Division of Materials Chemistry
– Nanospintronics –

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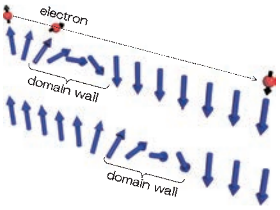
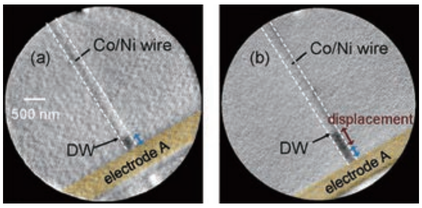
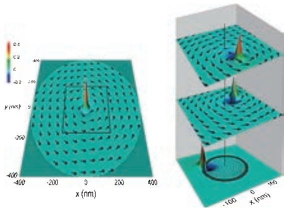
Scope of Research

Conventional electronics uses only the charge of electrons, while traditional magnetic devices use only the spin degree of freedom of electrons. Aiming at complete control of both charge and spin in single solid-state devices, an emerging field called spintronics is rapidly developing and having an impact on information technologies. 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.







Selected Publications

Kim, K.-J.; Kim, S. K.; Hirata, Y.; Oh, S.-H.; Tono, T.; Kim, D.-H.; Okuno, T.; Ham, W.; Kim, S.; Go, G.; Tserkovnyak, Y.; Tsukamoto, A.; Moriyama, T.; Lee, K.-J.; Ono, T., Fast Domain Wall Motion in the Vicinity of the Angular Momentum Compensation Temperature of, *Nat. Mater.*, doi: 10.1038/nmat4990 (2017).

Kim, S.; Jang, P.; Kim, D.; Ishibashi, M.; Taniguchi, T.; Moriyama, T.; Kim, K.; Lee, K.; Ono, T., Magnetic Droplet Nucleation with a Homochiral Neel Domain Wall, *Phys. Rev. B*, **95,** 220402 (2017).

Kim, S.; Chris, S.; Ishibashi, M.; Yamada, K.; Taniguchi, T.; Okuno, T.; Kotani, Y.; Nakamura, T.; Kim, K.; Moriyama, T.; Park, B.; Ono, T., Contributions of Co and Fe Orbitals to Perpendicular Magnetic Anisotropy of MgO/CoFeB Bilayers with Ta, W, IrMn, and Ti Underlayers, *Applied Physics Express*, **10,** 073006 (2017).

Ham, W.; Kim, S.; Kim, D.; Kim, K.; Okuno, T.; Yoshikawa, H.; Tsukamoto, A.; Moriyama, T.; Ono, T., Temperature Dependence of Spin-orbit Effective Fields in Pt/GdFeCo Bilayers, *Appl. Phys. Lett.*, **110,** 242405 (2017).

Kakizakai, H.; Yamada, K.; Ando, F.; Kawaguchi, M.; Koyama, T.; Kim, S.; Moriyama, T.; Chiba, D.; Ono, T., Influence of Sloped Electric Field on Magnetic-field-induced Domain Wall Creep in a Perpendicularly Magnetized Co Wire, *Jpn. J. Appl. Phys.*, **56,** 050305 (2017).

Kim, K.; Yoshimura, Y.; Ham, W.; Ernst, R.; Hirata, Y.; Li, T.; Kim, S.; Moriyama, T.; Nakatani, Y.; Ono, T., Energy-efficient Writing Scheme for Magnetic Domain-wall Motion Memory, *Applied Physics Express*, **10,** 043002 (2017).

Modulation of the Magnetic Domain Size Induced by an Electric Field

The electric field (EF) control of magnetism has intensively investigated because of its potential importance for the reduction of power consumption in magnetic storage devices. In the past few years, we have been focusing on the electric field modulation of the magnetic anisotropy and the Curie temperature in magnetic thin films. However, the microscopic mechanism of why those magnetic properties change with an electric field were not clear in spite of several theoretical suggestions. In this work, we particularly focused on the configuration of the magnetic domains upon the application of the electric field (see Figure 1a for the detail measurement setup). With the electric field of ±10V, we observed the significant change in the domain size (Figure 1b). Detail analyses on the modification of the magnetic domain size revealed that it is the exchange interaction that is modulated with the electric field and is changing about 50% with ±10V. Our results suggest that the EF control of the magnetism is mainly driven by the modification of the exchange interaction which is a fundamental measure determining the magnetic interaction between microscopic spins.

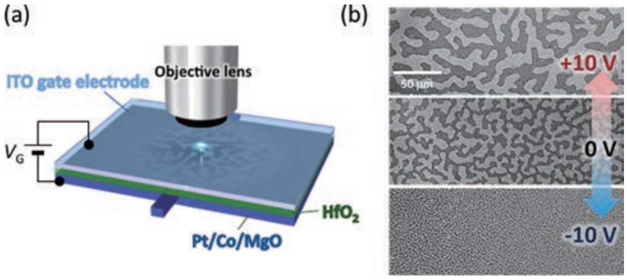


Figure 1. (a) Schematic illustration of the experimental setup (b) Modulation of the magnetic domain size with the electric field of ±10V.

Ultrafast Domain Wall Motion in Ferrimagnetic Materials

Antiferromagnetic spintronics is an emerging research field which aims to utilize antiferromagnets as core elements in spintronic devices. A central motivation towards this direction is that antiferromagnetic spin dynamics is expected to be much faster than its ferromagnetic counterpart. Recent theories indeed predicted faster dynamics of antiferromagnetic domain walls (DWs) than ferromagnetic DWs. However, experimental investigations of antiferromagnetic spin dynamics have remained unexplored, mainly because of the magnetic field immunity of antiferromagnets. Here we show that fast field-driven antiferromagnetic spin dynamics is realized in ferrimagnets at the angular momentum compensation point T_A. Using rare earth–3d-transition metal ferrimagnetic compounds where net magnetic moment is nonzero at T_A, the field-driven DW mobility is remarkably enhanced up to $20\,\mathrm{km\,s^{-1}\,T^{-1}}$. The collective coordinate approach generalized for ferrimagnets and atomistic spin model simulations show that this remarkable enhancement is a consequence of antiferromagnetic spin dynamics at T_A. Our finding allows us to investigate the physics of antiferromagnetic spin dynamics and highlights the importance of tuning of the angular momentum compensation point of ferrimagnets, which could be a key towards ferrimagnetic spintronics.

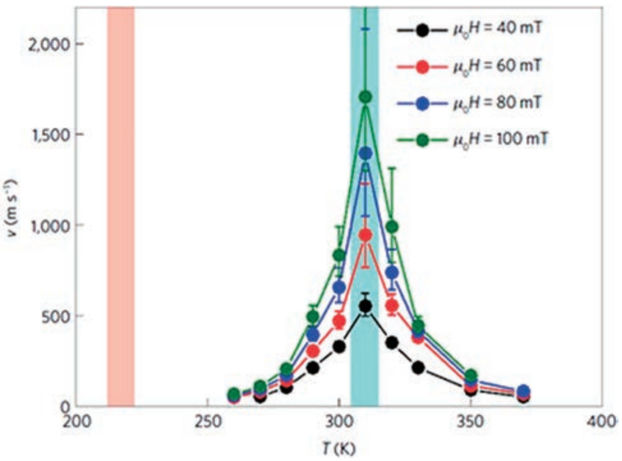


Figure 2. DW speed v as a function of temperature T for several driving fields. v diverges at T_A.