Division of Materials Chemistry
- Nanospintronics -

http://ssc1.kuicr.kyoto-u.ac.jp/english/index_e.html

Prof
ONO, Teruo
(D Sc)

Assoc Prof
KOBAYASHI, Kensuke
(D Sc)

Assist Prof
KASAI, Shinya
(D Sc)

Techn
KUSUDA, Toshiyuki

Students

HIMENO, Atsushi (D3)
WARNICKE, Peter (D3)
TANIGAWA, Hironobu (D1)
HASHISAKA, Masayuki (D1)
DELMO, Michael Picazo (M2)
TAMADA, Yoshinori (M2)
YANO, Kuniaki (M2)
INOUE, Takanori (M1)
KONDOU, Kouta (M1)
NAKAMURA, Shuji (M1)
YAMADA, Keisuke (M1)

Visitors

Prof NAKATANI, Yoshinobu	University of Electro-Communications, Japan, 28 April 2006
Prof THIAVILLE, André	Université Paris-sud, France, 30 May–31 August 2006
Dr PIODA, Alessandro	University of Tokyo, Japan, 30 November 2006

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 2006)

Presentations

$L1_0$-FePt Nanoparticles Synthesized via SiO_2-nanoreactor Method, Ono T, 10th MORIS, 6–8 June 2006, Tomiura, Chiba, Japan.

Mesoscopic Fano Effect in Quantum Hybrid Systems, Kobayashi K, Vietnam 2006: 6th Rencontres du Vietnam “Nanophysics: from Fundamentals to Applications”, 8 August 2006, Hanoi, Vietnam.

Excitation of Nano-spin-structure by Spin-polarized Current, Ono T, International Conference on Magnetism, 20–25 August 2006, Kyoto, Japan.

Magnetic Ratchet Effect in Submicron Magnetic Wires with Asymmetric Notches, Himeno A, Kasai S, and Ono T, Gordon Research Conferences (Magnetic Nanostructures), 3–8 September 2006, Oxford, UK.

Excitation of Spin-structure in Nano-magnet by Electrical Current, Ono T, 378th International Wilhelm and Else Heraeus Seminar –Spin Torque in Magnetic Nanostructures–, 22–26 October 2006, Rhöndorf, Germany.

Grants

Ono T, Control of Physical Properties by Utilizing Spin-polarized Current, Grant-in-Aid for Scientific Research (A), 1 April 2005–31 March 2008.

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

Ono T, Development of Writing Technology for Gbit-MRAM by Using Current-driven Domain Wall Motion, Industrial Technology Research Grant Program from NEDO, 1 January 2005–31 December 2007.

Ono T, Magneto-transport Engineering by Spin-polarized Current, The Asahi Glass Foundation, 1 April 2005–31 March 2008.

Award

Himeno A, Best Poster Award at the 17th International Conference on Magnetism (ICM), August 20–25 2006, Kyoto, Japan.

Resonant Excitation of the Magnetic Vortex Core

Manipulation of the magnetization by spin currents is a key technology for future spintronics. Underlying physics is that spin currents can apply a torque on the magnetic moment when the spin direction of the conduction electrons has a relative angle to the local magnetic moment. This can be generalized to the idea that any kind of spin structure with spatial variation can be excited by a spin-polarized current in a ferromagnet.

A typical example of such a non-collinear spin structure is a curling magnetic structure (magnetic vortex), which appears in a ferromagnetic circular dot. Here we demonstrate that a magnetic vortex core can be resonantly excited by an AC current through a ferromagnetic circular dot when the current frequency is tuned to the eigenfrequency originating from a confinement of a vortex core in a dot. Our micromagnetic simulations with the spin-transfer effect reveal the detailed motion during the excitation; an excited vortex core draws a spiral trajectory to settle in a steady orbital around the dot centre. We succeeded in detecting the predicted resonance by resistance measurements. We found the efficient excitation by an electric current due to the resonance nature and the tunability of the resonance frequency by dot shape, which opens up the potentiality of a simple magnetic dot as a building block for spintronic devices and a rotary actuator for nano-mechanical systems.

