FUNDING PROGRAM FOR NEXT GENERATION WORLD-LEADING RESEARCHERS

Project Title: Silicon low power nanodevices based on the control of single or a few electrons	
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1. Background of research

Recent rapid progress in the performance of the information processing and communication tools such as personal computers and cellular phones makes innovation in human life. On the other hand, the power consumption of large-scale integrated circuits used in these tools has been increased, being a serious problem from the viewpoints of environment and energy costs.

2. Research objectives

The aim of this project is to provide the technology for ultimate low power electronics based on the one-by-one control of electrons in semiconductors. The method of fabricating silicon nanometer-scale devices and manipulating and detecting individual electrons in the device is developed.

3. Research characteristics (incl. originality and creativity)

In order to realize circuits operated by non-conventional principles, the scheme of controlling single or a few electrons is established by clarifying how each electron behaves as a charge particle through precise measurements of the accuracy in single-electron manipulation. Silicon technology that is in the main stream of the modern electronics is used to make outcomes of the project more practical with technological impact. The originality of the project is to utilize silicon nanowire transistors with fine gates attached to control the movement of single electrons flowing through the wire channel. Two kinds of approaches will be made: one is to precisely measure the accuracy of manipulating or transferring one electron at high clock frequency and thereby characterize the bit-error rate quantitatively. The underlying physics is investigated for the ultimate control of electrons. The other approach is to utilize the stochastic behavior of single electrons as random numbers for new types of circuits with flexibility and fault-tolerance. For both approaches, a variety of science and technologies such as nanofabrication, material physics, and electrometry are included.

4. Anticipated effects and future applications of research

The developed device technology will lead to future development of the low power electronics and circuits of which power consumption is more than one order of the magnitude smaller than that of the conventional one. It also will contribute to the realization of ultra sensitive sensors and electrical standard devices with high accuracy.

Research subject

NTT Basic Research Laboratories
Nanodevices Research Group

High-speed and accurate single-electron transfer

- Accuracy evaluation
- Electron dynamics, quantum & spin
- Impurity/defect

Single-electron random number

- flexible function
- Noise-assisted phenomena

High-sensitive charge sensor

- Single-electron resolution
- High-speed sensing

Electro-optical

- Detection and emission of light

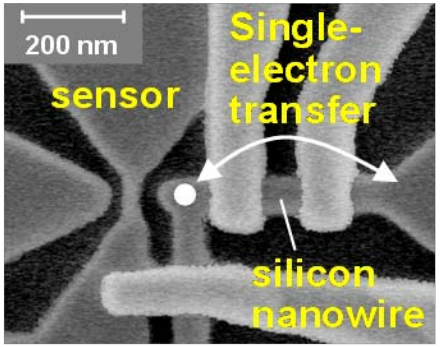
Silicon Nanodevice fabrication process

Device technology for control of single or a few electrons

- High accuracy (error < 10^{-8})
- Error compensation

Circuit architecture

- Power reduction 1/10-1/100



Single-electron transfer and its accuracy test