Single-electron Ammeter Based on Bidirectional Counting of Single Electrons

NTT, in collaboration with the Tokyo Institute of Technology, the Japan Science and Technology Agency, and Tohoku University, has successfully demonstrated an extremely sensitive ammeter that can measure extremely small currents that cannot be measured with any existing meter. The single-electron ammeter can detect the flow of one electron in either direction in real time, whereas a conventional high-sensitivity ammeter requires millions of electrons in order to detect them as a current. It consists of two quantum dots and a point contact integrated in a semiconductor device. A quantum dot is a small conductive nanostructure that accommodates a small number of electrons and a point contact is a small point-like contact through which electrical current flows between electrodes. An electron entering or escaping from one of the quantum dots influences the current flowing through the point contact, and this enables the change in electron occupation of a quantum dot to be monitored.

NTT fabricated this single-electron ammeter using semiconductor nanofabrication techniques. Each quantum dot has a diameter of about 100 nm and two of them are placed about 200 nm from the point contact. When an electron travels through the two quantum dots, the current through the point contact can take one of three different values depending on the location of the electron. Jumping between these values, for example, an electron entering the left dot, moving to the right dot, and escaping via the right lead, can be identified as an electron flow. In this way, a single-electron flow can be detected and the average current can be obtained by counting the net electron flow. NTT demonstrated the performance of the single-electron ammeter by connecting it to a single-electron transistor and successfully obtained the current flowing through the single-electron transistor (**Fig. 1**). The correct path of an electron in the device could also be traced.

Photon counters, in which individual photons can be counted, have been widely used to detect faint light. Similarly, the present single-electron counter should be useful for detecting extremely small currents in various applications. It should be especially useful for studies on nanoelectronics, which seek to examine electron transport through nanostructures, single modules, and biological cells, and often require the measurement of extremely small currents. Combining the ammeter with a device that converts photons or electron-spins into electronic charges could lead to the development of sensitive detectors for light or magnetic fields. Furthermore, statistical analyses of current noise measured with the single-electron ammeter would identify quantum entanglement, in which quantum information is shared between two separated electrons.

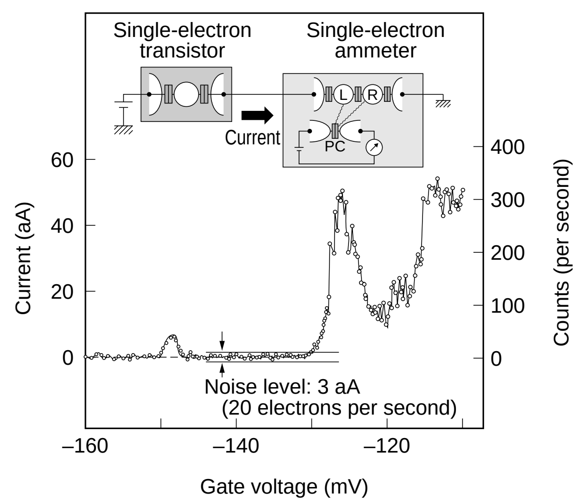

Fig. 1. Demonstration of the single-electron ammeter.

For further information, please contact:
Planning Department
NTT Science and Core Technology Laboratory Group
E. Tamechika
Tel: +81-46-240-5152
http://www.ntt.co.jp/sclab/contact_e/