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– Nanospintronics –

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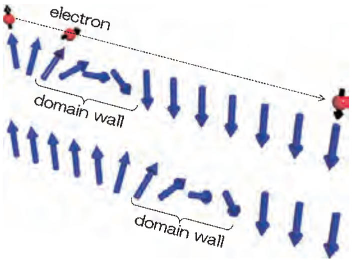
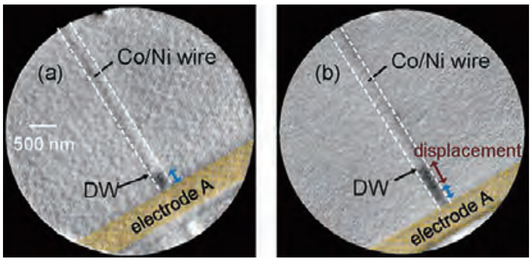
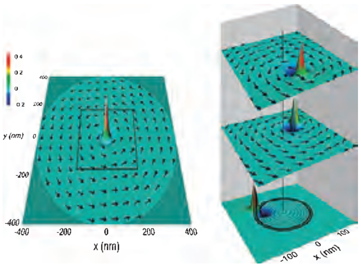
Scope of Research

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







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).

Observation of Super Conducting Diode Effect

Nonlinear optical and electrical effects associated with a lack of spatial inversion symmetry allow direction-selective propagation and transport of quantum particles, such as photons1 and electrons. The most common example of such nonreciprocal phenomena is a semiconductor diode with a p–n junction, with a low resistance in one direction and a high resistance in the other. Although the diode effect forms the basis of numerous electronic components, such as rectifiers, alternating–direct-current converters and photodetectors, it introduces an inevitable energy loss due to the finite resistance. Therefore, a worthwhile goal is to realize a superconducting diode that has zero resistance in only one direction. Here we demonstrate a magnetically controllable superconducting diode in an artificial superlattice $[Nb/V/Ta]_n$ without a centre of inversion. The nonreciprocal resistance versus current curve at the superconducting-to-normal transition was clearly observed by a direct-current measurement, and the difference of the critical current is considered to be related to the magnetochiral anisotropy caused by breaking of the spatial-inversion and time-reversal symmetries. Owing to the nonreciprocal critical current, the $[Nb/V/Ta]_n$ superlattice exhibits zero resistance in only one direction. This superconducting diode effect enables phase-coherent and direction-selective charge transport, paving the way for the construction of non-dissipative electronic circuits.

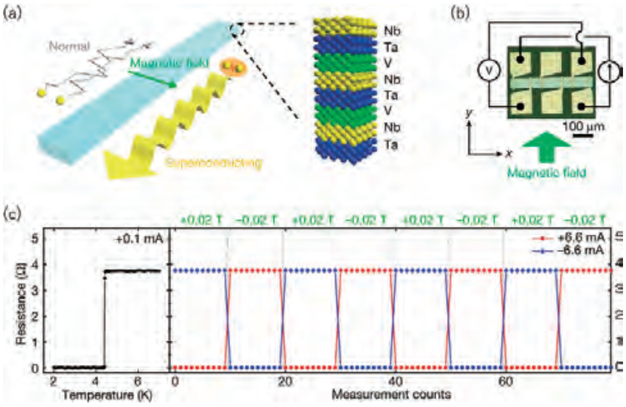


Figure 1. (a) Schematic images of the superconducting diode controlled by an external magnetic field and the artificial $[Nb/V/Ta]_n$ superlattice, in which the global inversion symmetry is broken along the direction of stacking. When the directions of the current, the magnetic field and inversion symmetry breaking are orthogonal to one other, the Cooper pairs can flow in only one direction. (b) Photomicrograph of the processed device and the measurement setup with the definitions of electric current and magnetic field. (c) Temperature dependence of the sheet resistance of the $[Nb(1.0\ nm)/V(1.0\ nm)/Ta(1.0\ nm)]_{40}$ film and alternating switching between the superconducting and normal conducting states by changing the sign of the applied current or magnetic field at 4.2 K.

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). Antiferromagnets are considered one of the material candidates for the racetrack memory. However, experimental explorations of STT in antiferromagnets remain elusive because of experimental difficulty accessing some of the magnetic properties. In this work, we instead examined the effects of STT in a ferrimagnetic material (a GdFeCo alloy), a more experimentally accessible material, which mimics an antiferromagnetic property at a certain temperature, the so-called angular momentum compensation temperature T_A. We measured the DW velocity under the application of electric current at various temperatures (see Figure 2(a) for the experimental setup). We found that, as shown in Figure 2(b), the DW velocity changes its sign in the vicinity of T_A. By fitting the experimental data with the theoretical model, we quantitatively determined the two components of STT, *i.e.* the adiabatic and non-adiabatic torques. Our result show that the non-adiabatic STT in antiferromagnets is indeed quite large, suggesting that an energy-efficient DW racetrack memory may be possible with antiferromagnets.

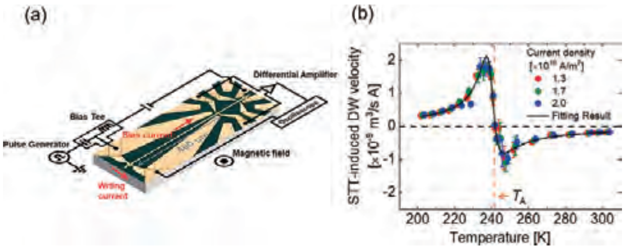


Figure 2. (a) Schematic illustration of the experimental setup. (b) The STT-induced DW velocity as a function of temperature. The dotted orange line represents the angular momentum compensation temperature T_A.