【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Engineering Ⅰ)

Title of Project : Exploring spin dynamics visualization and its application to new functional devices.

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Research Area : Engineering

Keyword : Scanning probe microscopy, Imaging, Nanophysics

【Purpose and Background of the Research】

The technology node of semiconductor devices has reached as small as 20-30 nm, and the fluctuations in the spatial distribution of dopants, which are introduced to control the properties of devices, and in the nanostructured interface between dissimilar materials directly affect the device functions obtained. Recently, functional materials and devices having new functions utilizing spin in addition to electric charge have been actively developed. The local order and structure fluctuations significantly affect the creation, annihilation, and mutual interaction (quantum correlation) of spins, similarly to those of electric charge, and the understanding and control of these processes is an important issue. In the recent remarkable progress in this nanoscale field, however, the analysis of spin dynamics has been carried out on the basis of the macroscopic properties of devices.

In this project, we aim to establish a new fundamental technology to measure the spin current dynamics in functional materials and devices at the nanometer scale and to visualize them in real space. It is important to develop a technology that reveals local properties, such as the transition and correlation between states, including spins; for example, in the currently rapidly developing field of spintronics, obtaining a detailed mechanism for spin dynamics and clarifying the relationship between nanostructure and the characteristic fluctuation. With the realization of this technology, it will become possible to obtain strategies for the development of new functional materials and devices based on quantum manipulation.

【Research Methods】

We have been involved in the development of a technique of visualizing the nanolevel carrier dynamics (electric charge) in a real space by integrating scanning tunneling microscopy (STM) and its related techniques with an optical method. Our method enables the observation of a small number of carriers injected in a device and the spatial mapping of carrier dynamics in nanostructures consisting of materials with different lifetimes. By incorporating mechanisms to control the excitation light and the probe, magnetic selectivity is introduced, thus realizing a technique for the measurement and analysis of spin dynamics. We have also developed a fundamental measurement technology using multiprobes. By combining this technique with multitunneling spectroscopy, which is now becoming achievable, local spin injection and its analysis will be possible. In this project, we aim to further develop the technologies that we have developed and to establish a fundamental technology that enables the measurement and visualization of nanoscale spin dynamics.

【Expected Research Achievements and Scientific Significance】

The establishment of a technique to evaluate the fluctuations in nanostructures and local quantum dynamics is important not only for specific applications such as the development of semiconductor devices but also as a potential fundamental technique in science and material development targeting a wide range of quantum structures including both organic and inorganic materials. Although a technique for the evaluation of nanoscale spin dynamics is one of the most important requirements for realizing novel functions, in addition to spin injection from magnetic clusters and the analysis of the scattering mechanism, no such technique has been sufficiently developed to satisfy these requirements.

This project is responding to these requirements, and its achievements are significant steps toward exploring a new academic field while deepening the understanding of nanoscale science. Our achievements are expected to have a strong impact on the development of a society in which next-generation devices are fabricated by nanoscale quantum dynamic control techniques.

【Publications Relevant to the Project】

1. "Ultrafast photoinduced carrier dynamics in GaNAs probed using femtosecond time-resolved STM." Y. Terada, M. Aoyama, H. Kondo, A. Taninaka, O. Takeuchi, and H. Shigekawa, Nanotechnology 18, 044028 (2007).
2. "Microscopic basis for the mechanism of carrier dynamics in an operating p-n junction examined by using light-modulated STM." S. Yoshida, Y. Kanitani, R. Oshima, Y. Okada, O. Taeuchi, and H. Shigeawa, Phys. Rev. Lett. 98, 026802 (2007). (Focus)

【Term of Project】 FY 2010-2014
【Budget Allocation】 167,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://dora.bk.tsukuba.ac.jp/