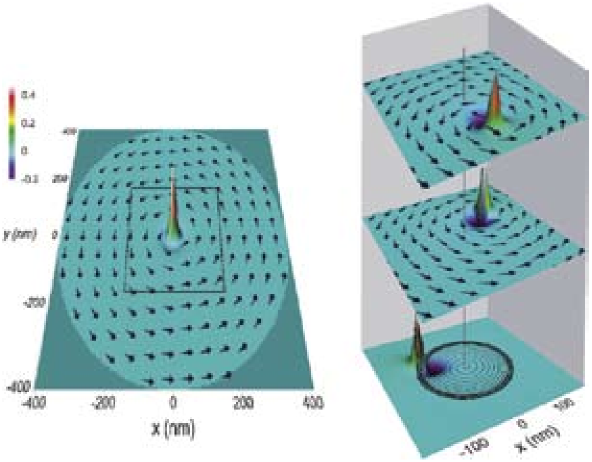

Figure 1. Time evolution of the vortex under the AC current application. Magnetization direction $\boldsymbol{m} = (m_x, m_y, m_z)$ inside the dot on the *xy* plane was obtained by micromagnetic simulation. The 3D plots indicate m_z with the $m_x - m_y$ vector plots superimposed. The plot on the left represents the initial state of the vortex core situated at the center of the dot with $r = 410$ nm. The 3D plots on the right show the vortex on the steady orbital at $t = 80.6$, 81.5, and 82.3 ns after applying the AC current.

Spin Injection into the Superconductor

The efficient spin injection, accumulation and transport in solid state devices are the central issue in both fundamental and technological points of view. In general, the spin polarized electrons injected from the ferromagnets (*F*) into the nonmagnetic materials (*N*) such as normal metals, semiconductors, and superconductors (*SC*) create nonequilibrium spin accumulation in *N*. The spin accumulation plays an important role in the field of spintoronics which will be realized by manipulating the spin degree of freedom of electrons.

Recently it was reported that a spin accumulation signal was detected in a lateral $Ni_{80}Fe_{20}/Cu/Ni_{80}Fe_{20}$ spin valve device by using a non-local spin transport measurement. However, the possible spin accumulation in *SC*'s still remained to be explored, which is stimulating because the strong competition between superconductivity and magnetism is induced by artificial spin polarization in *SC*'s. Theoretically, the non-local spin signal is greatly enhanced when *N* falls into the superconducting state below its transition temperature (T_C). This enhancement is due to the fact that *SC* is a low-carrier system for spin transport but not for charge transport.

We addressed the issue by using the tunnel-junction *F*/*SC*/*F* spin valve structure with the non-local measurement technique. By injecting an appropriate current, the spin signal was observed to be several times larger in the superconducting state than in the normal state, consistent with the theoretical prediction.

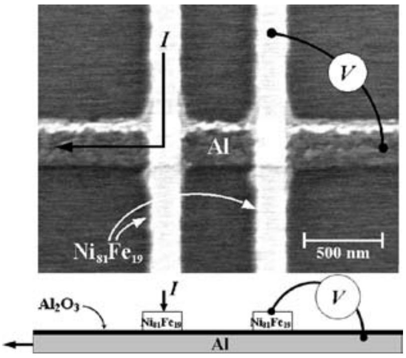

Figure 2. (Top) Scanning electron microscope image of a lateral spin valve device, with the geometry of the non-local measurement. (Bottom) Device cross-section.

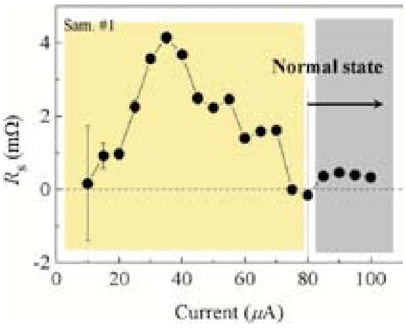

Figure 3. Current dependence of the non-local spin accumulation signal R_S at the superconducting state (at low current regime), showing the enhancement of the spin signal compared to that at the normal state (at high current regime).