Study on heat transports in metallic nanostructures using magneto-thermoelectric effects

エムディ，カムルザマン

（様式３）

氏　　名　：Md. Kamruzzaman

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論　文　内　容　の　要　旨

Recent development of nano-fabrication techniques enables to realize functional electronic devices with the lateral dimension down to nano-meter scale. In the operation of such nano sized devices, understanding and controlling the heat transfer is an important issue because a small cross section produces a significant Joule heating effect. Since the characteristic lengths such as the mean free path and phase coherent length are comparable to the device dimension, the heat transport in nanostructured systems may be different from the bulk state and its combination. On the other hand, In the field of spintronics, in addition to the intriguing spin-dependent transports, various conversion phenomena between spin and heat have been reported recently, and a new research field has been emerged named as spincaloritronics. Therefore, it is essential to deepen understanding the heat transfer in nanospintronic devices for manipulating the heat as well as for developing spincaloritronics. In this thesis, we studied heat transports in various ferromagnetic/nonmagnetic metal hybrid structures by using unique magneto-thermoelectric effects.

First, the spatial temperature distribution in a laterally configured nanostructure based on GMR nanowire has been investigated. A large thermal spin valve effect enables us to distinguish the flowing direction of the heat in the GMR nanowire. We find that the heat flow from the substrate is significant. Second, a temperature distribution in a ferromagnetic nanowire has been investigated by using various magneto-thermoelectric effects. The combination between the anisotropic magentoSeebeck effect and anomalous Nernst effect enables us to understand a three-dimension temperature gradient in a ferromagnetic nanowire precisely. We find that the transverse heat flow is a significant contribution on the field dependence of the Seebeck voltage. Finally, temperature dependence of the thermal spin valve effect and anisotropic magneto-Seebeck effect have been investigated. We find that the signs of the voltage changes were reversed at specific temperatures. Possible mechanism has been discussed in order to explain the unique signatures.

In summary, various thermoelectric effects in laterally configured nano-sized spintronic devices have been studied. By the optimization of the device structures, enhanced thermal spin valve version of the GMR effect, anisotropic magneto-Seebeck effect and anomalous Nernst effect have been obtained. Multiple ways in which heat interacts with spin and the interplay of such effects enable us to evaluate the heat distribution. These demonstration paves the way for the precise analysis of the heat flow in nano-structured electronic devices.