



**Groundbreaking New Technology for Improving the
Reliability of Spintronics Logic Integrated Circuits**

Progress towards the commercialization of circuits that enable
electronic devices to consume zero standby power

NEC Corporation (NEC; TSE: 6701) and Tohoku University have developed the world's first technology for improving the reliability of spintronics logic integrated circuits with the intention of reducing the standby power of electronic devices to zero. The behavior of this technology has been verified using a prototype chip.

Spintronics logic integrated circuits use two of the properties of electrons, namely negative charge and spin^{*1} (the fact that electrons are similar to tiny magnets), to remember the results of calculations by flipping the polarity of these tiny magnets between “north” and “south” according to the direction of an electric current. This technology has become the focus of interest as a semiconductor technology because it has non-volatility^{*2}, meaning that it can retain data even if the power supply is cut off because data is remembered using magnetic polarity. It is this non-volatility that has the potential to eliminate the power consumed by electronic devices while they are in standby mode.

These technologies use vertical domain wall elements^{*3}, which have vertical magnetization with respect to a magnetic body. Multiple vertical domain wall elements are loaded for each individual component of a logic integrated circuit, so that there is redundancy in the way that data is remembered. This enables

a high level of reliability to be achieved because the data errors^{*4} that occasionally occur with logic integrated circuits can be detected and corrected.

With this technology, spin elements are connected in a series, which prevents power consumption from increasing and prevents the area of the circuit from becoming larger. These highly reliable circuit components also support automatic placement and wiring, which means that highly reliable non-volatile logic integrated circuits can be designed even without expertise in spintronics technology.

Key features of this technology are as follows.

1. Delivers non-volatile logic integrated circuits with high reliability

Data redundancy is achieved by loading multiple “spin elements” (the elements that remember calculation results until the power is turned back on) for the components of logic integrated circuits. Although the probability of errors occurring with non-volatile logic integrated circuits is very low, errors where calculation result data is remembered incorrectly do occur, and having redundant spin elements enables these errors to be detected and corrected, so that the data can be read correctly.^{*5} Normally, adding redundant elements would make the physical size of the circuit larger, but vertical domain wall elements can be placed on top of transistor elements and the elements are connected in a series so there is no need for a new transistor to branch the wires. This means high reliability can be achieved without increasing the circuit area.

Vertical domain wall elements also feature low electrical resistance on a current pathway, and so by connecting the elements in a series very little extra time or current is required to write data.

2. Non-volatile circuits can be designed even without knowledge of spintronics technology

The circuit components that incorporate spin elements support automatic placement and wiring, whereby the placement and wiring of transistors is designed programmatically. This enables non-volatile logic integrated circuits to be designed easily, even without expertise in spintronics.

Recently the increasing power consumed by electrical devices has become an important issue, with the expansion of cloud computing, the rapid increase in the volume of communications data associated with the uptake of smart phones, and the tight balance between supply and demand following the Great East Japan Earthquake.

Spintronics logic integrated circuits can hold data even when the power is turned off, and then recover rapidly when the power is turned back on. There are great expectations for these spintronics logic integrated circuits as a technology capable of significantly reducing power consumption by eliminating the power consumed by electronic devices in standby mode.

These technologies enable circuits to become highly reliable, which is important for the commercialization of spintronics logic integrated circuits. Both NEC and Tohoku University will continue research and development with the goal of commercializing these circuits in the near future.

NEC and Tohoku University plan to present these results at the VLSI Circuit Symposium 2012, an international academic meeting held between Tuesday,

June 12 and Saturday, June 16 in Honolulu, Hawaii.

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*1: “Spin” is one of the properties of electrons (an elementary particle with negative electric charge) that makes them behave like tiny magnets.

*2: “Non-volatility” means that even if the power is turned off, the properties of the elements (data) will still be retained when the power is turned back on.

*3: A “vertical domain wall element” is an element where the structure and materials of the circuit have been optimized so that the magnetism from tiny magnets is perpendicular to the electrical current.

*4: Possible causes of errors include such things as cosmic rays, high and low temperatures, and fluctuations in the write voltage or the write current.

*5: It was not possible to avoid higher design costs and chip costs in order to completely eliminate the possibility of data errors occurring in non-volatile logic integrated circuits.

*6: The Funding Program for World-Leading Innovative R&D on Science and Technology is a national project with the goal of improving Japan’s international competitiveness by selecting core researchers in cutting-edge technologies and then pursuing research and development centered on these core researchers.

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