Division of Materials Chemistry
– Nanospintronics –

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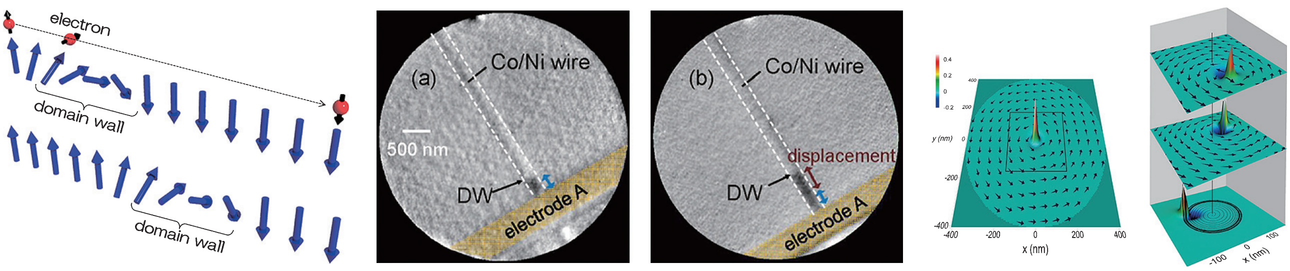
Scope of Research

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).

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 (Hdepin) and critical current density (Jc) for DW motion as a function of uniaxial magnetic anisotropy (Ku) in vertical DW motion memory with artificial ferromagnet. It is found that Hdepin and Jc show different Ku 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.

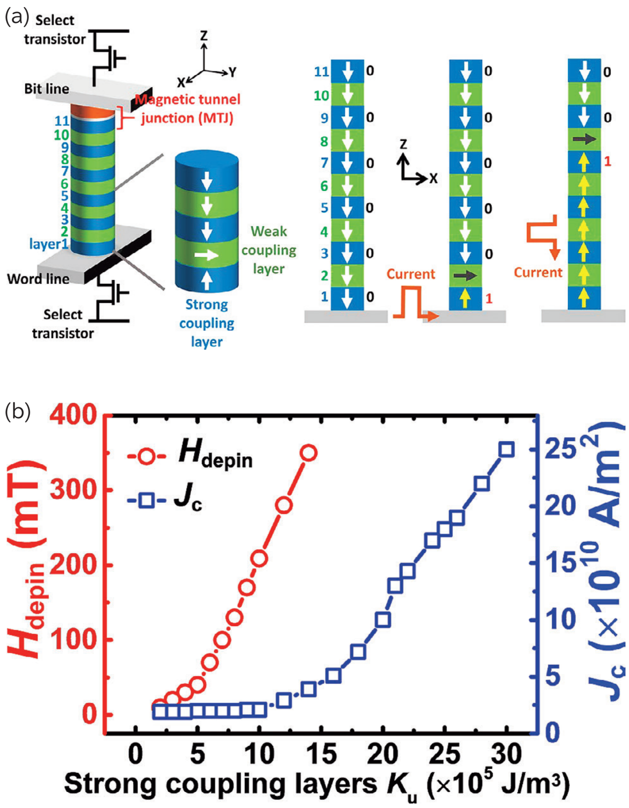


Figure 1. (a) Schematic illustration of the experimental setup. (b) The STT-induced DW velocity as a function of temperature. The dotted orange line represents the angular momentum compensation temperature T_A.

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 non-reciprocal 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.

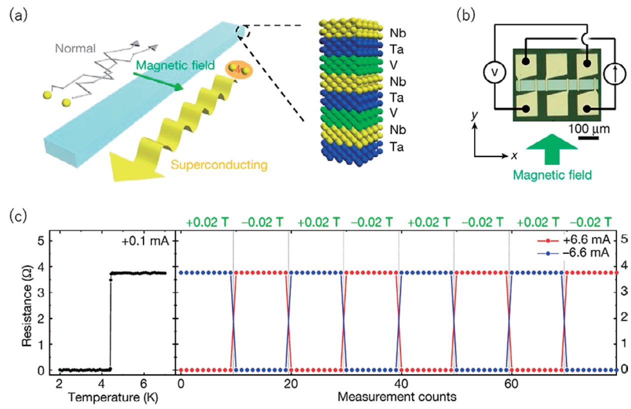


Figure 2. (a) Schematic images of the superconducting diode controlled by an external magnetic field and the artificial $[Nb/V/Ta]_n$ superlattice, in which the global inversion symmetry is broken along the direction of stacking. When the directions of the current, the magnetic field and inversion symmetry 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.