FOR IMMEDIATE RELEASE

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Hitachi, Ltd.
Hitachi Europe, Ltd.

Development of a device enabling control & measurement of spin current injected into semiconductor material

- Leading the way in spintronics to control spin current in the same way as electrical current -

Tokyo, 24th December 2010 --- The Hitachi Cambridge Laboratory of Hitachi Europe Ltd., a research center of Hitachi, Ltd. (NYSE : HIT/TSE : 6501) based in Europe (hereafter, Hitachi), today announced that 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 in the US (hereafter, the international team), have successfully developed the technology 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[*1] 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[*2] (Spin-Hall Effect[*3]) 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[*4]). 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[*5] 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 Spin-Hall Effect transistor developed

The device consists of a planar photodiode with a pn-junction[*6] diode and a n-type channel which forms the Hall Bar[*7]. By shining light on the diode, photo-excited electrons[*8] 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[*9], 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.

Notes

*1 Spintronics: An area of technology which uses both the electrical (electron) and magnetic (spin) characteristics of an electron.

*2 Up and down spin: Apart from electronic charge, an electron has an attribute of the elementary magnetic moment, the so-called spin. Spin has two directions, up or down.

*3 Spin Hall effect: The phenomena that up and down spins are separately accumulated along the edges of an electric current, when electrons flow through material with spin-orbit interaction. The spin-Hall effect was independently observed in 2004 for the first time in the world by the Hitachi Cambridge international research team and a research team at the University of California, San Diego.

*4 Spin Injection Hall effect: A method using the spin-Hall effect to detect up and down spins which are excited in semiconductor material by left or right polarized light.

*5 Polarization of light: Light is an electromagnetic wave which propagates in space. The polarization of light is the orientation of electromagnetic wave's oscillations in the plane perpendicular to a transverse wave's direction of travel. In this experiment, circular-polarized light was used. Circular-polarized light propagates as the orientation of oscillations rotates. There are two types of circular polarization light; right or left circular polarization which have a different rotation direction of the vector orientation of electromagnetic wave's oscillation.

*6 pn junction: Charge current is generated by the movement of electrons or holes. In a p-type semiconductor, the hole is the carrier which transports electric charge. In a n-type semiconductor, the electron is the carrier. A pn junction is a region where the p-type and n-type semiconductors are connected.

*7 Hall Bar: A device to measure the Hall Effect (in this case the Spin Hall Effect)

*8 Photo-voltaic effect: The phenomena that electric current is generated by light illumination to a pn junction.

*9 Quantum-relativistic effects: In this release, it refers to the spin-orbit interaction. In a material with spin orbit interaction, although the material is not subject to a magnetic field, electrons which move perpendicular to the electric field appear to also be influenced by an magnetic field. The spin is affected by this, and depending on the orientation of spin, the direction of electron orbit is deflected. Spin orbit interaction is the key to operating this device.

About Hitachi Europe Ltd.

Hitachi Europe Ltd., is a wholly owned subsidiary of Hitachi, Ltd., Japan. Headquartered in Maidenhead, UK, it has operations in 11 countries across Europe, the Middle East and Africa and employs approximately 460 people. Hitachi Europe comprises of nine business areas: air conditioning and refrigeration systems; digital media and consumer products; display products; industrial systems; power devices and procurement and sourcing. Hitachi Europe also has three Research and Development laboratories and a Design Centre. For more information about the company, please visit http://www.hitachi.eu

About Hitachi, Ltd.

Hitachi, Ltd., (NYSE:HIT / TSE:6501), headquartered in Tokyo, Japan, is a leading global electronics company with approximately 360,000 employees worldwide. Fiscal 2009 (ended March 31, 2010) consolidated revenues totaled 8,968 billion yen ($96.4 billion). Hitachi will focus more than ever on the Social Innovation Business, which includes information and telecommunication systems, power systems, environmental, industrial and transportation systems, and social and urban systems, as well as the sophisticated materials and key devices that support them. For more information on Hitachi, please visit the company's website at http://www.hitachi.com.

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