Division of Materials Chemistry
– Nanospintronics –

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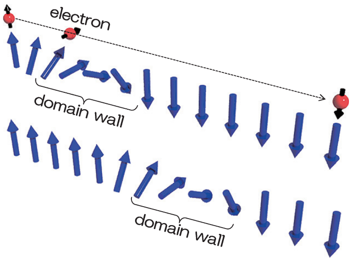
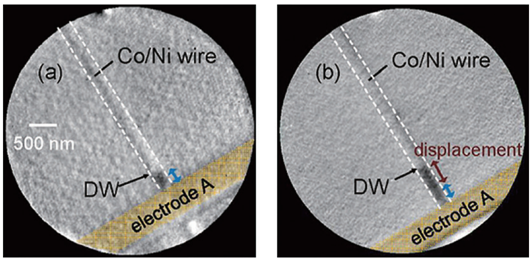
Scope of Research

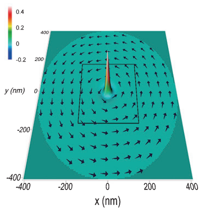
Conventional electronics uses only the charge of electrons, while traditional magnetic devices use only the spin degree of freedom of electrons. Aiming at complete control of both charge and spin in single solid-state devices, an emerging field called spintronics is rapidly developing and having an impact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

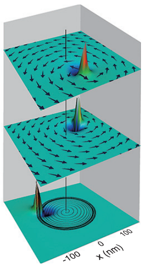
KEYWORDS

Spintronics
Magnetism
Magnetic Materials









Recent Selected Publications

Ando, F.; Miyasaka, Y.; Li, T.; Ishizuka, J.; Arakawa, T.; Shiota, Y.; Moriyama, T.; Yanase, Y.; Ono, T., Observation of Superconducting Diode Effect, *Nature*, **584,** 373-376 (2020).

Moriyama, T.; Hayashi, K.; Yamada, K.; Shima, M.; Ohya, Y.; Ono, T., Tailoring THz Antiferromagnetic Resonance of NiO by Cation Substitution, *Phys. Rev. Materials*, **4,** 074402 (2020).

Ishibashi, M.; Shiota, Y.; Li, T.; Funada, S.; Moriyama, T.; Ono, T., Switchable Giant Nonreciprocal Frequency Shift of Propagating Spin Waves in Synthetic Antiferromagnets, *Sci. Adv.*, **6,** eaaz6931 (2020).

Iwaki, H.; Kimata, M.; Ikebuchi, T.; Kobayashi, Y.; Oda, K.; Shiota, Y.; Ono, T.; Moriyama, T., Large Anomalous Hall Effect in $L1_2$-Ordered Antiferromagnetic Mn_3Ir Thin Films, *Appl. Phys. Lett.*, **116,** 022408 (2020).

Okuno, T.; Kim, D.-H.; Oh, S.-H.; Kim, S.-K.; Hirata, Y.; Nishimura, T.; Ham, W.-S.; Futakawa, Y.; Yoshikawa, H.; Tsukamoto, A.; Tserkovnyak, Y.; Shiota, Y.; Moriyama, T.; Kim, K.-J.; Lee, K.-J.; Ono, T., Spin-Transfer Torques for Domain Wall Motion in Antiferromagnetically Coupled Ferrimagnets, *Nat. Electron.*, **2,** 389-393 (2019).

Realization of the Field-Free Superconducting Diode Effect

The diode effect is fundamental to electronic devices and is widely used in rectifiers and AC–DC converters. At low temperatures, however, conventional semiconductor diodes possess a high resistivity, which yields energy loss and heating during operation. The superconducting diode effect (SDE), which relies on broken inversion symmetry in a superconductor may mitigate this obstacle: in one direction a zero-resistance supercurrent can flow through the diode, but for the opposite direction of current flow, the device enters the normal state with ohmic resistance. The application of a magnetic field can induce SDE in Nb/V/Ta superlattices with a polar structure, in superconducting devices with asymmetric patterning of pinning centres, or in superconductor/ferromagnet hybrid devices with induced vortices. The need for an external magnetic field limits their practical application. Here, we present implementation of zero-field SDE using noncentrosymmetric $[Nb/V/Co/V/Ta]_{20}$ multilayers. The magnetic layers provide the necessary symmetry breaking and we can tune the SDE by adjusting the structural parameters, such as the constituent elements, film thickness, stacking order, and number of repetitions. We control the polarity of the SDE through the magnetization direction of the ferromagnetic layers. Energy-loss-free SDEs as presented in this work may therefore enable novel non-volatile memories and logic circuits with ultralow power consumption.

