Common Al contact
  - Separate normal contacts
  - Sidegates
  - Wire length $L \sim 200$ nm
Measurements – Device A

- Differential conductance as a function of two finger bottom gates show resonance peaks with two different slopes
  - Two parallel quantum dots (QD1 and QD2) formed by Shottky barriers
  - Further hint: no background conductance

- Finger bottom gates uniformly change carrier density and aid the formation of potential barriers
  - Similar to a plunger gate
Measurements – Device A

- Differential conductance with one finger bottom gate fixed and varying source-drain bias (on both wires simultaneously)
  - Observation of (rough) Coulomb diamonds

- Tunnel couplings to normal contacts are strong -> Kondo ridge
  - Diamonds are not well shaped due to strong co-tunneling effect

- Addition energies
  - QD1: 4 – 5 meV
  - QD2: 5 – 7 meV
Measurements – Device A

- Addition energy is different in the two measurements

- Different gate capacitance due to missalignment with the finger bottom gates
  - Here: QD1 has a 7 times larger gate capacitance than QD2
  - But: Geometrical reasoning only allows a factor of 2
  - Discrepancy is probably due to the unevenness of the isolator between the gates and the wire
Measurements – Device A

- More negative voltage on both finger bottom gates
  - Regime with stronger tunnel or capacitive coupling between the wires

- "Honey-comb"-like pattern indicates parallel quantum dots with interdot electrostatic coupling (~0.4 to 0.6 meV)
  - One quantum dot reacts to the charge state of the other quantum dot

- However: No evidence of interdot tunneling due to surface oxide between the nanowires
• AC-bias voltage on the central superconducting electrode while measuring differential conductance of the respecting wires

• Both maps show resonance peaks due to formation of quantum dots
  ▪ Wires are seperately contacted with no inter-dot coupling (capacitive or tunneling under the superconductor)

• Adition energies:
  ▪ QD1: 2-3 meV
  ▪ QD2: 1-3 meV

• Smaller addition energies than device A due to larger length of the wires
- Gap features in both wires
  - Gap structure width: $\pm 0.20 - 0.32$ meV
- Poor transparency inhibits investigation of Andreev reflection
  - Better transparency of the Al contact would enable further studies with Cooper pair splitting
- Additionally, length ($\sim 500$ nm) makes local Andreev reflection more favorable than Crossed Andreev reflection
Conclusion

- Fabrication of a device with parallel nanowires and parallel quantum dots
- Individually controllable charge states and tuneable interdot electrostatic coupling with finger bottom gates
- Fabrication of a device with a common superconducting contact
- No influence from the common parallel region on the formed quantum dot
- Superconducting proximity gap feature
- Fabrication technique enables devices for further studies in order to generate Majorana Kramer pairs or Parafermions