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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

London, 24 December 2010 --- Hitachi Europe, Ltd. (hereafter Hitachi) today announced that an international research team formed by physicists from the Hitachi Cambridge Laboratory of Hitachi Europe Ltd. (henceforth Hitachi Europe), the University of Cambridge and the University of Nottingham in the UK, the Institute of Physics of the Academy of Sciences (henceforth, ASCR) and Charles University of the Czech Republic, and the Texas A&M University in the US, using gallium-arsenide semiconductor material, have successfully developed technology to enable the control and measurement of spin current in the same way as electrical current. Electronic devices such as information processing, semiconductor, storage and power devices which have been the driving force in the rapid advancement of industry, social infrastructure, lifestyle and science in the 20th century, have based on detecting the basic attribute of the “charge” of an electron. The technology developed is a new concept based on the second basic attribute of an electron which is its elementary magnetic moment, the so-called “spin,” and is opening the door to a new era of spintronics. The results of this study will be published in the December 24 edition of Science.

Sixty years after the development of the transistor by William Shockley in 1948, the operation of solid state electronic devices have utilized physical principles to electrically manipulate and measure the charge of electrons. The new science and technology field of spintronics which is based on the other basic attribute of an electron, its elementary magnetic moment, the so-called “spin,” has been an area which has attracted high expectations as when it is realized will open the way to new low-power consuming electronics, hybrid electric-magnetic systems and 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. Until the present time, however, there have been no experiments to manipulate spin current in the same way as electrical current or the measurement thereof.

In 2005, the international research team and Hitachi, were able to measure separately an up and down spin*1 (Spin-Hall effect*2) at an extremely low temperature of -269°C in a gallium-arsenide semiconductor, a non-magnetic material. Further, in 2009, using the same gallium arsenide semiconductor at a temperature of -53°C, they measured the flow of spin polarized current over a distance of a few microns (Spin-injection Hall effect*3). In the current development, the up or down spin was controlled by a gate voltage, and the ON/OFF operation as a transistor verified. In this development, a circularly polarized light*4 was used to generate pure spin current in the semiconductor however when in the future, spin-injection technology for ferromagnetic material is developed, the all solid spintronics device which was proposed as a theory by Supriyp Datta & Biswajit A. Das in 1990, will be achieved. Further, in 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*5 diode and a n-type channel which forms the hole bar. By shining light on the diode, photo-excited electrons*6 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*7, 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 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.

*2 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.

*3 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.

*4 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.

*5 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.

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

*7 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 moves 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

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 components and equipment; manufacturing systems; information systems; power and 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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