Quantum simulation of the Mott transition in the Fermi-Hubbard model using gate-controlled semiconductor quantum-dot chains

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In 1982, Feynman envisioned a special purpose universal quantum computer (quantum simulator) for using “one controllable quantum system to simulate another”. Recently there are impressive advances in developing quantum simulators to mimic the Bose/Fermi Hubbard model using ultracold atoms (at micro Kelvin temperatures) in optical lattices. Among the achievements are the synthesis of Mott insulators with large on-site repulsion and the observation of an insulator to superfluid transition.

In this talk, I will present our recent efforts on studying Mott transition via a low-temperature (20 mK) electron transport study of six-QD linear arrays. Our work aims to implement a quantum simulation of the Mott transition in the Fermi-Hubbard model in a solid-state system. In addition, our bias voltage controlled conductance map allows us to provide an on-chip laboratory for studying Mott physics. All the measurements were performed at 20 mK to 1K temperature range. Our observation was obtained by increasing the inter-dot coupling in a one-dimensional QDA. We found the QDA conductance spectrum undergoing a localization to delocalization transition process which is manifested as a collapse of the collective Coulomb blockade, analogous to the Mott insulator to metal transition. We hope this work will inspire research on quantum simulation of strong correlation effects in two dimensions, including a test of the controversial issue whether any superconducting phase fundamentally exists in the t-J model. The t-J model is the Hubbard model in the limit of ultra-large onsite repulsion. We also expect to have an important impact on developing engineered QD materials and artificial molecular devices.