【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : Semiconductor Spin-currentronics

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【Purpose and Background of the Research】

Spin current (pure spin current without a charge flow and spin polarized current) in solids attracts tremendous attention in basic and applied physics, and much effort has been paid for its research. One main reason of the attractiveness of spin current is that people can fabricate spin devices of which size is below spin diffusion length thanks to a development of nanotechnologies (whereas the charge current is a conservative current, the spin current is not, and thus spin dissipates with a length scale of spin diffusion length). In the earlier stage of spintronics, a study of spin current is focusing only on nonmagnetic metals. However, recently, spin current in semiconductors, such as Si, Ge, GaAs and Graphene, can be generated and propagated at room temperature, which allows advanced studies on it.

Researchers have been facing with difficulty in injecting and propagating spins in semiconductors at room temperature, and in addition, unfortunate confusion about a reliability of a measuring method of spin current, a 3-terminal method, has been hindering a progress of spin-currentronics in semiconductors. Now, the heated discussion is settled, but studies on spin-currentronics using a various semiconductor materials with artificial nano-structures and using novel semiconductors such as transition metal dichalcogenides (TMDs) have not been implemented. Furthermore, an application-oriented study based on semiconductor spin-currentronics is still in the early development stage.

【Research Methods】

In this research project, we focus on (1) inorganic semiconductors (group-IV[Si, Ge] and compound [GaAs, SiC]), (2) novel atomically flat semiconductors, such as transition metal dichalcogenides (WSe2 and so on) and graphene, and (3) topological insulators (BiSbTeSe, TlBiSe and so on) as potential "semicondcutors" for spintronics applications. In terms of devices structures, quantum-wells, 2-dimensional electron gases in compound and oxide semiconductors, in addition to bulk semiconductors. The research strategies are as follows:

I. Understanding of spin current properties in semiconductors by using a novel high-frequency method and conventional electrical, dynamical and thermal methods, and of underlying physics of semiconductor spin-currentronics.

II. Clarification of correlation between spin relaxation and carrier densities in semiconductors, especially in TMDs and topological insulators.

III. Creation of novel spin devices by using conventional inorganic semiconductors, TMDs and topological insulators.

【Expected Research Achievements and Scientific Significance】

Because of the unwanted confusion described above, progress of semiconductor spintronics was not so dramatic comparing with that of metallic spintronics, where GMR heads and MRAMs were in practical use. In the course of this project, we can establish a steadfast basis of semiconductor spintronics and obtain a direction for practical application of semiconductor spin devices.

【Publications Relevant to the Project】

1) S. Dushenko, H. Ago, K. Kawahara, T. Tsuda, S. Kuwabata, T. Takenobu, T. Shinjo, Y. Ando and M. Shiraishi, "Gate-tunable spin-charge conversion and a role of spin-orbit interaction in graphene", Phys. Rev. Lett. 116, 166102 (2016).
2) S. Dushenko, M. Koike, Y. Ando, M. Myronov and M. Shiraishi, "Experimental demonstration of room-temperature spin transport in n-type Germanium epilayers", Phys. Rev. Lett. 104, 196602 (2015).
3) Yu. Ando, T. Hamasaki, T. Kurokawa, F. Yang, M. Novak, S. Sasaki, K. Segawa, Yo. Ando and M. Shiraishi, "Electrical Detection of the Spin Polarization Due to Charge Flow in the Surface State of the Topological Insulator Bi1.5Sb0.5Te1.7Se1.3", Nano Lett. 14, 6226 (2014).

【Term of Project】 FY2016-FY2020

【Budget Allocation】 134,400 Thousand Yen

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