Noise Cross-Correlation Measurement of Capacitively-Coupled Silicon Nanometer-Scale Dots via Electron Counting Statistics

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Noise cross-correlation measurements can provide us with detailed information on electron dynamics in nanodevices [1]. In this study, we obtained the cross-correlation of thermal noise in capacitively-coupled nanometer-scale dots by performing electron counting statistics and estimated the statistics of energy transfer between the dots caused by the stochastic motion of electrons.

Our device fabricated on a silicon-on-insulator wafer had two capacitively-coupled nanometer-scale dots (Dot 1 and Dot 2) connected to an electron reservoir (ER), a gate that controls electron motion between the ER and the dots, and a sensor that has single-electron sensitivity (Fig. 1). All measurements were performed at room temperature.

We obtained stochastic changes in the number of electrons in Dot 1 and Dot 2, N_1 and N_2, respectively, by monitoring currents through the sensor (see the inset of Fig. 1) [2]. The random motion of electrons is thermal noise and has a Gaussian distribution [3]. The joint probability distribution of N_1 and N_2 has the shape of an ellipse with reduced probability for simultaneous electron occupation of dots that is caused by the repulsive Coulomb interaction between the electrons in the dots (Fig. 2).

The strength of the Coulomb interaction E_{Cm} was quantitatively estimated by using the cross-correlation function $C_{12}(\tau) = \langle N_1(t)N_2(t-\tau)\rangle$. It was found to be negative up to $\tau{\sim}20$ s (solid line in Fig. 3). This indicates that thermal noise in the dots fluctuates in opposite phase because of the Coulomb interaction. We estimated E_{Cm} to be ~2.0 meV in a Monte-Carlo simulation (dotted line in Fig. 3). We used this value to estimate the statistics of energy transport across the dots accompanying the individual motions of electrons [4] and observed net zero energy transfer across the dots, reflecting that the dots were in equilibrium.

In conclusion, noise cross-correlation measurements provided us with information on energy transport [4] and dissipation [5] at the nanometer-scale in integrated nanodevices including capacitively-coupled dots.

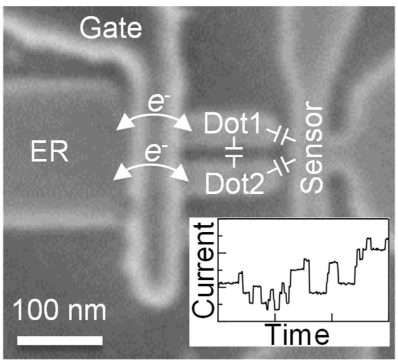

Fig. 1 Scanning electron microscope image of our device. Electrons thermally hop between the dots and ER. Inset: current through the sensor.

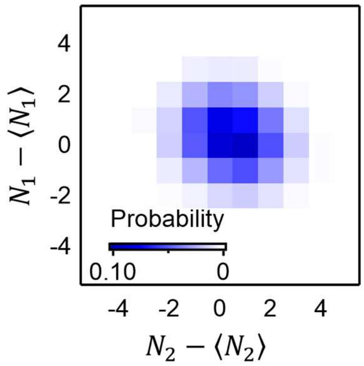

Fig. 2 Joint probability distribution of thermal noise in the dots indicating a repulsive interaction between electrons in the dots.

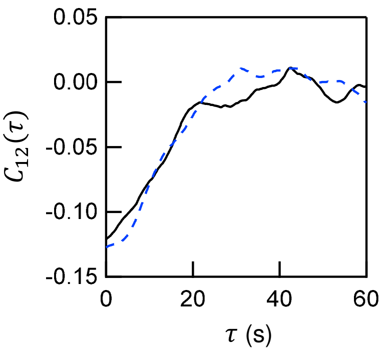

Fig. 3 Cross-correlation function of thermal noise in the dots reflecting the strength of the Coulomb interaction E_{Cm} ~2.0 meV.

References

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