Nonreciprocal Transport Property in Microfabricated Antiferromagnetic Metal $NdRu_2Al_{10}$

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The symmetry breaking is an important concept not only in condensed matter physics but in entire physics. Especially, the breaking of time-reversal symmetry and spatial inversion symmetry causes unconventional physical phenomena in condensed matter physics. The magnetoelectric effect is one of the best examples and is mainly observed in insulators. In metals, electric polarization is shielded by conduction electrons, but symmetry breaking is manifested in physical phenomena through the change of the band structure. Recently, a novel-type transport property that breaks Ohm's law has attracted much attention and is called nonreciprocal resistance.

So far, nonreciprocal resistance has been observed in materials without spatial inversion symmetry, for example, BiTeBr [1] and Te [2] in which the crystal structure breaks the spatial inversion symmetry. However, the observation of nonreciprocal resistance is mainly limited to applying an external magnetic field.

In this study, we aimed to perform the nonreciprocal resistance in a zero magnetic field. The target material is an antiferromagnetic metal $NdRu_2Al_{10}$ with a zigzag structure. The zigzag and honeycomb structures have spatial inversion symmetry, but the inversion center cannot be taken at the atomic positions. It is known that the antiferromagnetic ordering of the spin on the atoms in the aforementioned structure breaks the time-reversal symmetry and spatial inversion symmetry simultaneously [3]. Therefore, the appearance of zero-field nonreciprocal resistance is expected below the antiferromagnetic transition temperature in materials with zigzag structures.

We prepared the microfabricated device by using Focused Ion Beam (FIB) and measured the nonreciprocal resistance in order to take advantage of the following. First, since the nonreciprocal resistance is proportional to the current density, the signal is enhanced by reducing of sample cross section. In addition, antiferromagnets are generally known to form antiferromagnetic domains with sizes of 10-100 μm. By microfabrication, it is possible to measure voltage signals in a region equivalent to the domain size.

Measurements using the microfabricated device detected zero-field nonreciprocal resistance below the antiferromagnetic transition temperature T_N = 2.4 K for $NdRu_2Al_{10}$. The results also show that the zero-field nonreciprocal resistance depends on the antiferromagnetic domain. This result proposes nonreciprocal resistance as a detection method for antiferromagnetic domains and shows its potential application to antiferromagnetic spintronics.

[1] T. Ideue et al., Nat. Phys. 13, 578 (2017)

[2] K. Sudo et al., Phys. Rev. B 108, 125137 (2023)

[3] Y. Yanase, J. Phys. Soc. Jpn. 83, 014703 (2014).