Abstract for an Invited Paper
for the MAR10 Meeting of
The American Physical Society

Electric detection ofmagnetization dynamics through inverse spin Hall effects[1]

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Spin currents, flows of spin angular momentum, are essential in spintronics. To explore the physics of spin currents, effective methods for detecting and generating spin currents should be established. Here we report the observation of the inverse/direct spin-Hall effects in metallic films. These effects enable electric generation and detection of spin currents. We have applied these effects to the observation of the spin-Seebeck effect. The inverse spin-Hall effect (ISHE) is the generation of a charge current from a spin current via the spin-orbit interaction. We have observed ISHE in metallic films at room temperature. The sample used in the present study is a bilayer film comprising a 10-nm-thick ferromagnetic NiFe layer and a 7- nm-thick nonmagnetic metallic (NM=Pt, Pd, Cu, Nb, and Au) layer. In our sample system, a pure spin current is injected from the NiFe layer into the NM layer using the spin-pumping effect operated by ferromagnetic resonance (FMR). ISHE in the NM layer converts the spin current into an electric current, which causes charge accumulation at the edges of the NM layer, or a difference of electric potential between the edges. By measuring this potential difference, this method allows us to detect ISHE in the films. We also demonstrated that the reverse effect of this spin- pumping induced ISHE allows the electric manipulation of magnetization relaxation even in a large-area film. This result can be argued in terms of the combination of the spin-torque effect and the direct spin-Hall effect. A model calculation reproduces the experimental data. This effect can be applied to a quantitative measurement of spin currents without assuming microscopic parameters. We have applied ISHE to the observation of the spin-Seebeck effect. By means of ISHE, we measured spin voltage generated from a temperature gradient in NiFe. This thermally induced spin voltage persists even at distances far from the sample ends and its sign is reversed between the ends of the sample along the temperature gradient. These behaviors are consistent with a phenomenological two-band model for the spin-Seebeck effect. The spin-Seebeck effect can be applied directly to constructing thermal spin generators for driving spintronics devices, thereby opening the door to thermo-spintronics.

[1]We thank S. Maekawa, K. Ando, K. Uchida, G. Tatara, S. Takahashi, J. Ieda, G.E.W. Bauer for valuable discussions.