Division of Materials Chemistry
- Nanospintronics -

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Scope of Research

The conventional electronics utilizes only the “charge” of electrons, while the traditional magnetic devices use only “spin” degree of freedom of electrons. Aiming at the complete control of both charge and spin in single solid-state devices, a new field called *spintronics* is rapidly developing and impacting on information technology. By combining the atomic-layer deposition with nanofabrication, we focus on the development of spin properties of various materials and the control of quantum effects in mesoscopic systems for novel spintronics devices.

Research Activities (Year 2009)

Publications

Tanigawa H, Koyama T, Yamada G, Chiba D, Kasai S, Fukami S, Suzuki T, Ohshima N, Ishiwata N, Nakatani Y, Ono T: Domain Wall Motion Induced by Electric Current in a Perpendicularly Magnetized Co/Ni Nano-Wire, *Appl. Phys. Express*, **2**, 053002 (2009).

Delmo MP, Yamamoto S, Kasai S, Ono T, Kobayashi K: Large Positive Magnetoresistive Effect in Silicon Induced By The Space-Charge Effect, *Nature*, **457**, 1112 (2009).

Presentations

High DW Velocity in Co/Ni with Perpendicular Anisotropy, Ono T, IEEE International Magnetics Conference, 5 May 2009, Sacramento, USA.

Electric Field Manipulation of Magnetic Anisotropy in Ferromagnetic Semiconductors, Chiba D, IEEE International Magnetics Conference, 5 May 2009, Sacramento, California, USA.

Current-induced Domain Wall Motion in Perpendicularly Magnetized Co/Ni Wires, Ono T, SPIE, NanoScience + Engineering, SpintronicsII, 2 August 2009, San Diego, USA.

Grants

Ono T, Invention of Anomalous Quantum Materials, Grant-in-Aid for Scientific Research in Priority Areas, 1 April 2004–31 March 2010.

Ono T, Current-induced Spin Dynamics and its Application to Spintronic Devices, Grand-in-Aid for Young Scientists (S), 1 October 2007–31 March 2012.

Kobayashi K, Generation and Detection of Quantum Correlation in Semiconductor Nanostructures, Grand-in-Aid for Young Scientists (S), 1 October 2007–31 March 2012.

Chiba D, Study on the Electric-field Manipulation of Magnetization, Grand-in-Aid for Young Scientists (A), 1 April 2009–31 March 2012.

Current-induced Domain Wall Motion in Perpendicularly Magnetized Nano-wires

Motion of the magnetic domain wall (DW) induced by electric current in magnetic wires has been widely investigated because it is regarded as an important technique for future magnetic storage application as well as it provides exciting physics relevant to the interaction between spin current and local magnetic moment. A number of experiments and theoretical works have been reported so far. Among them, the systems with in-plane magnetization like NiFe are the most intensively investigated, although only a few works using perpendicularly magnetized systems has been reported.

Recently we have proven the domain wall motion induced by electric current in a Co/Ni nano-wire with perpendicular magnetic anisotropy. We detect the DW motion electrically by using the anomalous Hall effect. According to the theoretical calculations for the perpendicular magnetized systems, the decrease of the threshold current density for the DW motion has been predicted to be realized by the control of the wire dimension. As predicted, the threshold current density for the domain wall motion was found to decrease with decreasing the wire width. The observed behavior is consistent with the theory based on the spin transfer model and, therefore, our results are significant for future device application using DWs as well as understanding the physics of the current induced DW motion in perpendicularly magnetized materials.

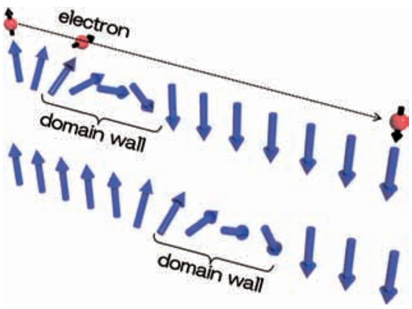

Figure 1. Schematic picture of the current-induced DW motion. The interaction between the conduction electrons and the DW plays the central role, which is called the spin-transfer torque.

New Feature of the Semiconductor Leader: Large Magnetoresistance in Silicon

Because silicon is one of the most intensively studied materials, on which the modern technology has been founded, one might think that no phenomenon remains to be discovered in it. Nevertheless, here, we report a new property of silicon; in a high electric field silicon shows large positive magnetoresistance between 0 T and 3 T more than 1,000 % at room temperature and 10,000 % at 25 K (see Figures in the bottom). The experiment on the lightly doped silicon reveals that when the carrier density decreases below ~10^{13} cm^{-3} the magnetoresistance exhibits linear dependence on the field between 3 T and 9 T in high electric fields. We propose that because of the quasi-neutrality breaking in the space charge effect, where no sufficient charge is present to compensate the electrons injected into the device, the electron motion becomes correlated with each other via the unscreened Coulomb interaction and thus the inhomogeneity is induced in silicon, yielding the unconventional non-saturating magnetoresistance as in the inhomogeneous semiconductors.

While large positive magnetoresistance at room temperature was achieved in the metal-semiconductor hybrid devices, it is now realized in a simpler structure in a way different from other known magnetoresistive effects. This novel effect can be utilized to develop new magnetic devices from silicon, which is expected to further advance the current silicon technology.

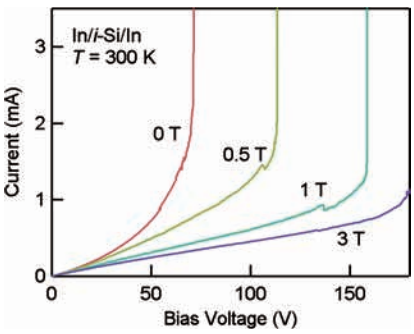

Figure 2. Large positive magnetoresistance in silicon induced by the space charge effect at room temperature.

Awards

Kobayashi K, the 3rd Young Scientist Award of the Physical Society of Japan, Experimental Study on the Controlling of the Coherence and the Many-body Effects of Electrons in Semiconducting Mesoscopic Systems, Physical Society of Japan, 28 March 2009.

Ono T, the 27th Osaka Science Prize, Pioneering Work on the Magnetization Control by Electric Currents, Osaka Prefecture, Osaka City and Osaka Science & Technology Center, 11 September 2009.

Kasai S, Nakano K, Kondou K, Ohshima N, Kobayashi K, Ono T, MSJ Distinguished Paper Award, Time-resolved measurement of the Magnetic Vortex Core Dynamics by Using the TMR Effect, the Magnetic Society of Japan, 13 September 2009.

Chiba D, the 4th Condensed-Matter Science Prize, Experimental Study on the Electric Field Effect in Ferromagnetic Semiconductors, 29 November 2009.