Division of Materials Chemistry
– Nanospintronics –

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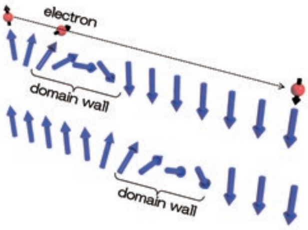
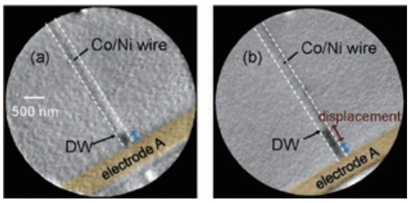
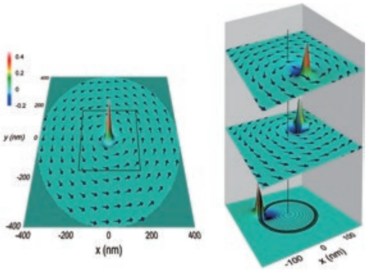
Scope of Research

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.

KEYWORDS
Spintronics
Quantum Transport
Nano-fabrication
Artificial Materials







Selected Publications

Moriyama, T.; Takei, S.; Nagata, M.; Yoshimura, Y.; Matsuzaki, N.; Terashima, T.; Tserkovnyak, Y.; Ono, T., Anti-damping Spin Transfer Torque through Epitaxial Nickel Oxide, *Appl. Phys. Lett.*, **16,** 162406 (2015).
Yoshimura, Y.; Kim, K.-J.; Taniguchi, T.; Tono, T.; Ueda, K.; Hiramatsu, R.; Moriyama, T.; Yamada, K.; Nakatani, Y.; Ono, T., Soliton-like Magnetic Domain Wall Motion Induced by the Interfacial Dzyaloshinskii-Moriya Interaction, *Nat. Phys.*, **12,** 157-161 (2016).
Matsuo, S.; Takeshita, S.; Tanaka, T.; Nakaharai, S.; Tsukagoshi, K.; Moriyama, T.; Ono, T.; Kobayashi, K., Edge Mixing Dynamics in Graphene p–n Junctions in the Quantum Hall Regime, *Nat. Commun.*, **6,** 8066 (2015).
Stigloher, J.; Decker, M.; Korner, H. S.; Tanabe, K.; Moriyama, T.; Taniguchi, T.; Hata, H.; Madami, M.; Gubbiotti, G.; Kobayashi, K.; Ono, T.; Back, C. H., Snell's Law for Spin Waves, *Phys. Rev. Lett.*, **117,** 037204 (2016).
Ando, F.; Kakizakai, H.; Koyama, T.; Yamada, K.; Kawaguchi, M.; Kim, S.; Kim, K.-J.; Moriyama, T.; Chiba, D.; Ono, T., Modulation of the Magnetic Domain Size Induced by an Electric Field, *Appl. Phys. Lett.*, **109,** 022401 (2016).

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 Fig. 1a for the detail measurement setup). With the electric field of ±10 V, we observed the significant change in the domain size (Fig. 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 ±10 V. 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.

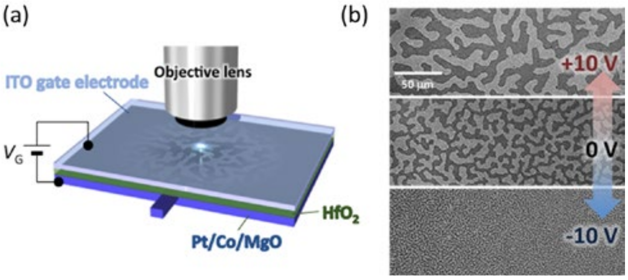


Figure 1. (a) Schematic illustration of the experimental setup (b) Modulation of the magnetic domain size with the electric field of ±10V.

Anti-damping Spin Transfer Torque through Antiferromagnetic Material

Spin transfer torque (STT) has been an efficient and promising technique to control magnetization of ferromagnetic materials in modern spintronic devices. This novel technique is based on an interaction between electron spin and local magnetic moments. The same interaction should be conserved in antiferromagnets in which there are microscopic local magnetic moments that compensate each other to exhibit no net magnetization. In this work, we prepared MgO(001) substrate / Pt 5 nm / NiO 10 nm / FeNi 3 nm / SiO_2 5 nm multilayers, in which the films are epitaxially grown until the NiO layer, and performed a spin torque ferromagnetic resonance (ST-FMR) measurement to quantify the anti-damping spin torque transported between the Pt and the FeNi through the antiferromagnetic NiO layer. A pure spin current is created by the spin Hall effect of the Pt and injected into the NiO. As shown in Figure 2(a), we found that the FMR linewidth monotonously varies with the spin current injection. As the ST-FMR measurement is only sensitive to the linewidth (i.e., magnetic damping) of the FeNi layer, this change in the linewidth in Pt/NiO/FeNi can be interpreted in a way that the spin current is transferred through the NiO and interacts with the FeNi. This intriguing spin current transport can be explained by the angular-momentum transfer mediated by the antiferromagnetic magnons as shown in Figure 2(b). Our results assure that the spin current exerts a spin torque on the NiO magnetic moments and excites their dynamics. The results open up a new field of antiferromagnetic spintronics.

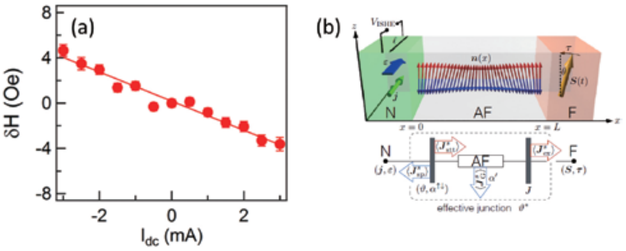


Figure 2. (a) FMR linewidth δH as a function of the dc current. Due to the spin Hall effect of Pt, the spin current injection is proportional to the dc current. (b) Schematic illustration of the N (Pt) / AF (NiO) / F (FeNi) structure in which the anti-damping spin transfer torque takes place. N (Pt) layer injects the spin current J^s_{stt} toward AF (NiO). The antiferromagnetic magnon in AF (NiO) carries the spin current J^s_{ex} toward F (FeNi).