Device controls, measures spin current injected into semiconductor material

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An international research team formed by physicists from Hitachi, the University of Cambridge and University of Nottingham in the UK, Charles University in the Germany, the Institute of Physics (ASCR), in the Czech Republic, and the Texas A&M University, have successfully developed the technology that enables control and measurement of spin current, a magnetic characteristic of electrons, in the same way as electrical current, using a gallium-arsenide semiconductor material.

In contrast to electronics technology which led industrial development in the 20th century and is based on the flow of electron charge (electric current), this technology is an achievement which leads the way in spintronics which is based on the other basic attribute of an electron, its spin. This technology is expected to contribute to significant energy conservation and increased functionality in social infrastructure, quantum computing and new directions in scientific development. The results of this development will be published in the 24th December 2010 edition of *Science*.

Since the development of the transistor in the 1940s, the operation of electronic devices which contributed to the advancement of the electronics industry have utilized physical principles to electrically manipulate and measure the charge of electrons (electric current). Meanwhile, on the other hand, the electron has another basic attribute, its elementary magnetic moment so-called spin. The application of spintronics based on the manipulation of the spin of an electron is highly expected to open the way to new low-power consuming electronics, hybrid electric-magnetic systems and devices with completely new functionalities. The theory of electrically controlling and measuring the spin of an electron was proposed 20 years ago in the area of spin-transistors. However, many fundamental and critical issues in spintronics such as spin-injection, generation of pure spin-current, spin-manipulation and spin observation needed to be achieved to verify this theory. Until the present time, there have been no demonstration to manipulate spin current in the same way as electrical current or the measurement thereof.

In response to this need, Hitachi and international research team measured separately an up and down spin (Spin-Hall Effect) at an extremely low temperature of -269°C in a gallium-arsenide semiconductor, a non-magnetic material in 2005. Further in 2009, using the same gallium arsenide semiconductor at a temperature of -53°C, the team measured the flow of spin polarized current over a distance of a few microns (Spin-injection Hall effect). In the current development, the up or down spin was controlled by a gate voltage, and the successful ON/OFF operation as a transistor have been verified. In this experiment, a circularly polarized light was used to generate pure spin current in the semiconductor. If we can develop spin-injection technology for ferromagnetic material, the spintronics device which was proposed as a theory by Supriyo Datta & Biswajit A. Das in 1990, will be realized. Further, realizing a solid device which can control and detect the polarization of the light, a new dimension of light polarization can be employed as information in future optical communication to open the way for even larger capacity information transmission systems, or in new analytical systems to which use the polarization of light to study the characteristics of biological or molecular material.

The device consists of a planar photodiode with a pn-junction diode and a n-type channel which forms the Hall Bar. By shining light on the diode, photo-excited electrons generated by the photovoltaic effect are injected into the device. The degree of circular polarization of the incident light is used to generate the spin-polarized electrons. The injected spin precede as a spin-current (Spin-injection Hall effect). At this point, if a p-type electrode is formed above the n-type channel and a voltage is applied, according to quantum relativistic effects, the precession of the spins are controlled by the input gate-electrode voltages. These effects are also responsible for the onset of transverse electrical voltages in the device, which represent the output signal, dependent on the local orientation of precessing electron spins.

Provided by Hitachi

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