Power spintronics
–Stabilization of spinmotive force and invention of a magnetic power inverter

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Spin current, a flow of spin angular momentum, is the main player in spintronics, an emerging field of science and technology in condensed matter physics. To harness the spin current, much experimental and theoretical effort is devoted and many interesting phenomena have been unveiled [1]. One of the key issues in this field is to understand the mutual interaction between the spin current and the magnetization of ferromagnets. This interaction leads to the so-called "spinmotive force" (SMF), an electromotive force of the spin origin. The SMF is responsible for the energy-transfer between the spin current and the magnetization, offering an important building block for the future spintronics devices.

Striking features of the SMF are listed as follows: (1) In contrast to the inductive voltage where the time variation of a magnetic flux is required, solely a *static* magnetic field can generate an electric voltage. (2) The conversion rate is given by fundamental constants apart from the spin polarization of the sample, enabling high energy-conversion efficiency. (3) Applications using this effect can operate as active devices with zero stand-by power and such power-conversion ability between magnetic and electric systems provides a unique functionality in ferromagnetic nanostructures.

SMFs have been primarily demonstrated in permalloy ($Ni_{81}Fe_{19}$), a material that is known as a soft magnet. However, the soft magnetic properties could occasionally be a major disadvantage for a SMF demonstration; certain magnetization profiles such as domain walls (DWs) that are required for generating SMFs are easily disturbed by applied magnetic fields, leading to an increased instability in the resulting output voltage signals as shown in Fig.1 (left). Therefore, the magnitude of the SMF induced by DW motion in NiFe nanowires is limited to a few μV.

In Ref. [2], we propose a solution for the above-mentioned difficulty encountered in the NiFe nanowires by the materials design; by using high perpendicular magnetic anisotropy (PMA) materials (hard magnets), we have shown that rigid DW motion is achieved, and hence, the associated SMF signals can be stabilized as shown in Fig.1 (right). We have numerically confirmed that SMFs in the order of tens of μV in a multilayered Co/Ni nanowire and in the order of several hundreds of μV in an $L1_0$-ordered FePt nanowire with the very large PMA can be obtained. In addition, the narrow DW structure and low mobility of a DW in PMA nanowires are suitable in downsizing of devices using SMFs.

Next, based on the above results, we have proposed a basic concept of a "magnetic power inverter," a device that converts DC magnetic fields to AC electric voltages, and investigated its operation characteristics using model calculations [3]. This device consists of a magnetic nanowire with the high PMA and the width modulation as shown in Fig.2. A DW introduced in the nanowire is subjected to not only applied DC magnetic field H_{DC} but also an effective magnetic field arising from the modulation of the DW energy that is proportional to the wire width. This results in time variation of the DW precession frequency and the associated voltage. We have shown that by tuning the magnetic field and the wire geometry the variable frequency ranging from MHz to GHz can be achieved. The proposed device operates as an active element in future spin-based power electronics, or *power spintronics*.

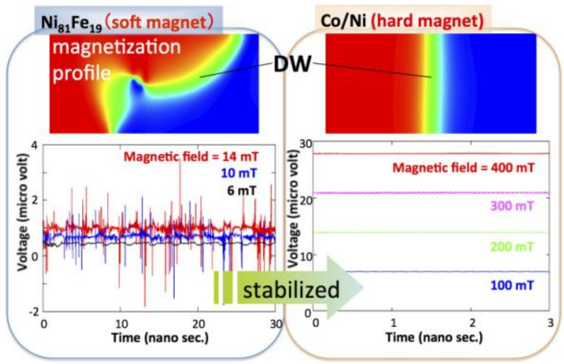

Fig.1 Numerical simulations of domain wall (DW) motion and the associated output voltages in $Ni_{81}Fe_{19}$ (left) and Co/Ni (right).

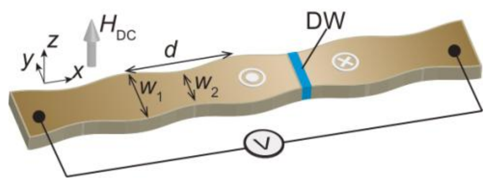

Fig.2 Schematic illustration of a magnetic power inverter consisting of a periodically modulated magnetic nanowire with a DW.

References

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