Spin-Transfer-Torque-Driven Magnetic Domain Wall Motion in Antiferromagnetically Coupled Ferrimagnets

Magnetic domain wall (DW) racetrack memory is a next-generation, non-volatile and high-density magnetic memory, where the magnetic domain walls work as information bits and they are controlled by electric current via the effect of spin transfer torque (STT). However, to enhance thermal stability while keeping low driven current is difficult in traditional domain wall (DW) motion devices. The increasing of energy barrier for thermal stability inevitably results in the enhancement of driven current. We numerically investigate depinning field (H_{depin}) and critical current density (J_c) for DW motion as a function of uniaxial magnetic anisotropy (K_u) in vertical DW motion memory with artificial ferromagnet. It is found that H_{depin} and J_c show different K_u dependence. The results indicate that it is promising to simultaneously achieve high thermal stability and low driven current in artificial ferromagnet based DW motion devices.

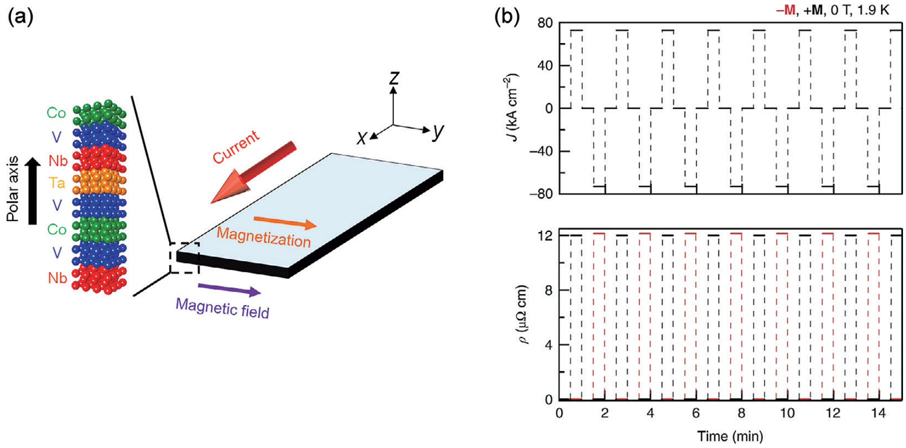


Figure 1. (a) Schematic of the SDE and measurement configuration. The magnetic field is applied perpendicular to both the polar axis and the electrical current. (b) Non-volatile SDE at 1.9 K. Red and black dots represent the results for negative magnetization (-**M**) and positive magnetization (+**M**), respectively. Current densities $J = 72.7$ kA cm^{-2} and $J = -72.7$ kA cm^{-2} at 1.9 K without a magnetic field were repeatedly applied. The device shows a superconducting state or normal conducting state depending on the polarity of the current. Note that the polarity of SDE depends on the direction of magnetization. The -**M** or +**M** state is achieved after sweeping the magnetic field in the order of +0.5, 0, −0.15, 0 T or −0.5, 0, +0.15, 0 T.

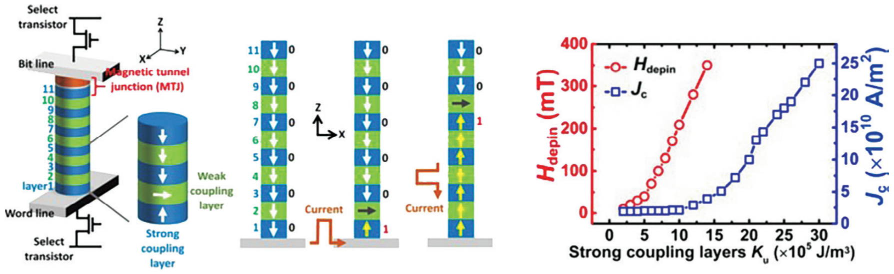


Figure 2. (a) Schematic illustration of the experimental setup. (b) The STT-induced DW velocity as a function of temperature. The dotted orange line represents the angular momentum compensation temperature T_A.