Single-electron devices based on silicon nanowire MOSFETs

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Silicon nanowire MOSFETs are expected to be key components for future nanoelectronics. Based on the top-down approach using MOSFET technology, we have shown that their ultimately scaled channel and excellent gate control provide us with the opportunity to realize single-electron manipulation/detection devices, in which individual electrons can be transferred, manipulated, and detected in a well controlled manner. Such an ultimate charge control is promisingly applicable to metrological current standards, high-sensitivity sensors as well as low-power devices and circuits.

In this presentation our recent work on single-electron devices is described. One is the fast single-electron transfer utilizing single-electron ratchet [1] composed of the nanowire MOSFETs with fine gates. The simple operation with a single clock signal applied to one of the gates realized GHz-clocked single-electron transfer via a charge island formed in the nanowire channel between the gates (Fig. 1). Moreover, it was found that the nonadiabatic single-electron dynamics and their dependence on the electron number in the island play a significant role and make the transfer accuracy better than the thermal-equilibrium limit determined by temperature and the island size [2, 3]. The other topic is the single-electron random-number generator and its application to stochastic information processing circuit operating at room temperature [4, 5] (Fig. 2). In contrast to the first topic we do not regulate the time interval of single-electron transfer and rather let them randomly pass through a nanowire MOSFET. We monitor them in real time by an electrometer that is capacitively coupled to the drain of the nanowire MOSFET, which is terminated at the tip and thereby acts as a small charge node. This is actually the real-time detection of the shot noise in the MOSFET. We then utilized the shot noise as high-quality random numbers and demonstrated data processing which stochastically extracts the most preferable pattern among various ones. Thus, we demonstrate that silicon nanowire MOSFETs are quite promising for the precise control of single electrons as well as new circuit applications based on charge discreetness.

References:

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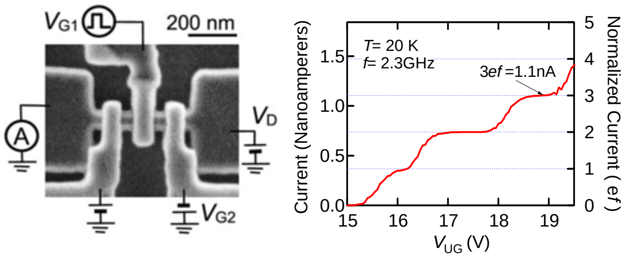

Fig. 1. GHz single-electron transfer by single-electron ratchet.

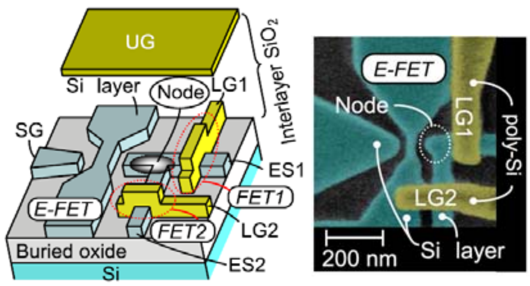

Fig. 2. Room-temperature operating single-electron counting device.