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 2008)

Publication

Tanigawa H, Koyama T, Bartkowiak M, Kasai S, Kobayashi K, Nakatani Y, Ono T: Dynamical Pinning of a Domain Wall in a Magnetic Nanowire Induced by Walker Breakdown, *Physical Review Letters*, **101**, 207-203 (2008).

Presentations

Current-induced Spin Dynamics in Nanomagnet, Ono T, International Workshop on "SPIN CURRENT 2008", 18–19 February 2008, Sendai, Japan.

Detection of Shot Noise in Coupled Mesoscopic Systems, Kobayashi K, International Workshop "Interaction and Interference in Nanoscopic Transport",18–23 February 2008, Dresden, Germany.

Coherence and Correlation of Electrons in Quantum Hybrid Systems, Kobayashi K, Moriond 2008, "Quantum Transport and Nanophysics", 8–15 March 2008, La Thuile, Italy.

Current-induced Resonant Motion of the Magnetic Vortex Core in a Ferromagnetic Circular Disk, Kasai S, International Magnetic Conference "Intermag Europe 2008", 4–8 May 2008, Madrid, Spain.

Current-induced Vortex Core Motion in Magnetic Disk, Ono T, Moscow International Symposium on Magnetism, 20–25 June 2008, Moscow, Russia.

Current-induced Magnetization Dynamics in Nanomagnet, Ono T, The 5th Asia Forum on Magnetics, 16–19 October 2008, Beijing, China.

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

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

Kobayashi K, Generation and Detection of Quantum

Real-time Imaging of the Current-driven Vortex-core Motion

Manipulating magnetization by spin currents is attracting scientific interest both due to the intricate physics involved in the interaction between the flowing spins and the localized spins that constitute magnetization and the technological potential to control future nanoscale spintronics devices. Since the efficiency of this spin torque effect is proportional to the spin-polarization of the current flowing in the ferromagnetic material an experimental quantification of the spin-polarization is of paramount importance. So far, the indirect methods used, i.e. transport measurements, such as tunneling spectroscopy, Andreev reflection, and giant magnetoresistance measurements have not shown conclusive results. Recently by using the at beamline 6.1.2 at the Advanced Light Source (ALS) in Berkeley we succeeded in a direct determination of the spin-polarization of the currents from quantitative high resolution X-ray imaging of the current-induced circular motion of a vortex core in a ferromagnetic disk (Figure 1). We are able to watch the motion of the core position with better than 25 nm spatial resolution with a 70 ps time resolution over a period of several nano-seconds. The spin-polarization of the current is determined to be 0.67 for Permalloy ($Fe_{19}Ni_{81}$), which is in excellent agreement with an analytical model in the framework of the spin transfer torque.

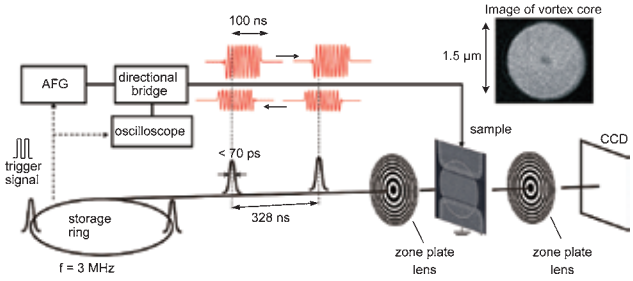

Figure 1. Schematic illustration of the experimental setup for imaging the spin dynamics by time- and space-resolved magnetic soft X-ray microscopy of the vortex core motion in a Permalloy disk (diameter: 1.5 μm; thickness: 40 nm).

New Scheme for the Quantum Noise Detection: Mesoscopic Bolometry

Coupled mesoscopic systems offer exciting opportunities to generate and control quantum correlations between electrons, which constitute an important step towards the integration of quantum optics and electronics. To explorer the interaction mediated by photons is one of the most imperative issues because well-prepared photons can link separate systems quantum-mechanically and, otherwise, they undesirably disturb the quantum state. We present a new scheme to detect the photon exchange between the systems by means of the precise noise thermometry; in the coupled quantum point contacts (QPC) we prove that the temperature of one QPC, where the single quantized conducting channel works as a photon detector, is in perfect proportion to that of the other QPC which is driven to non-equilibrium to emit photons (Figure 2). The present on-chip bolometry opens up a new way for the detection of the quantum correlation created by photons and for the attractive ultra-precise measurements such as the bolometric photon counting and the advanced metrology.

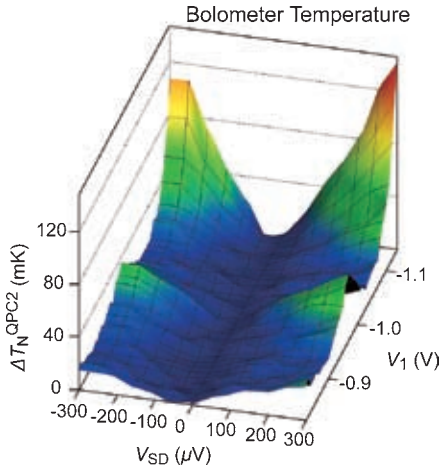

Figure 2. The experimental result of the bolometric detection of the quantum noise is shown in 3D image plot.

Correlation in Semiconductor Nanostructures, Grant-in-Aid for Young Scientists (S), 1 October 2007–31 March 2012.

Awards

Ono T, FFIT Prize, Development of the Magnetization Control Technology by Electric Currents, Funai Foundation for Information Technology, 19 April 2008.

Ono T, The 10th Sir Martin Wood Prize, Magnetization Control in Nano-Magnets by Electric Currents, Millennium Science Forum, 12 November 2008.

Ono T, Japan IBM Prize, Research on the Magnetization Control by Spin-polarized Currents, 26 November 2008.

Kasai S, Young Author Presentation Awards, Time-resolved Measurement of the Current-induced Vortex Core Dynamics in a Ferromagnetic Circular Disk, The Japan Society of Applied Physics, 29 March 2008.

Hashisaka M, IUPAP Young Author Best Paper Awards, Bolometric Shot Noise Detection in Coupled Quantum Point Contacts, The 29th International Conference on the Physics of Semiconductors, 1 August 2008.