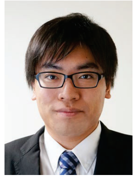
【Grant-in-Aid for Scientific Research (S)】

Exploration of angular momentum current science and its application to spin-orbit electronics



Principal Investigator	Keio University, Faculty of Science and Technology, Associate Professor ANDO Kazuya	Researcher Number:30579610
Project Information	Project Number : 22H04964 Keywords : Spintronics, Spin current, Orbital current	Project Period (FY) : 2022-2026

Purpose and Background of the Research

●Outline of the Research

This research explores the physics of orbital currents, the flow of orbital angular momentum of electrons in solids, to establish the foundation for a new technology (Fig. 1).

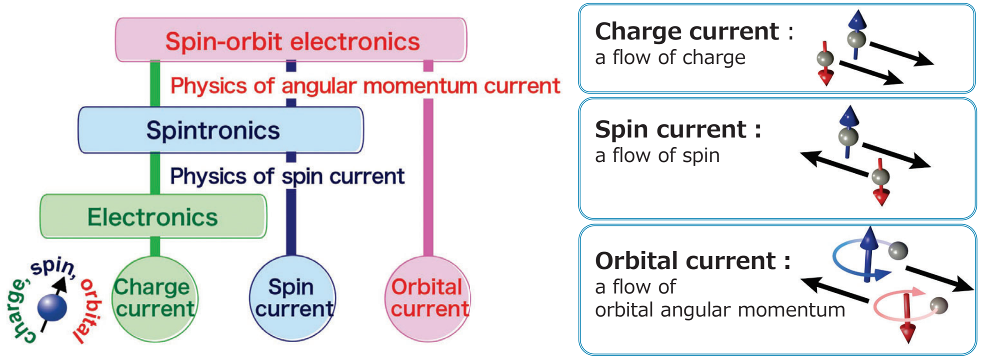


Figure 1. An overview of this research

●Background of the Research

Electronics is based on the manipulation of charge currents, the flow of electron charge. Recently, a complex field of condensed matter physics, materials science, and device engineering based on electron spins, spintronics, has grown rapidly. While charge currents are responsible for the functionalities of electronic devices, the foundation of spintronics is spin currents, the flow of electron spins. The manipulation of spin currents enables to realize device functions that are difficult to realize in electronics. A massive amount of research in spintronics has revealed that spin currents are responsible for a variety of quantum phenomena, which has led to the fundamental understanding of spin physics in condensed matter.

●Objectives of the Research

Spintronics has revolutionized the physics and technology of electrons by introducing the concept of spin currents to charge-based electronics. Since electrons in solids have not only charge and spin degrees of freedom but also orbital degrees of freedom, it is natural to expect the existence of orbital currents, the flow of orbital angular momentum, corresponding to charge and spin currents. However, the existence of orbital currents has been elusive. In this study, we explore the generation, conversion, and control of angular momentum currents, including spin and orbital currents. This will lay the foundation for a new technology, spin-orbit electronics, which is not an extension of conventional electronic technologies.

The diverse phenomena arising from spin currents enable the realization of a wide variety of devices based on angular momentum currents, ranging from nonvolatile memory devices, nanoscale microwave and terahertz wave sources, to thermoelectric and neuromorphic devices. The exploration of phenomena in which orbital currents play a central role promises to revolutionize the field of spintronics, which has been developed based on the concept of spin currents for over 30 years since the discovery of the giant magnetoresistance.

Expected Research Achievements

In this study, we experimentally explore the generation, conversion, and control of angular momentum currents, including spin and orbital currents (Figs. 2 and 3), and develop devices based on angular momentum currents.

It has been theoretically pointed out that the spin Hall and spin Rashba effects, the fundamental phenomena that generate spin currents, are secondary phenomena associated with the generation of orbital currents. This indicates that the orbital part of electrons is essential in phenomena in which angular momentum plays a key role. The dynamics of angular momentum is responsible for a variety of phenomena that couple various degrees of freedom, such as electricity, magnetism, light, and heat. Thus, clarifying the fundamental properties of orbital currents, which are particularly important but not explored so far, is the key for understanding and harnessing such phenomena.

●Generation, conversion, and control of angular momentum current

The establishment of methods to generate orbital currents by the orbital Hall effect and orbital Rashba effect, corresponding to the spin Hall effect and spin Rashba effect, allows to clarify the basic properties of orbital currents in solids. Furthermore, by exploring the conversion between orbital and spin currents and the control of the orbital current generation, the guidelines to realize highly efficient generation and conversion of angular momentum currents will be clarified.

●Devices based on angular momentum current

Principles and methods of manipulating angular momentum currents will enable the design of devices based on new principles with higher efficiencies than conventional spintronics devices.

Figure 2 A system for experimental investigation of spin and orbital currents

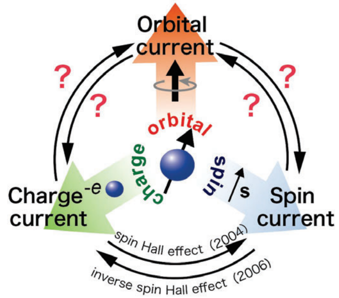


Figure 3 Conversion between charge, spin, and orbital currents

Homepage Address, etc.	https://www.ando.appi.keio.ac.jp