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（要　旨）
(Summary)

Qubits based on various quantum systems have been studied to build large-scale qubit systems. One promising qubit for large-scale integration is a spin qubit in a silicon quantum dot, which has a small structure, a long coherence time, and a compatibility with existing CMOS technology. For the readout of a spin qubit, one measures spin-dependent charge distribution from the impedance change of the charge sensor via spin-to-charge conversion techniques. For quantum error correction, a fast (wide-bandwidth) measurement within the coherence time (about 10^-5 second) is of particular importance. On the other hand, a wide bandwidth will inevitably increase the noise; hence, it is not easy to achieve high-speed spin detection.

To build the large-scale qubit system, it is considered to be important to study a qubit system having a balance among the following three ingredients: suitability to two-dimensional integration, good readability, and good controllability. Recently, integration of silicon quantum dot systems having good readability and controllability has been studied, however, where there is a lack of studies on two-dimensionally scalable systems. In this thesis, we first focus on development of a minimum unit of two-dimensional quantum dot array and then apply charge sensing techniques to the system as a first step to demonstrate its readability. Here, we separately utilize digital and analog techniques to the readout and demonstrate that both of them are useful to detect signal from noisy environment.

At first, we explore the low-temperature transport properties of two types of physically defined triple quantum dot devices: linear and triangular ones. The linear device has three tunnel-coupled quantum dots in line while the triangular device at each vertex of a triangle. This quantum dot system has the following advantages for large scale integration: 1) it is fabricated from an industry-standard silicon-on-insulator wafer; and 2) it is physically defined by the shape of the silicon channel layer itself, so that there is no need to use gate electrodes to define the quantum dot structure. In experiment, we studied charge transport through the systems by directly measuring the current and by charge sensing technique using additional quantum dot structures. The results reveal the formation of each triple quantum dot system without unintentional quantum dots as expected.

Next, we detect single tunneling events in a physically defined silicon triple quantum dot system. In measurements, we observe single-shot tunneling events by using a charge sensor; however, it turned out that the signals are too weak to acquire tunneling statistics by binary thresholding. To overcome this problem, we apply numerical treatments, one of which utilizes the maximum log-likelihood ratio test, and thereby, the step position is precisely indicated. Its superiority is confirmed by comparing a digital filtering in the simulation. The results demonstrate its potential for spin readouts from noisy environments.

Finally, we apply radio-frequency reflectometry technique to a physically defined silicon quantum dot system. To readout spins in this system, as in many other quantum dot systems, the radio-frequency reflectometry will be of a significant importance; however, measuring clear reflectometry signals depending on quantum states has so far been elusive. This is likely attributed to the top gate structure overlapping reservoirs, which causes leakage of radio-frequency signals. To avoid this common problem of insensitivity, here we employ physically defined quantum dots without the top gate structure, leading to successful reflectometry as expected. Moreover, we observe large phase shifts corresponding to conductance peak of quantum dot (about 45 degree). To reveal the mechanism, we analyze the data based on an equivalent circuit consisting of an inductor, a capacitor, a quantum dot impedance, and their parasitic components which are typically neglected in previous reflectometry studies. By a simulation with the equivalent circuit, the measurement data is successfully reproduced, which allows us to conclude that reflectometry phase signals can be greatly enhanced by a good impedance matching and an appropriate frequency detuning.

In conclusion, we have developed elemental technologies for fast charge detection using physically defined silicon quantum dots: detection of charge states in a triangular triple quantum dot structure, which is the smallest unit of integration; single-shot measurement of single tunneling events of electrons supported by log-likelihood ratio test; realization of radio-frequency reflectometry in physically defined quantum dot for wideband sensing and the analysis using equivalent circuit. We believe that this work paves a way for fast spin readout in large-scale quantum dot system.