Division of Materials Chemistry
- Nanospintronics -

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Visitors

Dr LETURCQ, Renaud	Solid State Physics Laboratory, ETH, Switzerland, 15–16 February 2007
Dr OHE, Junichiro	Hamburg University, Germany, 25 October 2007

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 2007)

Publications

Yamada K, Kasai S, Nakatani Y, Kobayashi K, Kohno H, Thiaville A, Ono T: Electrical Switching of the Vortex Core in a Magnetic Disk, *Nature Materials*, **6**, 269-273 (2007).

Tamada Y, Yamamoto S, Takano M, Nasu S, Ono T: Well-ordered $L1_0$-FePt Nanoparticles Synthesized by Improved SiO_2-nanoreactor Method, *Applied Physics Letters*, **90**, 162509 (2007).

Presentations

Excitation of Spin-structure in Nano-magnet by Electrical Current, Ono T, 7th Symposium on the Electron Spin Science and Engineering, 22–24 February 2007, Daemyung, Korea.

Excitation of Nano-spin-structure by Electric Current, Ono T, International Conference on Nanospintronics Design and Realization, 21–25 May 2007, Dresden, Germany.

Magnetic Vortex Excitation by Spin-polarized Currents, Kasai S, 6th International Symposium on Metallic Multilayers, 16 October 2007, Perth, Australia.

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

Awards

Ono T, Ichimura Academic Award, Pioneering Research on the Nanoscopic Spin-structure Control in Nanofabricated Magnets, The New Technology Development Foundation, 27 April 2007.

Electrical Switching of the Vortex Core

A magnetic vortex is a curling magnetic structure realized in a ferromagnetic disk, which is a promising candidate for a memory cell for future non-volatile data-storage devices. Thus, an understanding of the stability and dynamical behavior of the magnetic vortex is a major requirement for developing magnetic data-storage technology. Since the publication of experimental proof for the existence of a nanometer-scale core with out-of-plane magnetization in a magnetic vortex, the dynamics of vortices have been investigated intensively. However, a way to electrically control the core magnetization, which is a key for constructing a vortex-core memory, has been lacking. Here, we demonstrate the electrical switching of the core magnetization by using the current-driven resonant dynamics of the vortex; the core switching is triggered by a strong dynamic field that is produced locally by a rotational core motion at a high speed of several hundred meters per second (Figure 1). Efficient switching of the vortex core without magnetic-field application is achieved owing to resonance. This opens up the potentiality of a simple magnetic disk as a building block for spintronic devices such as a memory cell where the bit data is stored as the direction of the nanometer-scale core magnetization.

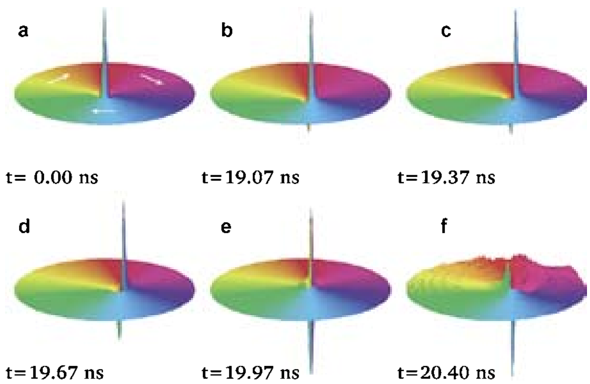

Figure 1. Perspective view of the magnetization with a moving vortex structure. After the electric pulse is applied to the initial status (a), the vortex core starts to rotate and finally reverses its direction in 20 ns (b-f).

Toward Pure Nanomagnets

Iron-Platinum (FePt) nanoparticles have been expected as a promising candidate for the future recording media with ultra-high densities beyond 1 Tbit/inch^2, as the FePt alloy with the $L1_0$ structure possesses high enough magnetic anisotropy to suppress super-paramagnetic fluctuation down to a particle size of about 3 nm. Recently, we have obtained the $L1_0$-FePt nanoparticles by developing a new synthetic "SiO_2-nanoreactor" method. However, the annealing condition in this method still suffered from the presence of the unconverted fcc-FePt nanoparticles that are super-paramagnetic at room temperature. For the practical applications in the magnetic recording media, it is highly desired that all nanoparticles possess well-ordered $L1_0$ structure. We have optimized the annealing condition and successfully achieved the well-ordered $L1_0$-FePt nanoparticles. The resultant room-temperature coercivity reaches an extremely large value of 28 kOe in spite of the very small particle size of 6.7 nm in diameter (Figure 2). Microscopic characterization by the Mössbauer spectroscopy proved that the synthesized $L1_0$-FePt nanoparticles have magnetic moments comparable to that of the bulk state even at the particle surface (Figure 3).

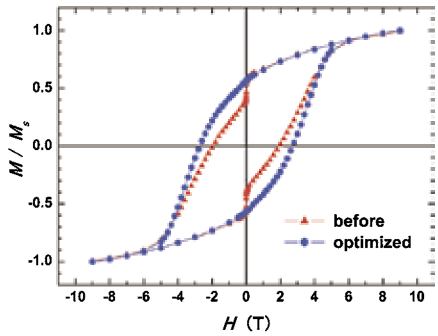

Figure 2. Hysteresis loops at 300 K of the FePt nanoparticles treated in the conventional and newly optimized annealing methods.

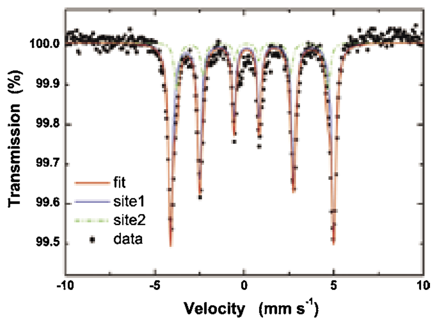

Figure 3. Mössbauer spectrum of the FePt nanoparticles treated in the optimized annealing method.

Ono T, MSJ Outstanding Research Award, "Research on the Current-driven Magnetic Domain Wall Dynamics", The Magnetic Society of Japan, 12 September 2007.

Morimoto Y, Tamada Y, Yamamoto S, Takano M, Ono T, MSJ Distinguished Paper Award "Detailed Study on the Structure and Magnetic Property of the Well-ordered $L1_0$-FePt Nanoparticles Synthesized by SiO_2-nanoreactor Method", The Magnetic Society of Japan, 12 September 2007.