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

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : Nanoscale Probing Photoinduced Dynamics by Optical Pump-Probe Scanning Tunneling Microscopy

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【Purpose and Background of the Research】

We have succeeded in developing an entirely new microscopy technique of visualizing photoinduced carrier dynamics, including spins, by integrating the scanning tunneling microscopy (STM) technique and the quantum optics technique (refs.). By the developed technique, the local structures and electronic states of atoms and molecules can be observed with femtosecond time resolution and the atomic-level spatial resolution of STM. In this project, we aim to obtain a deeper understanding of physical phenomena by revealing the elementary processes in the local dynamics of, for example, phase transitions and quantum transport, which have not been clarified by the conventional methods used to obtain information averaged over time and space domains, by improving the above STM technique. We also aim to establish the STM technique as the fundamental technology for creating new properties (functions) and to develop this new academic field of science using the STM technique.

【Research Methods】

Figure 1 shows a schematic of the time-resolved STM technique and the results obtained by STM. In Fig. 1, (1) the measured hole capture rate at a level in the band gap of a single Mn atom in a Mn/GaAs structure and (2) the first observation result obtained by time-resolved STM of the local spin precession movement in GaAs in a real space are shown. Owing to the limitations related to excitation systems, only a limited range of samples can be observed by STM. In this project, we will develop techniques that will enable STM observation to be applied to various systems. For example, we will develop a new modulation method based on the time domain of the dynamics and integrate a high-power variable-wavelength laser with the modulation method and the improved STM to establish a system for the time-resolved measurement of various quantum processes. Experiments will be carried out using specimens prepared in accordance with the progress in the development of the techniques. The achievements will be published in papers, at conferences, and via mass media accordingly.

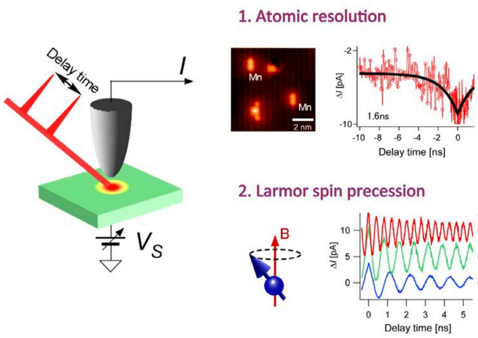

Fig. 1 Schematic of OPP-STM and obtained results.

【Expected Research Achievements and Scientific Significance】

The achievements of this project will markedly improve the femtosecond time-resolved STM technique and enable its application to various systems. In addition, we will be able to reveal the elementary processes in local quantum dynamics, which have not been clarified by the conventional methods. Understanding and controlling the nanoscale quantum dynamics are of scientific significance in establishing a new academic field of science and are expected to contribute to the development of next-generation functional devices that will have a major impact on human society.

【Publications Relevant to the Project】

・Y. Terada, S. Yoshida, O. Takeuchi, and H. Shigekawa: Real space imaging of transient carrier dynamics by nanoscale optical pump-probe microscopy. Nature Photonics, 4, 12, 869-874 (2010).
・S. Yoshida, M. Yokota, O. Takeuchi, H. Oigawa, and H. Shigekawa: Single-atomic-level probe of transient carrier dynamics by laser-combined STM, APEX 6, 032401 (2013).
・S. Yoshida, Y. Aizawa, Z. Wang, R. Oshima, Y. Mera, E. Matsuyama, H. Oigawa, O. Takeuchi, and H. Shigekawa: Probing ultrafast spin dynamics with optical pump-probe scanning tunneling microscopy, Nature Nanotechnology 9, 588-593 (2014).

【Term of Project】 FY2015-2019

【Budget Allocation】 154,600 Thousand Yen

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